RECLAMATION

Managing Water in the West

Final Environmental Assessment Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

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Mission Statements

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The mission of the Bureau of Reclamation is to management, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Final Environmental Assessment for Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

Proposed agency action:	Experimental releases from Glen Canyon Dam, Coconino County, Arizona, 2008 through 2012
Type of statement:	Environmental assessment
Lead agency:	Bureau of Reclamation, Upper Colorado Region
Cooperating agencies:	None
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1.0 Introduction

The Department of the Interior, acting through the Bureau of Reclamation (Reclamation), is proposing a series of experimental releases of water from Glen Canyon Dam to help native fish, particularly the endangered humpback chub, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

Glen Canyon Dam, authorized by the Colorado River Storage Project Act (CRSPA) of 1956 and completed by Reclamation in 1963, impounds the Colorado River some 15 miles upstream from Lees Ferry, Arizona. Below Glen Canyon Dam, the Colorado River flows for 15 miles through Glen Canyon. This area is managed by the National Park Service (NPS) as part of Glen Canyon National Recreation Area. Fifteen miles below Glen Canyon Dam, Lees Ferry, Arizona marks the beginning of Marble Canyon and the northern boundary of Grand Canyon National Park.

A major function of the dam is water conservation and storage. The dam is specifically managed to regulate releases of water from the upper Colorado River basin to the lower basin to satisfy provisions of the Colorado River Compact and subsequent water delivery commitments and thereby allow states within the upper basin (Arizona, Colorado, New Mexico, Utah, Wyoming) to deplete water from the watershed upstream of Glen Canyon Dam and utilize their apportionments of Colorado River water.

In addition, another function of the dam is to generate hydroelectric power. Water released from Lake Powell through Glen Canyon Dam's eight hydroelectric turbines generates power marketed by the Western Area Power Administration (Western). Between the dam's completion in 1963 and 1990, the dam's daily operations were primarily undertaken to maximize generation of hydroelectric power in accordance with Section 7 of the CRSPA, which requires production of the greatest practicable amount of power.

In 1970, Criteria for Coordinated Long-range Operation of Colorado River Reservoirs were established to govern operation of the mainstem reservoirs along the Colorado River. Annual operating plans prepared under the criteria include the requirement to:

> …reflect appropriate consideration of the uses of the reservoirs for all purposes, including flood control, river regulations, beneficial consumptive uses, power production, water quality control, recreation, enhancement of fish and wildlife, and other environmental factors. (Article 1(2))

Over time, additional considerations have arisen with respect to the operation of Glen Canyon Dam, including concerns regarding effects of dam operations on species listed pursuant to the Endangered Species Act of 1973, as amended (ESA). Later, by 1992, recognizing that how the dam is operated might affect Glen Canyon National Recreation Area and Grand Canyon National Park, President George H.W. Bush signed the Grand Canyon Protection Act (GCPA) into law.

The GCPA required the Secretary of the Interior to complete an environmental impact statement (EIS) evaluating alternative operating criteria, consistent with existing law, that would determine how the dam would be operated to both meet the purposes for which the dam was authorized and to meet the goals for protection of Glen Canyon National Recreation Area and Grand Canyon National Park (GCPA § 1804(a); S. Rep. No. 102-267, at 136 (1992)). The final EIS was completed in March 1995. The preferred alternative, the Modified Low Fluctuating Flow Alternative, was selected as the best means to operate Glen Canyon Dam in a record of decision issued on October 9, 1996.

Later in 1997, the Secretary adopted operating criteria for Glen Canyon Dam as required by Section 1804(c) of GCPA. The GCPA also requires the Secretary of the Interior to exercise:

> . . .other authorities under existing law in such a manner as to pro[t]ect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use. (GCPA §1802(a))

Additionally, the GCPA requires the Secretary of the Interior to undertake research and monitoring to determine if revised dam operations were actually achieving the resource protection objectives of the final EIS and record of decision, i.e., mitigating adverse impacts, protecting, and improving the natural, cultural, and recreational values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established. These provisions of the GCPA were incorporated into the 1996 record of decision and led to the establishment of the Glen Canyon Dam Adaptive Management Program (GCDAMP) under Reclamation and the Grand Canyon Monitoring and Research Center (GCMRC) under the US Geological Survey (USGS).

Monitoring and research conducted by these organizations since 1996 have shown that some of the expected benefits of dam operations under the record of decision have not occurred, or have occurred to a lesser degree than anticipated, e.g., for the endangered humpback chub (*Gila cypha*) and conservation of fine sediment. In proposing these experiments, it is important to recognize that all operations including those proposed here, must be implemented in compliance with other specific provisions of existing federal law applicable to the operation of Glen Canyon Dam. These pre-1992 requirements are specifically mandated in the GCPA.

> The Secretary shall implement this section in a manner fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona v. California, and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin. (GCPA § 1802(b))

This document is an environmental assessment and documents current conditions in Glen, Marble, and Grand canyons below Glen Canyon Dam (Figure 1). It describes how the proposed action, i.e., experimental high and steady flows from 2008 through 2012, is designed to help and assess the long-term benefits to the conservation of endangered humpback chub and fine sediment along the Colorado River downstream of Glen Canyon Dam.

This environmental assessment was prepared by the US Bureau of Reclamation (Reclamation) in compliance with the National Environmental Policy Act (NEPA) and the Council on Environmental Quality's regulations for implementing NEPA (40 CFR 1500-1508). This environmental assessment is not a decision document. The following outcomes could result:

1. a finding of no significant impact could be issued and the experiment could go forward as proposed;
2. a decision could be made to prepare an environmental impact statement; or
3. a decision could be made to withdraw the proposal on the basis of environmental impacts disclosed in this document.

1.1 Background and Related Actions

Reclamation, an agency within the US Department of the Interior, operates Glen Canyon Dam as part of the Colorado River Storage Project, which was authorized by Congress in 1956 (43 USC § 620). In 1995 Reclamation finalized an EIS on Glen Canyon Dam operations and in 1996 the Secretary of the Interior decided the dam would be operated using the Modified Low Fluctuating Flow Alternative in the EIS. In 2007 Reclamation completed an EIS that defines interim guidelines for lower basin shortages and the coordinated operations for Lake Powell and Lake Mead (Reclamation 2007a). Releases from Lake Powell are based largely on the contents of these two reservoirs. Coordinated operations under the 2007 record of decision govern the annual release from Lake Powell, while the 1996 record of decision governs releases from Lake Powell at shorter time increments, primarily daily and hourly releases. These two records of decision form the basis for no action here. This environmental assessment is tiered (40 CFR 1502.20 and 1508.28) from the 1995 EIS (Reclamation 1995) and the shortage and coordinated operations EIS described above (Reclamation 2007a).

Reclamation's (1995) EIS and Interior's (1996) decision called for an adaptive management approach, wherein the relationship between dam operations and downstream resources was recognized as uncertain and an active experimental approach was adopted. As a result, the GCDAMP was instituted and Reclamation collaborated with stakeholders in the GCDAMP and conducted numerous experimental releases from Glen Canyon Dam, including previous high-flow and steady-flow experiments, which helped inform the design of the proposed experimental releases described in this analysis. Experimentation was designed to assess relationships between dam operations and resources in and along the

Colorado River in Glen Canyon National Recreation Area and Grand Canyon National Park (Figure 1).

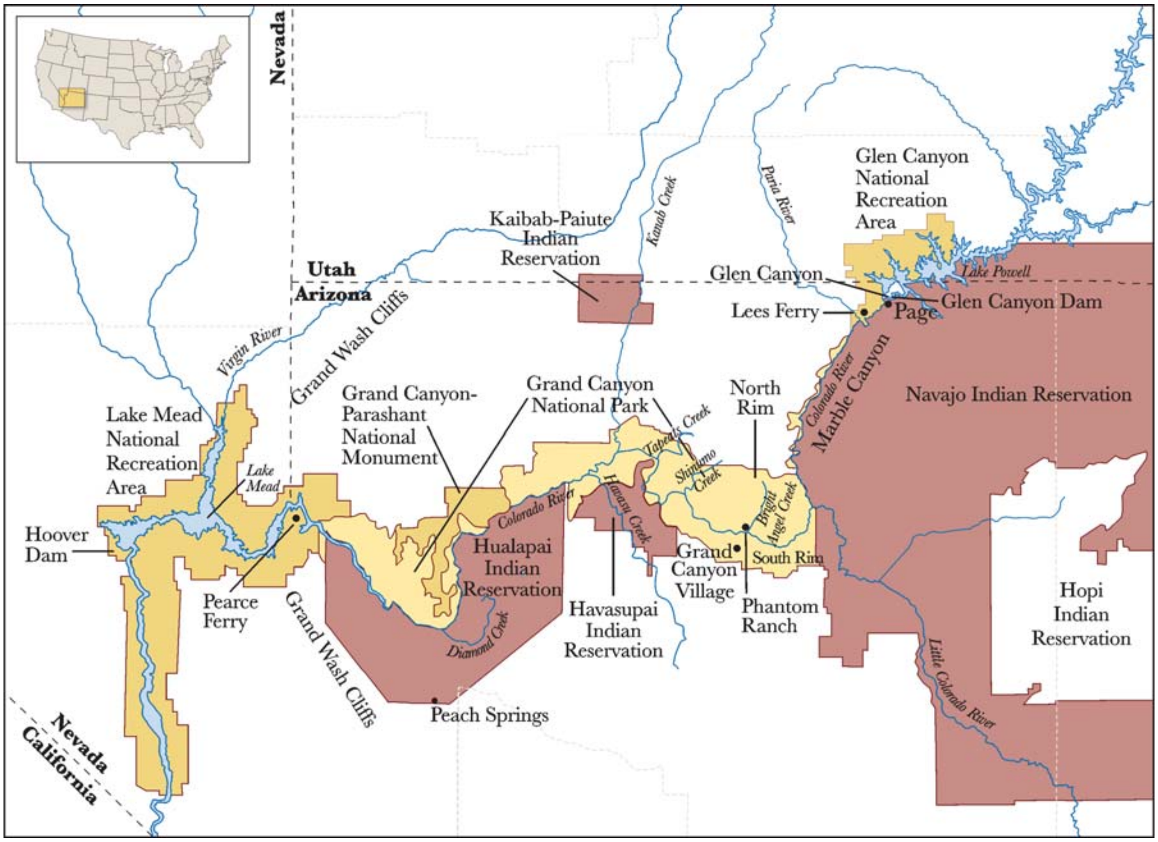

FIGURE 1 Geographic scope of the proposal, showing places referenced in the text. Map courtesy of USGS.

These experiments included a release of 45,000 cubic feet per second (cfs) beginning March 26, 1996, a powerplant capacity release of 31,000 cfs for 48 hours in 1997, and a combination of powerplant capacity releases and steady flows in March through September 2000. From 2003 through 2005, a series of test flows with higher winter fluctuations was conducted. From 2003 to 2006, mechanical removal of nonnative fish was undertaken to study whether populations of native fish, particularly the endangered humpback chub (*Gila cypha*), could be conserved by reducing numbers of nonnative fish, primarily trout.

Experimentation with dam releases also included high flows in November 2004 and alternating fluctuating and stable flows in the fall of 2005. The 2004 high flow test was timed to take advantage of enriched sediment in the Colorado River below the dam (Wiele et al. 2005). Suspended sediment concentrations during the 2004 experiment were 160 to 240 percent greater than during the 1996 experiment, although there was less sand in suspension below River Mile (RM) 42 (Topping et al. 2006). (River miles or RM are measured downstream from Lees Ferry, Arizona.)

1.2 Purpose of and Need for Action

The purpose of the proposed experimental releases from Glen Canyon Dam is to determine if prescribed releases can benefit resources located downstream of the dam in Glen, Marble, and Grand canyons, Glen Canyon National Recreation Area and Grand Canyon National Park, respectively, in accordance with applicable federal law, including the GCPA, while meeting the project purposes of the dam. Specifically, the purpose of the high flow test portion of the proposed action is to rebuild sandbars and beaches and rejuvenate backwaters – which may be important rearing habitat for native fish – during a period of enriched sediment storage conditions and to monitor changes over time. The purpose of the steady flow portion of the experiment is to potentially enhance the continuance of recent positive trends in the population of humpback chub and test the impact of fall steady flows on the endangered humpback chub and other aspects of the aquatic environment, particularly backwater environments.

This proposed action is needed because (1) much of the positive initial results of previous high flow tests have eroded, impacting recreational use and aquatic habitat; (2) previous tests were conducted under depleted and moderately enriched sediment conditions and there is a strong need to assess effects under current enriched sediment conditions; (3) the scientific information from the proposed high flow test will help inform the evaluation of long-term sustainability of the sediment resource; (4) there is a desire to enhance the current positive trends in the humpback chub population; and (5) there is a need to test whether recruitment of humpback chub can increase under fall steady flows. While recent population estimates show an improving humpback chub population, the experiment will help scientists better understand the cause of this improvement and methods by which further improvement could occur.

Both aspects of the proposed action have been designed to assist in and enhance the conservation of humpback chub. This document assesses whether these objectives could be accomplished during 2008 through 2012 without significant adverse impacts to natural, cultural, or socioeconomic resources.

1.3 Science Plan

While Reclamation has conducted two prior high flow tests in 1996 and 2004 with initial positive results, sandbars and backwaters declined thereafter. (Discussion of this point in contained in section 3.1.4.) In addition, recent tributary inputs to the Colorado River below Lees Ferry are the greatest in approximately a decade. Conducting a high flow test under these conditions is hypothesized to create more substantial sandbars and beaches rather than let this sediment be transported downstream to Lake Mead, and increase the overall conservation of fine sediment. Prior experimental high releases from the dam have had similar stated objectives (Schmidt et al. 1999:30)

1. remove or reduce predation of nonnative fish on endangered native fish;
2. rejuvenate backwater habitats for native fish, especially the endangered humpback chub (*Gila cypha*);
3. redeposit sand at higher elevations;
4. preserve and restore camping beaches; and
5. reduce near-shore vegetation.

The GCMRC was charged in 2007 by the Department of the Interior to create a science plan for a proposed high-flow release. The plan thus developed had as its major elements studies to assess impacts to sediment, archeological sites, and backwaters; riparian vegetation; aquatic food base; rainbow trout; and water quality. It also proposes a knowledge synthesis at the conclusion of the experiment and mitigation measures to reduce incidental take of Kanab ambersnail (USGS 2007a).

As this plan was finalized in anticipation of a potential high flow test in 2008, additional scientific efforts were included in the plan to identify impacts to the endangered humpback chub and its habitat. Greater emphasis was placed on understanding the potential benefits of backwaters created by the high-flow release for native fish, with substantially increased native fish and habitat monitoring and research. The resulting plan is included as an Appendix A.

With respect to the fall steady flow portion of the proposal, a September 2008 river trip is scheduled with significant efforts directed toward both fish and habitat sampling. Ongoing monitoring within the GCDAMP will also contribute to determining the effect of these flows. To improve the scientific understanding from this portion of the proposal, if the proposed action is approved, in April 2008 Reclamation will initiate discussions with the GCMRC and within the GCDAMP on potential additional scientific activities associated with the fall steady flows that may be proposed and undertaken during the period 2008 through 2012.

The total cost of the science plan is approximately $4.1 million, including the cost of the knowledge synthesis (USGS 2007a). Funding of the science plan would come from power revenues within the GCDAMP, Reclamation appropriated funds, and NPS funds.

1.4 Relevant Resources

Reclamation utilized the scoping results from the prior NEPA analyses, as well as knowledge gained from prior experimental releases from the dam (e.g. Valdez and Hoffnagle 1999), to determine relevant issues or resources for this environmental assessment. In 2000, a longer period of steady flows was conducted within existing NEPA compliance, and in 2002 and 2004 Reclamation, NPS, and GCMRC prepared an environmental assessment on a proposed high flow test. Consistent with these earlier experiments Reclamation has now prepared a biological assessment and an environmental assessment on the proposed action. Issues related to high magnitude releases from the dam are relatively well-known. In fact, one of the major purposes of this proposal is to replicate selected elements of the 1996, 1997, and 2004 experimental high flow tests, but under enriched sediment conditions. Also, this new proposal follows the high flow with steady fall flows; building on knowledge learned during previous steady-flow experiments in 2000. Based on prior scoping and experimental results, Table 1 lists (in alphabetical order) the issues or resources considered for this environmental assessment under the broad categories of natural, cultural and socioeconomic resources. The effects to resources are presented following a description of the alternatives under consideration.

TABLE 1 Summary of resources evaluated

Environmental Issue
Air Quality
Birds
Cultural Resources
Environmental Justice
Fish, Sport Fish, Endangered Fish
Floodplains and Wetlands
Hydropower
Indian Trust Assets
Invertebrates, Herptofauna
Population Growth
Public Health and Hazards
Recreation
Sediment, Soils, and Geomorphology
Transportation and Traffic
Vegetation
Water Resources or Dam Operations
Wilderness

1.5 Authorizing Actions, Permits or Licenses

Implementation of this proposal would require a number of authorizations or permits from various federal and state agencies and Indian tribal governments. Any field work within the boundaries of Glen Canyon National Recreation Area or Grand Canyon National Park would necessitate permits from the NPS. Tribal permits from the Hualapai Indian Tribe or Navajo Nation would be needed should any field work be proposed within reservation boundaries; permits might also be required by the Bureau of Indian Affairs (BIA). Researchers working with threatened or endangered species would have to obtain a permit from the US Fish and Wildlife Service (FWS). Researchers working with resident fish or wildlife species may need an Arizona Game and Fish Department (AGFD) permit. No other permits are known to be required at this time.

2.0 Alternatives

In light of recent population increases and new information about humpback chub, Reclamation re-initiated consultation under the ESA with the FWS on November 13, 2007. The proposed action included in Reclamation's biological assessment was developed during informal consultation with the FWS in November 2007. The proposed action in this environmental assessment prepared under NEPA is identical to that contained in Reclamation's biological assessment dated December 21, 2007. Reclamation's proposed action consists of continued implementation of Modified Low Fluctuating Flows selected in the 1996 record of decision (Interior 1996) with the added elements of identified experimental dam operations for the five-year experimental period (the remainder of water year 2008 through 2012). Accordingly, the FWS issued a biological opinion on the proposed action on February 27, 2008 which "…replaces the 1995 final biological opinion on the operation of Glen Canyon Dam (FWS 1995; Consultation No. 2-21-93-F-167)." The FWS further noted in its final biological opinion (FWS 2008) that "[a]t the end of the five year period of the proposed action, it is expected that Reclamation will reconsult with FWS" under the ESA.

Following the conclusion of this environmental assessment Reclamation will reassess work on the long-term experimental plan as described in a February 12, 2007 *Federal Register* notice (Reclamation 2008a). This environmental assessment considers two alternatives: no action and the proposal, synonymous with proposed action.

2.1 No Action Alternative

Reclamation would continue to operate the dam as described in prior NEPA analyses (Reclamation 1995, 2007a). For the purpose of this NEPA analysis, no experimental flows or actions would be assumed to occur from 2008-2012. Projected monthly dam releases for various annual releases are summarized in Table 2, with the data from Reclamation (2007a). Annual and monthly release volumes would continue to be projected for different hydrologic conditions prior to the beginning of the water year and described in annual operating plans and in new operating guidelines (Reclamation 2007a). Scheduled monthly release volumes would continue to be updated at least monthly. Daily operations would conform to the limits imposed by the 1997 operating criteria for Glen Canyon Dam.

TABLE 2 No Action Glen Canyon Dam releases under dry (7.48 million acre-feet or maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	Annual Releases								
	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	5,300	10,300	9,758	6,800	12,800	9,378	6,800	12,800
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	7,100	13,100	10,588	7,600	13,600	21,056	19,400	25,000

2.2 Proposed Action

The proposal consists of two types of experimental flows to be implemented beginning in 2008 and concluding in 2012: (1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours beginning March 4, 2008; and (2) steady flows in September and October of each year, 2008 through 2012. The overall concept of the experiment is to determine the effectiveness of sandbar building and backwater formation using a high flow test during enriched sediment conditions, and the subsequent impact on humpback chub in those backwaters during fluctuating flows in the spring and summer and steady flows in the fall. This experimental design is reflected in the science plan developed by GCMRC (Appendix A), but may be expanded as discussed in section 1.3.[1]

To gain a better understanding of the relationships between high releases and downstream resources, the March 2008 high flow test hydrograph (Figure 2) is proposed to partially replicate the November 2004 high flow test hydrograph with the following elements:

- on March 4, 2008 at 2200 hours the modified low-fluctuating flows described in Reclamation (1995) would increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;
- on March 5 once powerplant capacity is reached, each of the four bypass tubes would be opened, where once every three hours bypass releases would be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;

[1] This proposed action was developed and builds on previous adaptive management experiments analyzed in environmental assessments prepared by Reclamation and other Interior agencies.

- an essentially constant flow of 41,500[2] cfs would be maintained for 60 hours;
- discharge would then be decreased at a down-ramp rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached (Figure 2).[3]

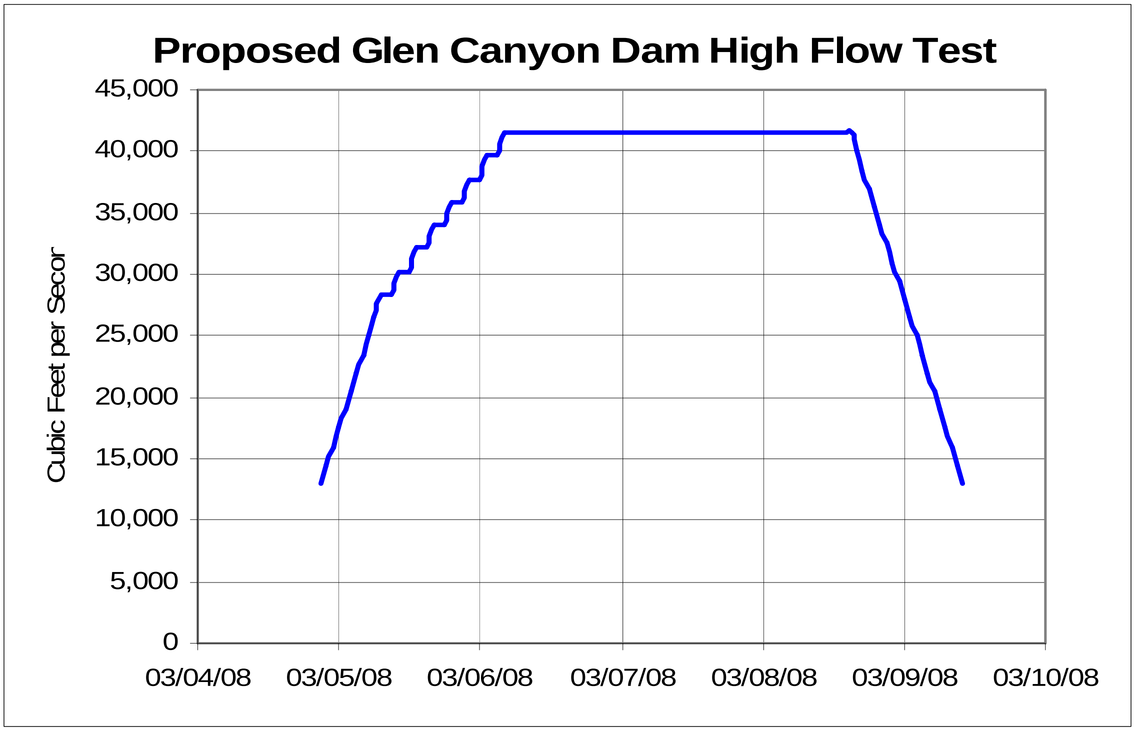

FIGURE 2 Hourly hydrograph of Glen Canyon Dam releases during the March 2008 high flow test.

As described in section 3.1.4, conservation of fine sediment is a key objective in the GCDAMP and determining the long-term sustainability of the sediment resource is a critical objective of the proposed action. Significant progress has been made in understanding sediment transport processes over the last decade, particularly as a result of high flow tests, but the long-term sustainability question cannot yet be answered. The proposed action is an essential step in that effort. This portion of the proposal is unique in proposing a high flow test during enriched sediment conditions, to be followed by modified low fluctuating flow operations during a low annual release year.

This proposed experiment neither mandates nor precludes future experimentation. Rather, this proposed experiment was developed consistent with the principles of adaptive

[2] The sum of powerplant capacity (approximately 26,500 cfs) plus the capacity of the four bypass tubes (15,000 cfs). Maximum powerplant capacity value calculated from the November 24-Month Study projected March 2008 Lake Powell reservoir elevation of 3,586 feet and interpolated from the maximum full gate turbine capacity for seven units. One of the powerplant units will be off-line for repairs and unavailable for use in the experiment.

[3] If this element of the proposal is undertaken, implementation of the high flow experiment would not affect the annual volume of water released from Glen Canyon Dam during water year 2008.

management to require full scientific and public analysis of the effects of the experiment and integration of such results into future decision making, as described at page 7 of the biological assessment (Reclamation 2007b).

The proposal also includes steady flows in the fall. The period and characteristics of these flows were developed during informal consultation with the FWS in November 2007. As described in the February 27, 2008 biological opinion, the FWS believes the following.

> Although the status of the Grand Canyon population of humpback chub has been improving, there is no clear indication for the cause of this improvement. Thus the proposed action takes a conservative approach to changes in dam release in an attempt to capitalize on this trend in status without unduly risking these gains with more drastic changes in dam operation. However, there exists the possibility that the population could decline, despite the current trend and potential for beneficial effects from Reclamation's proposed action. Reclamation has agreed to reinitiate consultation if the trend in humpback chub status should reverse and the population decline…" (FWS 2008:10)

The proposed action and the 2007 biological assessment rely on the best and most recent scientific information regarding the status and population trend of the humpback chub. This includes recognition that improvement in the humpback chub population began between 1994 and 1999 - before any of the recent suite of specific actions to benefit the species were undertaken (Coggins 2007) - and that significantly greater numbers of young humpback chub have been found in the mainstem Colorado River during 2002 through 2006, including above the Little Colorado River (Ackerman 2007). These improvements were seen during implementation of modified low fluctuating flow as adopted in the 1996 ROD. Subsequent to the improvement in humpback chub status, but before the improvement was detected by scientists, a 2004 high flow test, 2003 – 2005 high winter fluctuations, and 2003-2006 non-native fish removal efforts were proposed by Reclamation, NPS, and GCMRC and conducted.

The positive response of the humpback chub and the risks associated with warming of fish habitats were primary factors in the FWS conclusion that a conservative approach was warranted. The risks cited in the FWS's biological opinion refer primarily to the threat of warm water nonnative fish predation and competition (FWS 2008:49). Through the GCDAMP, GCRMC is developing a fish control program to address this threat but that plan has not been finalized. To date, efforts to control warm water nonnative fish predators has not been shown to be effective.

The timing of fall steady flows follows or is timed with young-of-year emergence of humpback chub from the Little Colorado River into the mainstem, depending on the timing of Little Colorado River monsoon floods. Releasing steady flows earlier in the year would warm backwaters more, but would enhance the potential for increases in small-bodied cyprinids that utilize the same habitats. The FWS concludes that steady flows during the September - October time period should also increase the productivity of backwaters. Intense monitoring and research conducted throughout this period will be undertaken to identify resultant beneficial or adverse effects of this element of the proposed action on these geomorphic features and aquatic species.

The steady flow portion of the proposal also utilizes the discussions held during the April 2007 science workshop sponsored by GCMRC. The basic conclusion of that workshop was that if humpback chub goals were being met, then continuation of the Modified Low Fluctuating Flow Alternative was the appropriate action, while if the goals were not being met, then steady flows during July through October should be tested (USGS in prep.). Recovery goals for the humpback chub are currently being developed by the FWS, but the "non-jeopardy" assessment of the 2008 biological opinion is an important consideration in determining if goals for the humpback chub are being met. Desired future conditions for the humpback chub and sediment resources are currently being developed by the NPS, FWS, and within the GCDAMP. A recommendation from the GCDAMP to the Secretary of the Interior is expected in the near future. When the Secretary of the Interior responds to this recommendation and determines specific target levels for various resources, the objectives for humpback chub and sediment will become clearer. However, Reclamation concurs with the FWS conclusion that the proposed action is a logical next step in the implementation of adaptive management and for the conservation of the humpback chub.

In addition, the 2008 biological opinion uses an adaptive management approach to the implementation of steady flows and describes triggers which would lead to reinitiation of formal consultation under ESA, including either a significant decline in the Grand Canyon population of humpback chub or a single year population estimate of 3,500 fish or less (FWS 2008:10). The purpose of the consultation would be to evaluate and determine the cause of the decline and propose actions to reverse the decline. Potential actions could include expanding the months when steady flows would be released from the dam, as well as other responses to scientific assessment of the causative factors.

Steady flow releases during September and October of 2008 through 2012 would include the following constraints:

- typical monthly dam release volumes would be maintained in all water years except 2008, where reallocation of water would occur due to the high flow test in March;
- dam releases for September and October would be steady[4] with a release rate determined to yield the appropriate monthly release volumes;
- if possible, dam operations would be managed so September and October releases would be similar (Table 3), but September releases may be structured to provide a transition between August and October monthly volumes.

[4] Regulation release capacity of ± 1,200 cfs within each hour will be available if needed for hydropower system regulation during the fall steady flow periods. Each hourly average release is expected to be very close to the steady flow target for the day. Also, spinning reserves will be available if needed for emergency response purposes.

2.2.1 Annual, Monthly, and Hourly Releases

Annual water volumes are established pursuant to the recently adopted Interim Guidelines for Coordinated Operations of Lake Powell and Lake Mead (approved December 13, 2007) and would not be affected by any aspect of this proposal, but monthly release volumes during 2008 would be adjusted due to the 41,500 cfs peak in March (Table 2). Tables 3 and 4 project monthly release volumes and mean, minimum, and maximum daily releases for 10th, 50th, and 90th percentiles. Statistically, the 7.48 maf release pattern corresponds to the 10th percentile category (dry hydrology), the 50th percentile corresponds to the 8.23 maf pattern, and the 12.3 maf monthly release pattern (wet hydrology) corresponds to the 90th percentile volume. All monthly volumes are modeled values and subject to change based on actual hydrology and operations. Descriptions of the model, its limitations and assumptions, are in prior documents (Reclamation 1988, 1995, 2007a).

The interim guidelines for coordinated operations of Lake Powell and Lake Mead define four operation tiers: (1) the Equalization Tier, (2) the Upper Level Balancing Tier, (3) the Mid-elevation Tier, and (4) the Lower Elevation Balancing Tier. Releases greater than 9.5 maf would occur during the Equalization Tier. Annual releases of 7.48 maf occur in the Mid-elevation Tier. Annual releases between 7.48 and 9.5 maf generally occur in the two balancing tiers. Implementation of equalization and balancing will follow descriptions in the Shortage EIS (Reclamation 2007a). Of note is that when operating in the Equalization Tier, the Upper Elevation Balancing Tier, or the Lower Elevation Balancing Tier, scheduled water year releases from Lake Powell would be adjusted each month based on forecast inflow and projected September 30 active storage at Lakes Powell and Mead.

TABLE 3 Comparison of alternative releases, water year 2008

	No Action				Proposed Action			
Month	Monthly volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)	Monthly Volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	600	9,758	6,800	12,800	601	9,774	6,800	12,800
Nov	600	10,083	7,100	13,100	604	10,134	7,200	13,200
Dec	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Jan	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Feb	600	10,804	7,800	13,800	600	10,804	7,400	13,400
Mar	600	9,758	6,800	12,800	830	13,499	7,200	13,200[1]
Apr	600	10,083	7,100	13,100	550	9,243	6,200	12,200
May	600	9,758	6,800	12,800	555	9,042	6,000	12,000
Jun	650	10,924	7,900	13,900	650	10,924	7,900	13,900
Jul	850	13,824	9,800	17,800	820	13,336	9,300	17,300
Aug	900	14,637	10,600	18,600	820	13,336	9,300	17,300
Sep	630	10,588	7,600	13,600	600	10,083	10,083	10,083

[1] Maximum releases during normal modified low fluctuating flow operations in March 2008. During the high flow test the maximum release would be 41,500 cfs.

TABLE 4 Proposed Glen Canyon Dam releases under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	Annual Releases								
	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	7,002	8,002	9,758	9,258	10,258	9,378	8,878	9,878
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	8,575	9,575	10,588	10,088	11,088	21,056	20,556	21,556

2.2.2 Mitigation Measures in the Proposal

Under NEPA, mitigation means reducing, eliminating, or compensating for the impact of an alternative (40 CFR 1508.20). Mitigation measures incorporated into the proposal are designed to accomplish these objectives. More complete descriptions of potential impacts of the proposal are contained in the various resource areas in section 3.0. As discussed under Socioeconomics in section 3.3, increased hydropower costs was a factor in proposing a steady flow test during the fall rather than the summer when much higher economic impacts would occur. In addition, the timing of the high flow test was designed to minimize impacts to recreation, tamarisk seedling dispersal, the aquatic foodbase, and the Kanab ambersnail.

With respect to the high-flow experiment conducted in November 2004, conservation measures were designed to mitigate any adverse impacts on endangered Kanab ambersnail (*Oxyloma haydeni kanabensis*) at Vaseys Paradise in Grand Canyon National Park as a result of temporary high-flow inundation of ambersnail habitat. These efforts included moving 4 percent of the total habitat of plants and animals. The current proposal repeats the 2004 mitigation measures for the Kanab ambersnail. Reclamation proposes to temporarily relocate snails that would be inundated by a 41,500 cfs flow to higher elevations at Vaseys Paradise. Further mitigation commitments could develop as a result of the completion of formal consultation with the FWS under the Endangered Species Act of 1973, as amended (ESA).

As part of information gathering during the formulation of the proposed action, the FWS, NPS, Western, and AGFD conducted a meeting with fishing guides and business owners in the Marble Canyon area. Their concerns were primarily socioeconomic and associated with public perception of impacts to fishing success in the Lees Ferry reach. To minimize potential adverse economic impact, Reclamation agreed to shift the timing of the proposed high flow test as early in 2008 as possible and to work with the FWS, NPS, and

AGFD to propose measures within the GCDAMP dedicated to improving communication between management agencies and the angling guides, dependent local businesses, and the public. These proposed measures include:

- creation of an ad hoc group within the GCDAMP to facilitate discussion among trout fishing guides and anglers, Marble Canyon business owners, recreational rafting companies, and other interested parties regarding proposed experimental actions affecting these resources, and
- consideration of updating the Lees Ferry Management Plan. The NPS and AGFD have primary authority and responsibility for this action, with the FWS and Reclamation participating in an advisory role. If this proposal were accepted by these agencies, workshops could be used to help develop the specific aspects of the management plan.

3.0 Environmental Impacts of the Proposal

This chapter describes environmental impacts of the proposal compared with taking no further experimental flow actions over the next five years. The action area or geographic scope is from the tail water below Glen Canyon Dam downstream along the Colorado River to Lake Mead, as shown in Figure 1. The lateral extent of the action area is the ground surface that would be inundated by the proposed high release of 41,500 cfs or the area indirectly or cumulatively affected.

Reclamation convened an interdisciplinary team of resource specialists to review alternatives and consider potential effects to natural, cultural, and socioeconomic resources listed in Table 1. They concluded that should the proposal be implemented, most resources would be temporarily and beneficially affected; however, implementing the proposal would result in adverse impacts to hydropower customers, trout guides, small businesses in the Marble Canyon area, and the Hualapai Tribe. By definition, this economic or social effect would not require preparation of an EIS (40 CFR 1508.14). Detailed information on resources affected by the proposal is provided below. The chapter is organized by resources, with natural resources described first, followed by cultural, then socioeconomic resources.

3.1 Natural Resources

Natural resources reviewed to determine effects of the proposed action include air quality, floodplains and wetlands, geology and soils (including prime farmlands), threatened and endangered species, vegetation, water resources (hydrology, water delivery systems, water quality), and wildlife. Based on this review of all natural resources in the action area, only those natural resources likely to be directly, indirectly, or cumulatively affected by the proposal are described here.

Of particular importance in evaluating effects of the proposal is humpback chub habitat, especially nursery backwaters, and the possible downstream transport of young humpback chub. Evaluation of the steady fall flow is important to better understand the contrast between fluctuating and steady flows with respect to the extent of longitudinal warming, warming of shoreline habitats and nursery backwaters, stability of shoreline habitats, and the effects to humpback chub survival, growth, and bioenergetic expenditure. Full evaluation of this aspect of the proposed action is important to better understand how discretionary releases from the dam might affect humpback chub and long-term species conservation. In the sections below, the relevant natural resources are presented by trophic levels.

3.1.1 Climate Change

The hydrologic model, Colorado River Simulation System (Reclamation 1988, 2007a), used to present future dam releases under both alternatives does not project future flows or take into consideration climatic projections, but rather relies on historic records of the Colorado River to depict a range of possible future storage levels in Lakes Powell and Mead and dam releases. Using the Colorado River Simulation System, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100-year historic record. This record includes years of under and over average flow. Studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River basin, indicate droughts of greater severity and duration than those in the 100-year historic record. Such findings, when coupled with today's understanding of decadal cycles brought on by the el Niño-Southern Oscillation, Pacific Decadal Oscillation, upstream consumptive use, and improved understanding of millennial-scale climate cycles (Bond et al. 1997), suggest the current drought could continue over the action period or there could be a shift to wetter conditions (Webb et al. 2005). Thus, the action period for this environmental assessment may include wetter or drier conditions than today or wetter or drier conditions than modeled in the Colorado River Simulation System. A continued drought like those documented in proxy records could result in decreased mean annual inflow to Lake Powell and decreased average storage in Lake Powell. This could affect downstream water resources and the effects on water resources under no action or the proposal.

3.1.2 Water Resources or Glen Canyon Dam Operations under No Action

As mentioned above, this environmental assessment is tiered off prior NEPA analyses. Full descriptions of the methods used for water resources modeling and other resources are described in these prior documents. The details of annual and monthly projected water resources and dam operations through the experimental period are in Reclamation (2007a). Only a summary is provided here. Annual releases from the dam would be the same under either alternative as noted in section 2.2, only monthly and hourly release volumes would differ. Tables 2 and 3 present the most probable future values if no action is taken.

3.1.3 Water Resources under the Proposal

One of the differences examined by Reclamation hydrologists was the level of Lake Powell and Lake Mead should the proposal be implemented. Projected differences in Lake Powell elevation with the proposal would be less than projected seasonal change within a given water year. The greatest differences in the elevation of Lake Powell would occur in March 2008 when the reservoir would decrease a projected 2.6 feet as a result of the proposed high-flow release. The effect on Lake Mead would be an increase by 2.5 feet in March. However because the 2008 water year release from Lake Powell is unchanged under the proposal, elevations of both Lakes Powell and Mead would be the same elevation under either alternative by September 30, 2008.

In terms of dam releases, Table 3 contrasts monthly volumes under the two alternatives. Tables 2 and 4 show proposed releases if the water year is dry (7.48 maf), median conditions (8.23 maf), or wet (12.3 maf). Predicted changes in levels of Lakes Powell and Mead or Glen Canyon Dam releases are minor, temporary effects. (Hydropower effects are covered under Socioeconomic Resources.)

3.1.3.1 Water Quality

Effects of the 2008 high flow are projected based on prior experiments and knowledge of water quality processes. Prior experimental high flows weakened the persistent chemical and thermal stratification below the depth of the penstock-withdrawal zone. The volume of water below this zone is normally relatively isolated from the convective and advective mixing processes of the upper portions of the reservoir. The water below the penstock withdrawal zone is typically cooler than the upper level of the reservoir and more saline with a marked reduction of dissolved oxygen concentrations. Releases from the powerplant following the 1996 high flow test had reduced water density and higher dissolved oxygen concentrations, the result of lowering the depth of chemical stratification in the reservoir. Similar positive water quality effects are projected under the proposal.

Water quality effects during a high flow test in 2008 would likely include a slight reduction in downstream temperature and a slight increase in salinity. During the year following the high flow test, salinity levels would probably decrease slightly, downstream temperatures would return to the no-action condition, and dissolved oxygen concentrations could increase slightly. The increase in the dissolved oxygen concentration from fluctuating flows is the result of down-ramping.

Based on model results, the release temperatures of the proposed September and October steady flows would not be significantly different from normal fluctuating releases. Determining the effect of subsequent downstream warming in near shore and backwater areas is one of the important purposes of this portion of the experiment. The proposed steady flows could increase the effect of low dissolved oxygen levels. However, analysis of past data shows than on average steady flow reduced dissolved oxygen level by about 0.25 mg/L. Both steady and fluctuating flows should come to saturation level below the dam at approximately the same distances.

3.1.4 Sediment and Geomorphology

The proposal is designed to test the hypothesis that sediment may be entrained from the channel bed and debris fans and deposited at higher elevations along river channel margins during a high flow, preserving or enhancing camping beaches and sediment conservation.

Significant sediment research in the Grand Canyon has occurred during the past 25 years. While this proposal builds on that monitoring, research and experimentation, this assessment does not intend to fully summarize all that information. During that period of time, there has never been a high flow test conducted during highly enriched sediment conditions nor has a high flow test ever been followed by Modified Low Fluctuating Flow releases during a low annual release year. Reclamation believes such an experiment is critical in determining the potential for long-term sustainability of the sediment resource. Topping et al. (2006) found that in the 1996 high flow test under depletion sediment concentrations, volumes of high elevation bars were increased at the expense of lower elevation portions of upstream sandbars. In 2004, moderately enriched sediment concentrations in upper Marble Canyon produced sandbars in many cases larger than the 1996 deposits, but downstream of RM 42 only 18 percent of sandbars were larger than was produced in the 1996 high flow test (Topping et al. 2006). Their final conclusion was that "…in future controlled floods, more sand is required to achieve increases in the total area and volume of eddy sandbars throughout all of Marble and Grand Canyons." Such condition currently exists as a result of significant sediment inputs during 2006 and 2007. In addition, if no action is taken, recent tributary sediment inputs eventually will be transported downstream to Lake Mead with no high elevation sandbar rebuilding.

With respect to the retention of sandbars thus created, Figure 3 shows the total sandbar volume at 12 sandbar sites in Marble Canyon from 1990 through 2006. Several conclusions are evident with respect to sandbar volume at these sites.

1. there is currently more sediment in these sandbars above 25,000 cfs than prior to the first high flow test in 1996. Mid-elevation and total storage volumes are similar to 1996 levels.
2. in contrast to the declining trend in total sediment storage prior to 1996, the high flow tests of 1996, 1997, 2000, and 2004 have each increased the amount of sand storage, for both mid-elevation and high elevation deposits
3. initial increases in sand storage decline rapidly, with half of the initial increases in total sediment storage eroded within 6 months in 1996 and within 15 months in 2004.

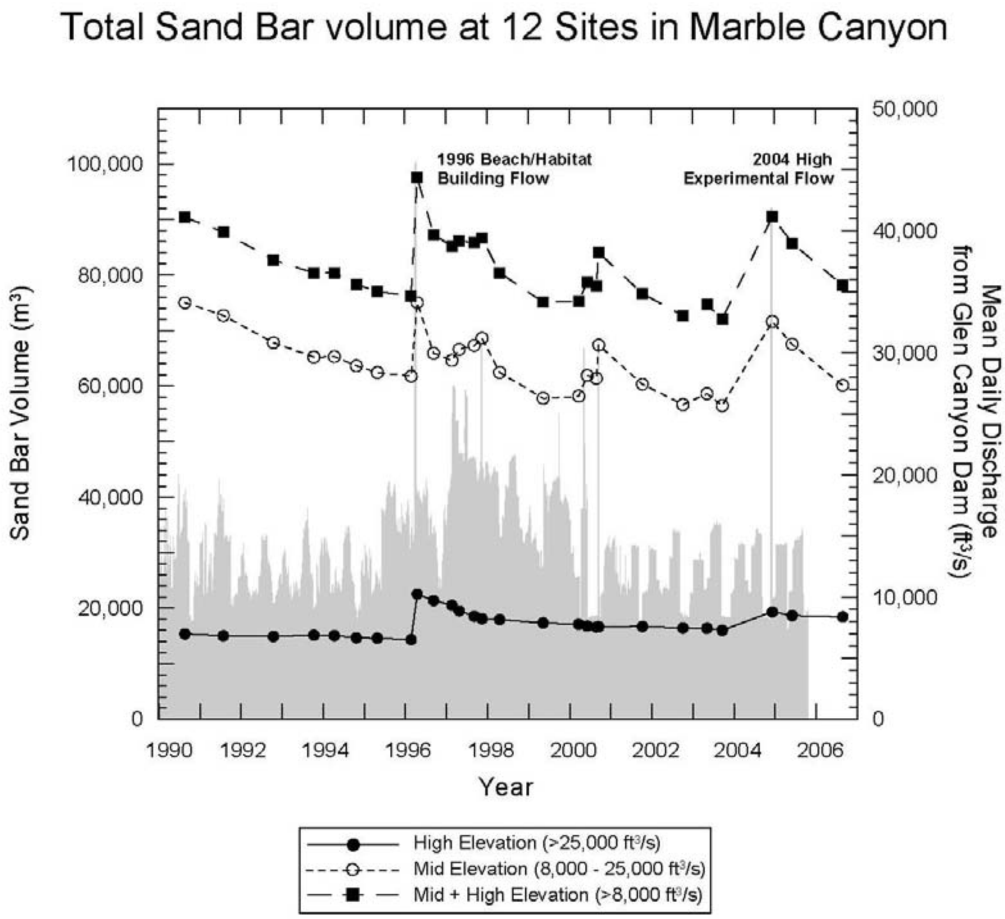

FIGURE 3 Total sandbar volume at 12 sites in Marble Canyon. *Source*: J. Hazel, preliminary data courtesy of Northern Arizona University.

Dam releases following historic high flow tests have had a significant effect on newly created sandbar deposits and the high flows which followed the 1996 and 2004 tests have been implicated in the rapid erosion of these sandbars (Schmidt et al. 2004). Following the 1996 high flow test, maximum daily releases usually reached 20,000 cfs during water year 1996 and exceeded 20,000 cfs for much of water year 1997, and following the 2004 high flow test, high fluctuating winter releases designed to disadvantage nonnative trout spawning reached daily maximums of 20,000 cfs for the January through March 2005 period (Reclamation 2008b). In contrast, Glen Canyon Dam releases during 2006 and 2007 had low annual volumes and Modified Low Fluctuating Flow constraints and have resulted in suppressed sediment transport, allowing sediment accumulation in the Colorado River mainstem above the Little Colorado River confluence and RM 30 (USGS 2007b); sediment transport conditions are expected to be similar in 2008.

While it is generally expected that significant positive sandbar building will occur during the high flow test, it is uncertain where that sandbar building will occur, how long those effects will persist, what benefits will accrue, and whether high flows will enable long-term sediment conservation. It is expected that monitoring and research activities will be followed by analysis and modeling to answer these questions.

3.1.4.1 Sandbars under No Action

Some geomorphologists believe that Grand Canyon sandbars will continue to degrade due to the existence of the dam; others hypothesize that dam operations, particularly high flows, may be used to rebuild, conserve, or enhance sandbars, particularly when combined with significant tributary sediment inputs (Topping et al. 2006). As stated above, an underlying purpose of this and prior experimental dam releases is to test such hypotheses, measure rates of sand deposition and erosion, as well as to observe changes in sandbar topography over time in relation to dam operations. Under the No Action Alternative, no specific experimental flow tests would occur, beach-habitat building flows triggered by a risk of spills would occur as specified in the 1997 Glen Canyon Dam operating criteria, and sandbars and beaches would likely decline in area and volume as in the period 1990 - 1996.

3.1.4.2 Sandbars under the Proposal

Based on prior experimental flows, sediment would likely be entrained quickly and efficiently by the proposed 41,500 cfs release. Suspended sediment concentrations within the river and eddies would be expected to decrease after the river stage reaches its peak. This response is expected to vary from that measured in 1996 due to current abundant sediment supply in the river. Together with sand supplied from the Little Colorado River, sand storage on average throughout Marble and Grand canyons is currently substantially greater than that preceding the 2004 high flow test (D. Topping, pers. comm..). As of August 2007, about 1.75 million metric tons (mmt) of fine sediment relative to October 2006 was still situated above the confluence of the Little Colorado River, with about 1.5 mmt above RM 30 (USGS 2007b). These conditions present an opportunity to evaluate effects of a high flow test under more sediment-rich conditions than observed during previous experiments.

Based on the results of high releases conducted in 1996, 1997, and 2004, a high flow test would likely increase the number and size of sandbars and campsites immediately after the event. For example, the 1996 flood created 84 new campsites, while destroying three others (Kearsley et al. 1999). A key question is whether a high flow under sediment enriched conditions might result in larger or more lasting effects.

3.1.4.3 Backwaters under No Action

Backwaters may be important rearing habitat for native fish due to low water velocity, warm water, and high levels of biological productivity. The importance of backwaters in Grand Canyon with respect to native fish is uncertain, and this is one of the key questions associated with the proposal. Backwaters are created as water velocity in eddy return channels declines to near zero with falling river discharge, leaving an area of stagnant water surrounded on three sides by sand deposits and open to the main channel environment on the fourth side. Reattachment sandbars are the primary geomorphic feature that functions to isolate near shore habitats from the cold, high velocity main channel environment.

Backwater numbers vary spatially among geomorphic reaches in Grand Canyon and tend to occur in greatest number in river reaches with the greatest active channel width, including the reach immediately downstream from the Little Colorado River (RM 61.5-77; McGuinn-Robbins 1995). Numbers and size of backwaters also vary temporally as a function of sediment availability and hydrology, and their size can vary within a year at a given site. Under no action, backwaters would continue to fluctuate with ongoing geomorphic and hydrologic processes.

3.1.4.4 Backwaters under the Proposal

Persistence of backwaters created during 1996 appeared to be strongly governed by post-high flow dam operations. Whereas the 1996 high flow test resulted in creation of 26 percent more backwaters potentially available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999; Hazel et al. 1999; Parnell et al. 1997; Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999). One of the key tests of this proposal is how summer Modified Low Fluctuating Flows and fall steady flows might affect backwaters (USGS 2007a).

Goeking et al. (2003) found no relationship between backwater number and flood frequency, although backwater size tends to be greatest following high flows and less in the absence of high flows due to infilling. Considering both area and number, however, no net positive or negative trend in backwater availability was noted during 1935 through 2000. At the decadal scale, several factors confound interpretation of high flow effects on backwaters bathymetry, including site-specific relationships between flow and backwater size, temporal variation within individual sites, and high spatial variation in reattachment bar topography (Goeking et al. 2003). Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, hydrology of previous years (Rakowski and Schmidt 1999) and post-high flow river hydrology, which can shorten the duration of backwaters to a few weeks depending on return channel deposition rates or erosion of reattachment bars (Brouder et al. 1999).

Biologically, the 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring (Brouder et al. 1999; Parnell and Bennet 1999). Invertebrates rebounded to pre-test levels by September 1996, but researchers thought that the rate of recolonization was hindered by a lack of FPOM. Still, recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer’s cohort of young-of-year (YOY) native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell and Bennet (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater. The proposal is expected to have the same effects on backwaters: an immediate reduction in benthic invertebrate numbers and fine particulate organic matter, but over time, a potential beneficial change in backwaters. Another key purpose of the proposal is to determine the effect that flow stability has on backwater temperature, and consequential impacts to productivity and native and nonnative fish.

3.1.5 Vegetation

Vegetation along the river is distributed along a gradient with the first 60 miles classified as Upper Sonoran or cold desert plants, gradually shifting to warm desert species typical of Lower Sonoran vegetation. At any one location where cross-sections are taken, the more xerically adapted species such as four-wing saltbush (*Atriplex canescens*), brittle bush (*Encelia farinosa*), and rubber rabbitbrush (*Chrysothamnus nauseosus*), are found on the terraces away from the river. These upland plants would be largely unaffected by the proposal and are therefore not considered here.

Within the area that would be inundated by a flow of 41,500 cfs, vegetation has changed over time in response to changes in the water-levels of the Colorado River, increased soil salinity, climatic changes, and other factors (Carothers and Aitchison 1976, Kearsley et al. 2006). Prior to 1963, riparian vegetation was common in Glen Canyon and along the lower Colorado River, but relatively rare in Grand Canyon due to the combination of high flows, sediment deposition, and entrained debris scouring the floodplain (Clover and Jotter 1944; Kearsley and Ayers 1999:310; Stevens and Waring 1988; Stevens et al. 1995). By 1973 after 10 years of regulated flows, species that were ephemeral pre-dam occupants (Clover and Jotter 1944; Turner and Karpriscak 1980) expanded into the newly stable habitat. From 1983 to 1985, summer flows were maintained at or above 40,000 cfs, altering the composition, density, and location of riparian plants (Stevens and Waring 1988). Since then, the total size of the riparian zone or new high water zone has increased to 10 square miles (2,500 hectares) (Kearsley and Ayers 1999; Schmidt and Graf 1990) with salt cedar or tamarisk (*Tamarix ramosissima*) being the most dominant species, and arrowweed (*Pluchea sericea* (Nutt.) Cov.), black willow (*Salix gooddingii*), coyote willow (*Salix exigua* Nutt.), and Emory seepwillow (*Baccharis emoryi* Gray), found in lesser abundance (taxomony is after Welsh et al. 1987).

Stands of emergent marsh vegetation in the riparian zone tend to be dominated by a few species, depending on soil texture and drainage. A cattail (*Typha domingensis*) and common reed (*Phragmities australis*) association grows on fine-grained silty loams while a horseweed (*Conyza canadensis*), knotweed (*Polygonum aviculare*), and Bermuda grass (*Cynodon dactylon*) association grows on loamy sands. The riparian vegetation located at stage elevations above daily inundation fall out along moisture gradients and species tolerance to water stress (Kearsley et al. 2006; Stevens et al, 1995). Kearsley et al. (2006) demonstrated through four years of monitoring that annual operations affects plant species diversity and cover up to 35,000 cfs. Operational effects include duration of mean discharge and maximum discharge for at least three months or more. Vegetation above this surface elevation tends to be affected more by local precipitation than by annual operations. The effects of hydrologic gradients on species abundance and diversity in riparian areas has been observed in other semi-arid rivers (Shafroth et al. 1998; Stromberg et al. 1996).

3.1.5.1 Vegetation under No Action

If no action were taken by Reclamation through 2012, riparian vegetation would continue to change due to processes of expansion and colonization by invasive species such as tamarisk, camelthorn, Russian-thistle (*Salsola iberica*), red brome or foxtail brome (*Bromus rubens*), cheatgrass (*Bromus tectorum*), yellow sweet-clover (*Melilotus officinalis*), spiny sow-thistle (*Sonchus asper*), and Bermuda grass (*Cynodon dactylon*). Other natural processes would continue to result in alteration of the riparian zone. Kearsley et al. (2006) developed predictive models for vegetation dominance based on stage changes in river flows and cycles of inundation. Essentially, frequent changes in inundation resulting from dam operations led to an increase in total volume of tamarisk and other woody riparian species and is accompanied by a reduction in herbaceous species (Kearsley and Ayers 1999; Kearsley et al. 2006): a reduction in species is predicted in the absence of disturbance. Many of the changes in riparian vegetation can be accounted for with a reduction in fine sediments due to frequent water-level fluctuations and the lack of flooding which is integral to riparian system function (Nilsson et al. 1989; NRC 2002). Within Grand Canyon, Bowers et al. (1997) and Webb (1996) have demonstrated that short-lived plants such as *Brickellia longifola, Stephanomeria pauciflora, Gutierrezia sarothrae, Encelia frutescens*, and *Baccharis emoryi*, are actively colonizing the youngest and more disturbed surfaces. Longer-lived species are not as quick to colonize disturbed areas. For example, *Ephedra* spp., *Opuntia* spp., and *Acacia gregii* are found on surfaces older than seven years and as young as 28 years. Without the disturbances caused by the proposal or on-going formation of debris fans at tributary mouths, the longer-lived species will continue to expand towards the river edge.

Of course, some changes to riparian vegetation are occurring due to management actions. Executive Order 13112 defines invasive species as alien species whose introduction is likely to cause economic or environmental harm or harm to human health. This executive order calls on federal agencies to work to prevent and control the introduction and spread of invasive species. Both Glen Canyon National Recreation Area and Grand Canyon National Park support programs of noxious and invasive plant control and these programs are projected to continue.

3.1.5.2 Vegetation under the Proposal

Effects of prior experimental flows of similar magnitude on riparian vegetation were minimal (Valdez 1999:346), but subsequent flows do affect plant response to a disturbance. A study conducted in 2000 (Porter 2002) for flows of slightly lower magnitude (31,000 cfs) documented an increased germination of nonnative species in exposed areas (e.g. tamarisk). Studies during the 1996 flood did not specifically focus on seedling establishment (Kearsley and Ayers 1999), but expansion of Bermuda grass following the 1996 experimental release was noted by Phillips and Jackson (1996). As noted above, it is the long-term operations following a disturbance that affects riparian vegetation response to a disturbance event (Kearsley et al. 2006; Kearsley and Ayers 1999; Porter 2002). Long-term effects of the high flow in March and steady flows in September and October are predicted to be minor. Prior high flow experiments showed that sedimentation along channel margins and in eddy deposition zones buried low-growing plants; however, this effect was of insufficient magnitude, duration, or both, to restructure most vegetation patches in the long term (Kearsley and Ayers 1996; Valdez 1999:345).

In terms of effects to individual species, an increase in the density of cattails was noted in lower reaches of Grand Canyon following the 1996 high flow test as well as increased abundance of woody species in Kwagunt Marsh (Kearsley and Ayers 1996), but this may have been a result of high sustained releases that followed the high flow. Also, total foliar cover was diminished as a result of the 1996 flood, but no localities showed a significant change in area covered by wetland plants (Kearsley and Ayers 1996). The proposed 2008 flood would likely result in similar minor effects: short term burial of seeds and plants on existing sandbars, some scouring of riparian vegetation, and a short-term increase in groundwater and soil nutrient concentrations. Newly exposed sediment may be subject to exotic colonization, particularly low velocity, low elevation sandbars (Porter 2002), but subsequent establishment in these sites is dependent on long-term operation during the summer growing season. Over time, later successional, woody species may occupy these areas.

The proposed high flow would increase the rate at which sediment is deposited at the delta of Lake Mead, as predicted in the Sediment section. However, because of the short duration of the flow, the extensive area available for sediment deposition in Lake Mead, and the highly fluctuating water levels of Lake Mead, effects on riparian vegetation would be minor.

Established tamarisk and camelthorn located on sand bars and along channel margins are expected to survive a flood, growing up through newly deposited sand and vigorously resprouting and recolonizing sandbars, though the extent of the expansion is dependent on subsequent discharge. This expansion is likely to continue whether there is an experimental flood or not (Valdez 1999:346). One effect of prior floods on riparian vegetation was the burial of the seed bank by new sediment deposits (Kearsley and Ayers 1999; Valdez 1999), although, it is unclear whether the newly buried seeds remain viable, leading to further expansion of undesired plants onto sandbars. The creation of new habitat through the deposition of sediment during flooding can lead to increases in exotic species, especially fast-colonizing annuals and tamarisk (Kearsley et al. 2006; Porter 2002).

In conclusion, there might be changes in individual plants or patches of plants, but over time these changes would be minor against the larger changes wrought by processes of succession and adaptation along a hydrological gradient and those caused by daily fluctuations. Compared to no action, the action alternative would likely lead to deposition of new sediment that could lead to some increase in nonnative plants, especially tamarisk and *Bromus* spp. Kearsley et al. (2006) demonstrated that these changes can be predictable over large spatial and temporal scales.

3.1.6 Terrestrial Invertebrates and Herptofauna

In this section, effects of the proposal are analyzed for specific terrestrial invertebrates or herptofauna of interest, particularly those listed as endangered, threatened, or of concern to states or tribal managers. A separate biological assessment of these effects was submitted to the FWS (Appendix B) and is reflected in a new biological opinion issued under Section 7 of the ESA (Appendix C). (The effects of the proposal on aquatic invertebrates are included under the discussions of fish and birds.)

The Kanab ambersnail (*Oxyloma haydeni kanabensis*) was listed as endangered in 1992. Populations of Kanab ambersnail presently occur at three springs, one at Three Lakes near Kanab, Utah; one at Vaseys Paradise, a small spring-fed riparian area adjacent to the Colorado River in Grand Canyon; and a translocated population at Upper Elves Chasm. Kanab ambersnails located at Elves Chasm would not be affected by this action.

Over 27 species of herpetofauna have been documented in the riparian zone of the Grand Canyon (Kearsley et al. 2006). Within this area, herpetofauna densities are highest where riparian vegetation has developed since construction of Glen Canyon Dam, i.e., between the more xeric terraces and the river shoreline. Toads and tree lizards use the shoreline proportionally more than other species (Carpenter 2006). Water level fluctuations can also help maintain areas with reduced vegetation cover and could likely lead to increase in use by basking reptiles. This zone would also provide an area with elevated humidity and increased food production such as insects (Kearsley et al. 2006)

Common lizards in the riparian zone are the side-blotched lizard (*Uta stansburiana*), Western whiptail (*Cnemidophorus tigris*), desert spiny lizard (*Sceloporus magister*), and the tree lizard (*Urosaurus ornatus*). The collared lizard (*Crotaphylus insularis)* and chuckwalla (*Sauromalus obesus)* are less common in the riparian zone than in the more xeric terraces. Warren and Schwalbe (1985) reported lizard densities during June averaged 858/hectare in the riparian zone versus 300/hectare in the old high water zone. Kearsley et al. (2006) suggested that the high density of lizards in the riparian zone may be attributed to increased abundance of food resources (insects) and to some degree to organic debris left on popular camping beaches.

Snakes are common in the higher and drier elevations of the riparian zone and in the more xeric terraces and hillsides. Eight snake species have been documented within the riparian zone; the most common of these are the Grand Canyon rattlesnake (*Crotalus viridis abyssus*), the southwestern speckled rattlesnake (*C. mitchellii pyrrhus)* and the desert striped whipsnake (*Masticophis taeniatus)*.

Amphibians include frogs, spadefoots, and true toads. Recent surveys have found abundant populations of Woodhouse's toad (*Bufo woodhousii*), red-spotted toad, (*B. punctatus*), canyon treefrog, and tiger salamander (*Ambystoma tigrinum*) (Kearsley et al. 2003, 2006). Northern leopard frog (*Rana pipiens*) populations, on the other hand, have declined (Drost 2004, 2005). Listed as a candidate species in Arizona, the northern leopard frog is declining throughout its range. Leopard frogs have disappeared from 70 percent of the known sites above and below Glen Canyon Dam and there appear to be declines among some of the remaining populations (Drost 2004). The only known population below the dam is located in Glen Canyon in a series of off-channel pools. Inundation at this site occurs at approximately 21,000 cfs. This population has experienced wide year-to-year fluctuations in numbers, but a recent survey indicates a sharp decline in population with only two adult individuals found in 2004 (Drost 2004).

The canyon treefrog is confined to relatively steep side canyons, while the two toad species are found in the active riparian zone in spring and fall and along the shoreline in summer (Kearsley et al. 2003). For amphibians, egg deposition and larval development generally occurs in the backwaters or along the shallow water at the boundary of the aquatic and riparian habitats.

3.1.6.1 Terrestrial Invertebrates and Herptofauna under No Action

Kanab ambersnails are found in the riparian vegetation associated with the spring at Vaseys Paradise. Through analysis of historic photographs, an increase in the vegetative cover along the river in Grand Canyon has occurred since the completion of Glen Canyon Dam in 1963 (Turner and Karpiscak 1980). The increase in cover, reduction in beach-scouring flows, and introduction of nonnative water-cress, *Nasturtium officinale,* has led to a greater than 40 percent increase in suitable Kanab ambersnail habitat area at Vaseys Paradise from pre-dam conditions (Stevens et al 1997a). Under the no action alternative Kanab ambersnails are expected to maintain their population at Vaseys Paradise.

Herpetofauna densities are generally highest where riparian vegetation has developed since construction of Glen Canyon Dam. However, Carpenter (2006) found that, other than the resident frogs, herpetofuana utilize habitats from the river up to the xeric terraces. Toads and tree lizards use the shoreline proportionally more than any of the other species (Carpenter 2006). Amphibians and reptiles are not expected to change under the no action.

3.1.6.2 Terrestrial Invertebrates and Herptofauna under the Proposal

The proposed 2008 high flow test would result in a minor loss of the Vaseys Paradise habitat of Kanab ambersnail. But pre-dam, the Kanab ambersnail population in the Grand Canyon survived and recovered from innumerable flows equal to or higher than the proposal. The population of Kanab ambersnail at Vaseys Paradise and the effects of the proposal on them are currently under consultation with the FWS. Reclamation's finding is that the proposal "may affect, is likely to adversely affect" a percentage of snails and their habitat during the high flow test. No effect on snails or habitat would result from fall steady flows. At flows of 45,000 cfs, approximately 17 percent of Kanab ambersnail habitat would be inundated. This habitat varies from high to low suitability for Kanab ambersnail. If the proposed high flow is implemented, Reclamation would move approximately 25 percent of affected habitat, including higher quality vegetation and snails within the flood zone, as was done in 2004. Additionally, all vegetation in the potentially flooded zone will be searched for snails and all snails that are found will be temporarily moved with the vegetation. The vegetation and snails would be replaced after the flood waters have receded. Moving snails and their habitat, as mentioned under the section on mitigation measures, could result in an adverse effect or "take" of the species. This potential for take is the reason for the "may affect" finding in Reclamation's biological assessment.

Populations of northern leopard frog in the Glen Canyon reach were monitored before and after the 1996 flood and the populations were little affected in the short-run and recovered quickly over time (Spence 1996). However, since 1996 northern leopard frogs have declined dramatically in Glen and Grand canyons and in 2004 only two adults were found in an off-channel pool in Glen Canyon. Clearly other factors besides high flows have played a role in this decline. Using the conclusions of the 1997 report and the 2004 status of this population, effects are uncertain to populations of these species from the proposal.

3.1.7 Fish under No Action

The river from the dam to the Paria River presently supports a self-sustaining fishery of rainbow trout (*Oncorhynchus mykiss)* and occasional brown trout (*Salmo trutta)*. Prior to implementation of the 1996 record of decision and flow changes made therein, stocking was necessary to maintain the fishery. Management of trout in this reach, as agreed to by the management agencies is for rainbow trout and not for brown trout; the latter is a particularly piscivorous predator on native fish. This reach of river also supports small numbers of bluehead sucker (*Catostomus discobolus*), flannelmouth sucker (*Catostomus latipinnis*), and speckled dace (*Rhinichthys osculus*). The flannelmouth sucker spawns in this reach and up the Paria River (McIvor and Thieme 2000; McKinney et al. 1999; Thieme 1998), although the water is too cold in the mainstem for survival of eggs and larvae.

From the Paria River to the Little Colorado River, rainbow trout is the dominant nonnative species (Ackerman 2007; Johnstone and Lauretta 2007), but this 61 miles of the Colorado River supports low to moderate numbers of native bluehead sucker flannelmouth sucker, humpback chub, and speckled dace (*Rhinichthys osculus*) (Hoffnagle et al. 1999). Most native fish in the mainstem from the dam to the Little Colorado River are large juveniles and adults. Earlier life stages rely extensively on more protected nearshore habitats, primarily backwaters (Lauretta and Serrato 2006; Trammell et al. 2002). Native fish spawning may occur in warm springs at RM 30-32 (Valdez and Masslich 1999). Other nonnative species sporadically found in that reach include brown trout, common carp (*Cyprinus carpio*), red shiner (*Cyprinella lutrensis*), plains killifish (*Fundulus zebrinus*), fathead minnow (*Pimephales promelas*), and channel catfish (*Ictalurus punctatus*).

The 174 miles from the Little Colorado River to Bridge Canyon has six major tributaries and supports a diverse fish fauna of cool- to warm-water species to about Havasu Creek, including the three non-listed native species and seven known aggregations of humpback chub. Non-listed native fish are also well represented in the tributaries: Bright Angel, Shinumo, Tapeats, Kanab, and Havasu creeks (Leibfried et al. 2006), especially during spawning periods.

Below the Little Colorado River, warm water nonnative species such as common carp, channel catfish, and fathead minnow increase in numbers and are most abundant between Shinumo and Diamond creeks (Ackerman 2007). Red shiner and plains killifish are common in backwaters immediately below the Little Colorado River and occur sporadically downstream from that point (Johnstone and Lauretta 2007; Lauretta and Serrato 2006).

The 45-mile reach of the Colorado River from Bridge Canyon to Pearce Ferry is flat and muddy due to high lake elevation sediment deposition on the old river channel.

Abundances of flannelmouth suckers, speckled dace, and bluehead suckers are limited due to lack of spawning habitat and large numbers of predators (Valdez 1994; Valdez et al. 1995).

Razorback suckers in Grand Canyon, if any exist, are likely old and no reproduction has been documented. Razorback suckers evolved under a water regime featuring high spring flows, and adult suckers would be able to locate refuge areas during the proposed flow and would suffer no adverse effects. There is no indication that young razorback suckers occur in Grand Canyon today. The status of this species in Grand Canyon was included in the FWS's biological opinion (2008:86), with a concurrence that the proposal "may affect, but is not likely to adversely affect" the species.

All fish above the Paria River rely heavily on algal and invertebrate benthic production in the Lees Ferry reach as a food source; food resources for fish in lower reaches, in which there are larger and more frequent fine sediment inputs, are presently being investigated by GCMRC and cooperators. Year-to-year variance in algae, macrophytes, and macroinvertebrates (amphipods, chironomids, oligochaetes, and snails) is primarily due to differences in hydrology and sediment discharges from tributaries (Blinn et al. 1994; Shaver et al. 1997). Invertebrate production and abundance has typically decreased during the fall and winter seasons (McKinney et al. 1999; Rogers et al. 2002). Under the No Action Alternative, the food base should continue to demonstrate seasonal patterns of varying abundance. Organic matter drift magnitudes would continue as at present under record of decision flow constraints.

3.1.8 Fish under the Proposal

Effects of the proposal are expected to be comparable to those from other experimental flow tests (Hoffnagle et al. 1999; Makinster et al. 2007; McKinney et al. 1999; Valdez and Hoffnagle 1999). Catch-per-unit effort (CPUE) of humpback chub and flannelmouth sucker did not differ in 1996 pre- versus post-flood periods. Valdez and Hoffnalge (1999) concluded there were no significant adverse effects on movement, habitat use, or diet of humpback chub. The CPUE of plains killifish, bluehead sucker, and fathead minnow decreased following the high flow while the CPUE of speckled dace and rainbow trout increased. There were some shifts in the distribution of fish within the river from prior high flow tests, changes indicative of downstream displacement, but most changes were short-term. Hoffnagle et al. (1999) concluded that catch rates of all species before and after the high flow test were similar to those recorded in previous years. In other words, high flows did not significantly affect fish distributions or abundances through Glen or Grand canyons.

A March high flow test would probably temporarily disrupt native flannelmouth suckers and native bluehead suckers in the area from the dam to the Paria River, but these species were largely unaffected by the 1996 and 2004 floods. Speckled dace is the most common native fish species in the mainstream and in most tributaries. Little is known about population size, distribution, reproductive success, movement, or survival for this species in Grand Canyon, although there were shifts observed in habitat use by speckled dace during the 1996 flood (Valdez and Cowdell 1996).

High flow tests are not expected to significantly impact standing biomass of benthic invertebrates over the long term. During the March 1996 high flow test, benthic algal and invertebrate standing stocks on cobble bars and in backwaters were reduced immediately following the test but had rebounded to pre-test levels within a few months afterwards (Blinn et al. 1999; Brouder et al. 1999; McKinney et al. 1999).

Stabilization of flows during September and October has the potential for improving food base production because of the absence of negative effects brought about from desiccation and dewatering that occurs in the zone of fluctuation. Drift during steady flows may be reduced compared to fluctuating flows (Blinn et al. 1992; Rogers et al. 2002; Shannon et al. 1996). Most of the fish species in the project area, as is true of stream fish in general (Gerking 1994:375), are not food specialists and are capable of foraging from the benthos or feeding on organic matter drift. The catastomid suckers likely are the most specialized feeders, and they feed primarily by scraping algae and invertebrates from the surface of benthic substrates. Rainbow trout are rather catholic feeders on a wide variety of invertebrates and, although they feed primarily on organic drift, they also forage directly from the benthos and on terrestrial invertebrates (Elliott 1973, Gerking 1994:236; Tippets and Moyle 1978,). Diminished drift rates will be short-lived and should not affect higher trophic levels, however, and steady flows should allow for greater standing biomass of algal and invertebrate prey overall. Small native fish in low velocity nearshore habitats intended to be positively affected by the steady flows will not be dependent on drift for their food resources.

In terms of species listed under the ESA and consultation with the FWS, Reclamation's conclusion in its biological assessment (Reclamation 2007b) is that the proposed action is not likely to result in the destruction or adverse modification of designated critical habitat for the humpback chub or razorback sucker. Reclamation's finding is that the proposal may affect, and is likely to adversely affect the humpback chub due to the "take" that is likely to result from downstream transport of young humpback chub during the high flow. The long-term effects on humpback chub from creation and improvement of rearing habitats are expected to be positive.

Creation and improvement of backwater rearing habitats expected from the high flow test could expand spatial extent of backwater habitat. Steady flows could result in more hydraulically stable nearshore rearing habitats, slightly warmer temperatures and increased abundance of invertebrate prey items (Reclamation 2007b). Collectively, these effects should result in improved growth and survival of young-of-year humpback chub and other native fish prior to the onset of winter. However, the same benefits could be accrued to predatory or competitive nonnative fish, primarily small-bodied cyprinids which utilize the same backwater habitats as young native fish. Thus, in order for the proposal to be most beneficial to humpback chub and other native fish, it is essential that a nonnative fish control plan (coldwater and warmwater) be developed and implemented. This effort was referenced in the Shortage EIS biological opinion as a conservation measure. Progress to this end is being made at this time by USGS, and active management of warm and cold water nonnative fish should begin as soon as possible.

Effects of high flows on rainbow trout in the Lees Ferry reach suggest at most a temporary reduction in abundance of smaller sizes classes, but no lasting impacts to the fish population size, size structure, body condition or diet. McKinney et al. (1999) noted a decline in proportion of <152 mm (age 1) fish following the 1996 high flow test suggesting some downstream displacement, but overall found no lasting impacts to either trout abundance or condition. Speas et al. (2004) noted no change in age 1 fish abundance following powerplant capacity flows in 1997 and 2000. Similar results were observed during the 2004 high flow test (AGFD, unpublished data).

Lasting effects of fall stable flows on the rainbow trout population are likely to be minimal. Korman et al. (2005) noted increased growth of young-of-year rainbow trout during periods of relatively stable daily flows, suggesting similar results may be seen due to the proposed action. However, Speas et al. (2004) noted no clearly defined response by the rainbow trout population (including fish growth rates) to low steady summer flows conducted in 2000.

3.1.9 Birds under No Action

More than 30 species of birds have been recorded breeding in the riparian zone along the Colorado River in Grand Canyon (Brown 1988). Most birds in this area nest and forage for insects within the riparian zone and the adjacent upland area. Of the 15 most common riparian breeding bird species, 10 are neotropical migrants that breed in the study area but winter primarily south of the United States-Mexico border. The rest of the breeding birds that use the canyon are year-round residents or short-distance migrants that primarily winter in the region or in nearby southern Arizona (Brown 1989; Brown et al. 1987).

Eleven of the breeding birds in Glen and Grand canyons are considered obligate riparian birds due to their complete dependence on the riparian zone. Obligate riparian birds nesting within the riparian zone include the neotropical migrants Lucy's warbler (*Vermivora luciae*) and Bell's vireo (*Vireo bellii*), two species identified as "high priority" under regional Partners-in-Flight bird plans and area state bird plans. The remaining riparian obligates include common yellowthroat (*Geothlypis trichas*), yellow warbler (*Dendroica petechia*), yellow-breasted chat (*Icteria virens*), black-chinned hummingbird (*Archilochus alexandri*), the endangered Southwestern willow flycatcher (*Empidonax trailii extimus*), and Bewick's wren (*Thryomanes bewickii*), a sometimes permanent resident of Grand Canyon (Spence 2004). Black Phoebe (*Sayornis nigricans*) is a common permanent resident of the canyon with a close association to water (Spence 2004).

Winter songbirds include ruby-crowned kinglet (*Regulus calendula*), white-crowned sparrow (*Zonotrichia leucophrys*), dark-eyed junco (*Junco hyemalis*), and song sparrow (Spence 2004). Spence (2004) found that winter species diversity increased below RM 205. Breeding and wintering songbirds are not expected to be impacted by no action.

The aquatic bird community is almost exclusively made up of winter residents (Spence 2004, Yard and Blake 2004). Thirty-four species of wintering waterfowl along with loons, cormorants, grebes, herons, rails, and sandpipers use the river corridor. Increases in abundance and species richness have been attributed to the increased river clarity and productivity associated with the presence of Glen Canyon Dam (Spence 2004; Stevens et al. 1997b). The majority of waterfowl tend to concentrate above the LCR due to the greater primary productivity that benefits dabbling ducks and greater clarity for diving, piscivorous ducks. Common waterfowl species include American coot (*Fulica americana*), American widgeon (*Anas americana*), bufflehead (*Bucephala albeola*), common goldeneye (*B. clangula*), common merganser (*Mergus merganser*), gadwall (*A. strepera*), green-winged teal (*A. crecca*), lesser scaup (*Aythya affinis*), mallard (*A. platyrhynchos*), and ring-necked duck (*A. collaris*). Other than great blue heron (*Ardea herodias*) and spotted sandpiper (*Actitis macularia*), which are fairly common winter and summer residents along the river, other shorebirds are rare in this area (Spence 2004, Yard and Blake 2004). Aquatic birds would be unaffected by no action.

The southwestern willow flycatcher (SWFL; *Empidonax traillii extimus)* was designated by the FWS as endangered in 1995. Critical habitat for SWFL was redesignated in October of 2005 and no longer includes habitat within the action area (FWS 2005). In recent years, SWFL have consistently nested along the river corridor in the Grand Canyon as new riparian habitat, primarily tamarisk, has developed in response to altered river flow regimes (Gloss et al, 2005). This expansion of riparian vegetation may have provided additional habitat for the flycatcher, but populations in the upper river corridor persist at a very low level at only one or two sites. Resident birds have been documented in a limited stretch of Marble Canyon and the lower Canyon near the inflow to Lake Mead (Sogge et. al. 1995a, Tibbets and Johnson 1999, 2000; Unitt 1987). Population numbers have fluctuated between five breeding pairs and three territorial, but non-breeding, pairs in 1995 to one single breeding pair in more recent years. The year 2004 marked the sixth consecutive year in which surveys located a single breeding pair at the upper sites, the lowest population level since surveys began in 1982. In 2006 two nests were detected during the breeding season at the inflow area to Lake Mead (Koronkiewicz et al. 2006), but no flycatchers were found in Marble Canyon in either 2006 or 2007. Due to extreme drops in water levels in Lake Mead that started in 2000, much of the occupied habitat of the 1990s is now dead or dying. More recently, new stands of vegetation have been developing in areas exposed by receding water and this vegetation is now developing into suitable flycatcher habitat.

The SWFL is an insectivorous riparian obligate. It breeds and forages in dense, multistoried riparian vegetation near surface water or moist soil (Sferra et al. 1995; Whitmore 1977) along low gradient streams (Sogge 1995). Nesting in the Grand Canyon typically occurs in nonnative tamarisk approximately 13-23 ft (4-7 m) tall (Tibbetts and Johnson 1999). Resident birds arrive in Grand Canyon in May. Under the No Action Alternative, the SWFL are not expected to be impacted.

The bald eagle (*Haliaeetus leucocephalus*) was listed as endangered under the ESA in 1967 and down-listed to threatened in 1995. (Additionally, it was listed as endangered under the California Endangered Species Act in 1971.) It is a species of special concern in Arizona. The bald eagle was proposed for federal delisting in 1999 (FWS 1999) and was delisted on July 9, 2007 (FWS 2007).

A wintering bald eagle concentration of bald eagles was first observed in Grand Canyon in the early 1980s and numbers have increased dramatically since 1985 (Brown 1992; Brown and Stevens 1991, 1992; Brown et al. 1989). Territorial behavior, but no breeding activity, has been detected. This wintering population has been monitored since 1988 and it occurs throughout the upper half of the Grand Canyon (in Marble Canyon). Density of the Grand Canyon bald eagles during the winter peak (late February and early March) ranged from 13 to 24 birds between Glen Canyon Dam and the Little Colorado River confluence from 1993 to 1995 (Sogge et al. 1995b). A concentration of wintering bald eagles often occured in late February at the mouth of Nankoweap Creek, where large numbers of rainbow trout congregated to spawn (Gloss et al. 2005). However a flash flood recently destroyed the spawning habitat and the eagles no longer congregate there. Under no action, bald eagles are expected to benefit from current conditions and no changes are expected.

Following successful recovery efforts, the American peregrine falcon (*Falco peregrinus*) was removed from the endangered species list in 1999. The Endangered Species Act requires a minimum of five years of post-delisting monitoring to confirm recovery. Although peregrine falcons are uncommon year-round residents in the action area, the population has gradually increased since the 1970s (Brown 1991). In recent years, as many as twelve active eyries have been found in the canyon. Nest sites are usually associated with water. In Grand Canyon, common prey items in summer include white-throated swift (*Aeronautes saxatalis*), swallows, other song birds, and bats (Brown 1991), many of which feed on invertebrate species (especially Diptera) that emerge out of the Colorado River (Stevens et al. 1997b). In winter, a common prey item is waterfowl.

Under the No Action Alternative, no effects are expected to the bird community in Glen and Grand canyons.

3.1.10 Birds under the Proposal

Many birds using the Colorado River below Glen Canyon Dam depend on the aquatic food chain associated with green alga (*Cladophora glomerata*). No long-term adverse impacts to *Cladophora* and associated organisms are expected to result from the proposed high flow test because none were observed during the 1996 experiment (Shannon et al. 2001; Blinn et al. 1999; McKinney et al. 1999). Although other algae and submerged plants use sand or silt as substrate and may be temporarily lost, they are expected to recover relatively quickly if there is no additional disturbance.

A March high flow would probably have no negative effect on the bald eagle because wintering and migrant bald eagles have largely left the Grand Canyon region by this time (Sogge et al. 1995b). Birds were unaffected by prior high flows so no effects are expected from the proposal. Most wintering waterfowl have left the canyons by the time of the flood and would not be affected by it. However, mallard, mergansers, late migrating gadwall, and American widgeon may be present (Spence 2004). These birds are ground nesters and a spring flood might impact them, although adequate waterfowl nest cover exists at higher elevations. Furthermore, the timing of the high flow test is prior to the primary nesting period for all these species.

The SWFL are not found in the action area during the proposed high-flow test so no effects are expected. As with other endangered species, Reclamation and the FWS are currently consulting on effects to the SWFL. The steady flows during September and October are also not expected to affect SWFL. Reclamation's finding for the proposed action is "may affect, is not likely to adversely affect" the SWFL. Numbers of bald eagles would continue to fluctuate around Nankoweap Creek, with or without the proposal, and no effects are anticipated.

3.1.11 Mammals under No Action

Within Grand Canyon National Park 34 species of mammals have been found (Carothers and Aitchison 1976; Frey 2003, Kearsley et al. 2003, 2006; Warren and Schwable 1985). Of these mammals only three are obligate aquatic mammals—beaver (*Castor canadensis*), muskrat (*Ondatra canadensis*), and river otter (*Lutra canadensis*). Despite occasional reported sightings of river otters in Grand Canyon, no reliable documentation exists since the 1970s (Kearsley et al. 2006). River otters are classified as extirpated and muskrats are considered extremely rare.

An increase in the population size and distribution of beaver in Glen and Grand canyons has occurred since the construction of the dam, likely due to the increase in riparian vegetation and relatively stable flows (Kearsley et al. 2006). Beavers cut willows, cottonwoods, and shrubs for food and can significantly affect riparian vegetation. Beaver in Grand Canyon excavate lodges in the banks of the river with the entrance located underwater and a tunnel leading up under the bank to a living chamber. Beaver are affected by fluctuating water levels since their lodges can become flooded by increases in water levels or the entrances can be exposed by falling water levels. Both situations can expose beaver to increased predation since they are forced to abandon the lodge if flooded or predators can enter the den if the opening is exposed.

Muskrats in Grand Canyon also construct and use bank dens or old beaver dens (Perry 1982) and can be affected by fluctuating water levels. Impacts to muskrats of current flow fluctuations from Glen Canyon Dam are unknown but could result in increased stress and exposure to predation (Perry 1982).

Bats in the Grand Canyon typically roost in desert uplands, but forage on abundant insects along Lake Powell, the Colorado River and its tributaries. Bats would continue to forage on the insects present in the riparian corridor.

3.1.12 Mammals under the Proposal

Beaver typically mate from January through March and the kits are born in March to June (Hill 1982). Young-of-year beaver occupy the lodge with the parents until their second year, when they leave their natal range and search for unoccupied habitat to colonize (Hill 1982). Because the proposal includes a relatively high flow that beaver have not experienced in several years, it is likely that the high flow would temporarily disperse sub-adult and adult beaver. Kits born prior to the high-flow-test would likely be killed due to drowning because they would be unable to disperse from the lodge. Steady flows in September and October would have little to no effect on beaver.

Muskrats in Grand Canyon would similarly be dispersed from their bank dens by high flows during March. However, muskrats rarely give birth before May (Perry 1982), and they are polyestrous and capable of producing multiple litters within the year. Muskrats would not be affected by steady flows in September and October.

Bats could be indirectly affected by the proposal. Insect production from steady flows in September and October could be altered, which might have an impact on foraging by bats.

However, any change in insect abundance is not expected to have long-term consequences and will likely be minor.

3.2 Cultural Resources

Cultural resources include prehistoric and historic districts, sites, buildings, structures, and objects. The term includes sites of traditional religious and cultural significance to Indian tribes and communities. Section 106 of the National Historic Preservation Act of 1966, as amended, requires federal agencies to take into account the effects of their undertakings on those historic properties listed on or eligible for inclusion in the National Register of Historic Places. Cultural resources also include sacred sites as defined by Executive Order 13007.

3.2.1 Cultural Resources under No Action

Adverse effects of ongoing operations to archeological sites are currently being mitigated through a long-term treatment plan. Archaeological data recovery efforts are scheduled over the next five years. No adverse effects to sacred sites have been documented as a result of dam operations and none are expected through 2012.

3.2.2 Cultural Resources under the Proposal

Consultation on the proposal with the Arizona State Historic Preservation Officer and the Navajo and Hualapai Tribal Historic Preservation Officers has been initiated. Reclamation's finding is that one historic property in Glen Canyon National Recreation Area could have been adversely affected by the high flow, but archeological data recovery was conducted as a mitigating measure. No other historic properties would be affected by this undertaking.

During consultation, the Hopi, Kaibab Paiute, and other tribes expressed concern with high flows impacting the salt mines. The Hualapai Tribal Historic Preservation Officer has expressed concern with native vegetation. The two prior high flows resulted in short-term adverse impacts to native vegetation of concern to the Hualapai, but there was a long-term benefit from previous high flows. Similar long-term benefits are predicted for the proposal. Consultations with concerned Indian tribes (Table 6) are continuing.

3.3 Socioeconomic Resources

Social and economic conditions were examined to determine whether the proposed action would affect them. The indicators reviewed include environmental justice (E.O. 13175), Indian trust assets, population growth and housing, public health (focusing on flood risk), recreation, the regional economy (focusing on economic cost associated with altering hydropower produced), and traffic and transportation.

3.3.1 Hydropower

One of the primary purposes of Glen Canyon Dam, as stated in 43 USC § 620, is the generation of hydropower or electric power. Glen Canyon Dam and Powerplant are part of the Colorado River Storage Project (CRSP), a federal project from which Western markets power. The CRSPA directs that Glen Canyon Dam and other facilities be “operated in conjunction with other Federal powerplants … so as to produce the greatest practicable amount of power and energy that can be sold at firm power and energy rates.” Western's Salt Lake City Area Integrated Projects Office (SLCA/IP) annually markets more than 4.3 billion kilowatt-hours (kWhr) from Glen Canyon Powerplant. The power is sold to end-use consumers across Arizona, Colorado, Nebraska, New Mexico, Nevada, Utah, and Wyoming. The power from Glen Canyon represents about three percent of the summer capacity in this seven-state region (Harpman 1999:351).

Demand for electric energy is known as "load." Load varies on a monthly, weekly, daily, and hourly basis, with the highest demand for electricity in the winter and summer when heating and cooling needs, respectively are greatest. Load is less in the spring and fall (Harpman 1999:352). The period when demand is highest is called "on peak." In the Glen Canyon service area, the on peak period is from 7:00 a.m. to 11:00 p.m., Monday through Saturday Mountain Standard Time (MST). All other hours are off peak. During normal operations at Glen Canyon Dam, water releases fluctuate from a low base flow during off peak hours to a high flow that corresponds to the largest electrical demand, subject to the limitations established in the 1996 record of decision.

The maximum amount of electric energy than can be produced by a powerplant at a single moment in time is its "capacity," measured in megawatts (MW). Electrical energy or generation is the capacity in MW over a period of time or megawatt-hours (MWh). The rate at which a powerplant can change from one generation level to another is called a "ramp rate," measured in change in cubic feet per second (cfs) over a one-hour period.

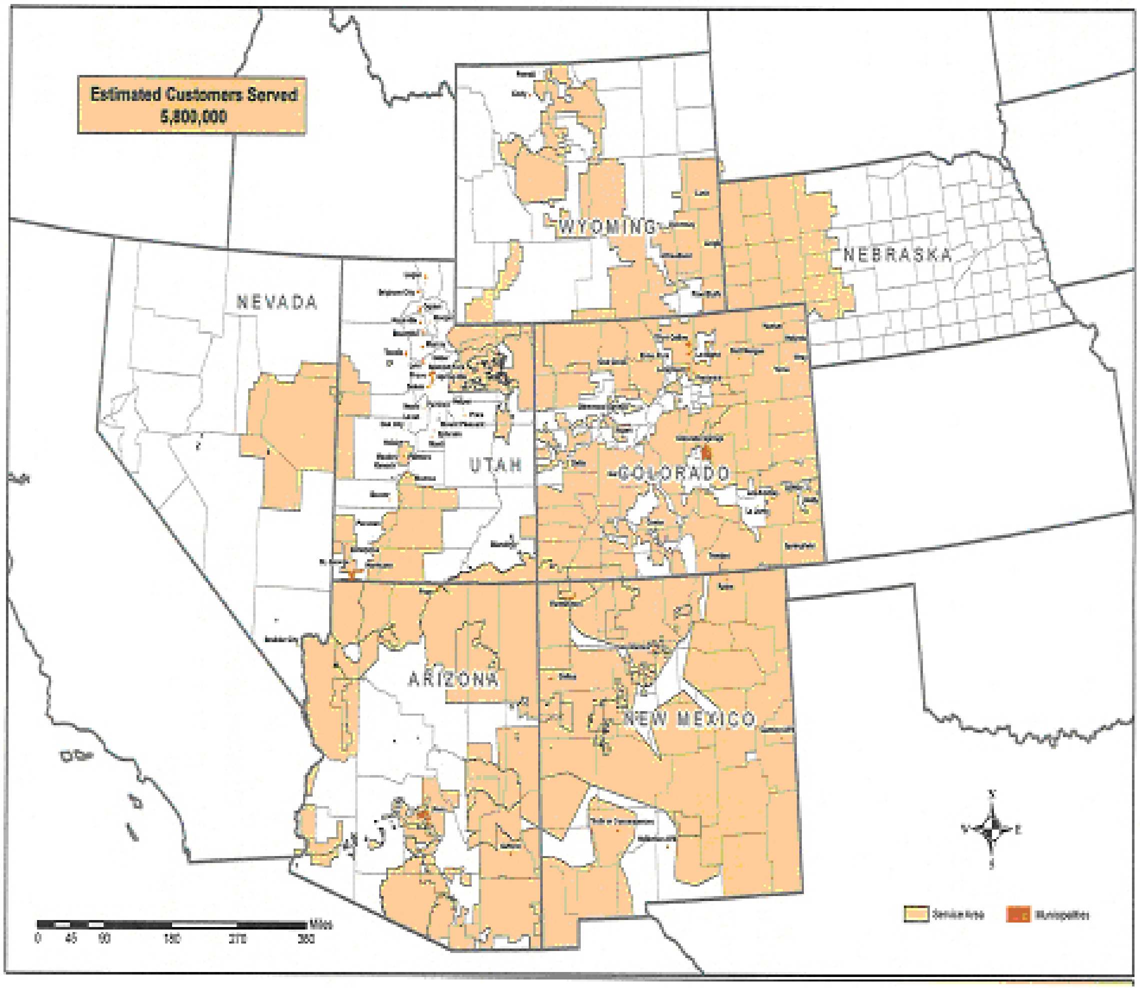

FIGURE 4 Colorado River Storage Project management center service territory. Map courtesy of Western.

3.3.1.1 Effects on Hydropower under No Action

Methods, models, and the amount of hydropower expected to be generated through 2012 are described in Reclamation (2007a:4-251-4-278). The description of the preferred alternative in that EIS serves as the description of hydropower under no action in this environmental assessment. If Reclamation takes no action, 4,481 GWh would be produced in 2008. During the period of the proposed action, additional power must be purchased to meet firm power contract provisions; in 2008 about 4,440 GWh would be produced and this additional purchase power cost is projected to be $43.5 million (Western 2008). To preserve the liquidity of the Basin Fund, increases in the firm power rate charged to power customers may need to be increased, particularly during periods of below average annual dam releases. Such a rate adjustment process is currently underway (Western 2008). This establishes a baseline against which effects of the proposal may be compared.

3.3.1.2 Effects on Hydropower under the Proposal

The economic effect of past experiments has been measured in "avoided costs," essentially the opportunity cost of the experiment. The avoided cost is the difference between the cost of satisfying the demand for electric energy with and without operating the hydropower plant (Harpman 1999:353). During steady flows, the ability to fluctuate water releases to match electrical demand ceases. This means that during periods of low electrical demand power must be sold at a reduced price and during high electrical demand power must be bought at an increased price on the spot market to meet customer contracts. When the volume of water released from the dam is greater than the capacity of the powerplant, the outlet works must be used to release flows. The powerplant is bypassed and water is "spilled" through the outlet works where it is unavailable to produce electric energy. During high flows, more power may be generated than would have been the case without the experiment, depending on the circumstances of the release.

Based on projections by Western of additional purchases required to meet the SLAC/IP contractual requirements, the projected total cost of the high flow test for water year 2008 is $4.1 million, or a 9.4 percent increase in the purchase power requirement for 2008. This includes the effect of moving water from the summer months that have large electrical demand and high prices to “shoulder” months where electrical demand and prices are lower.

The steady flow portion of the experiment during September and October, 2008 - 2012 has a projected annual power replacement cost for both months of about $815,000. No adjustment of monthly water volumes occurs during the subsequent years of the experiment, other than potential minor adjustment of September release volumes. Additional scientific studies will be planned as part of the GCDAMP for the succeeding years for fall steady flows but costs for these studies have not yet been determined.

Replacement of power foregone through the experiment would likely come from carbon-producing sources such as coal or gas fired generation. Due to the reduction in annual energy generation of about 41 GWh from the high flow test, it is estimated that if this power were replaced by coal-fired power sources, this would produce additional carbon emissions of about 45,800 tons, or approximately 0.02 percent of the 261,687,000 tons annually emitted from coal-fired powerplants in the region.

3.3.2 Recreation

Recreational resources of concern are the trout fishing and boating from Lees Ferry to below Glen Canyon Dam, whitewater boating through Grand Canyon, and the Hualapai Indian tribe's boating enterprise at the western end of Grand Canyon and into Lake Mead. No effects are expected within Lake Mead.

3.3.2.1 Fishing under No Action

The Colorado River from below the dam to Lees Ferry is a blue ribbon rainbow trout fishery, attracting anglers from the state and abroad. Most angling occurs from boats or is facilitated by boat access, including guide services, but some anglers wade in the area around Lees Ferry. Based on input from Lees Ferry fishing guides, the quality of the fishery has fallen and angler use has declined recently, but AGFD reports a significant increase in trout condition in 2006 (AGFD 2007). In 2006, angler use was approximately 13,000 user days. The monthly distribution of angling use is shown in Figure 5. The heaviest angling use in 2006 occurred in April.

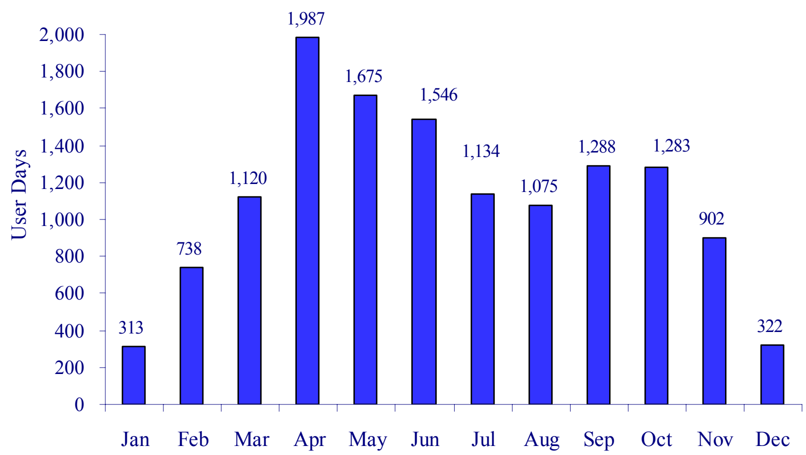

FIGURE 5 Fishing user days by month, 2006 in the Lees Ferry reach.

3.3.2.2 Fishing under the Proposal

During previous high flow tests in 1996 and 2004, most anglers elected not to fish and the same behavior would be expected under the proposal. In previous high flow tests, at least one company canceled all guided fishing trips during the high flow period (Reclamation 1998). Some anglers continued to fish, although they reported that their success was greatly reduced (Reclamation 1998:43). Many public comments received on this assessment indicated that anglers believe the fishing in the Lees Ferry area declined during and after the past high flow tests and they expect similar declines would occur should the proposal be implemented.

Data from AGFD (McKinney et al. 1999) on catch rates and condition indices of trout indicated the 1996 high flow had no effects on catch rate or condition indices of trout. Likewise, data from Shannon et al. (2001) indicates that prior high flows resulted in benthic scour and entrainment of both primary and secondary producers, but macroinvertebrates and filamentous algae recovered within three months, depending on the taxa. The 1996 test flow removed suspended particles from the water column and increased water clarity, which enhanced benthic recovery (Shannon et al. 2001:672), a benefit to the trout fishery.

Similar effects on the food base and sport fish are expected from the high flow, and the steady flow is not expected to have measurable effects on Lees Ferry fishing. To estimate effects of the high flow portion of the proposal, a minimum of three days out of March, or 108 user days, would be expected to be lost due to the experiment (Figure 5).

For those wading anglers who elect to fish during the event, rapid increases in river stage would place them at risk, if they are unaware and unprepared. Advance publicity, onsite warnings provided by management agencies, and the obvious nature of the flow would allow anglers to make personal assessments of danger during this period.

It is likely that the effects of a 2008 high flow test would be similar to the previous tests, although shorter in duration. At least three days to a week of user days would be lost, but the aquatic food base and the trout fishery would likely recover and improve within three months based on the previous research of Shannon et al. (2001) and McKinney et al. (1999.)

3.3.2.3 Boating under No Action

The 15-mile reach between Glen Canyon Dam and Lees Ferry is used by anglers who launch from Lees Ferry and visitors who take one day scenic raft trips offered by a NPS concessionaire. These commercial scenic raft trips launch at the base of Glen Canyon Dam. Day use rafting in 2006 amounted to more than 44,000 user days, as shown in Figure 6. Most day-use rafting occurs during the summer; June is typically the peak use month.

Since 2007, the NPS's (2006) Colorado River management plan has governed recreational use from the Lees Ferry reach down to Diamond Creek and upper Lake Mead. Under this plan, total whitewater boating use increased and annual distribution of use was altered. Currently, only estimated river use data are available, with Figure 6 illustrating the 2007 distribution of expected Grand Canyon whitewater boating use for trips starting at Lees Ferry.

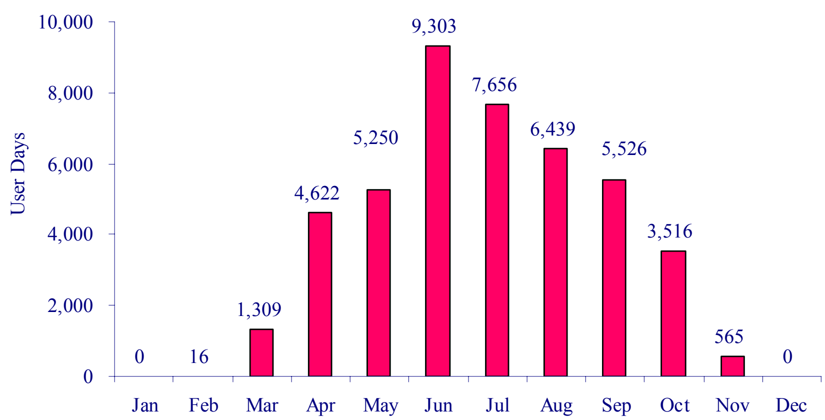

FIGURE 6 User days for day-use boaters, Lees Ferry reach, 2006.

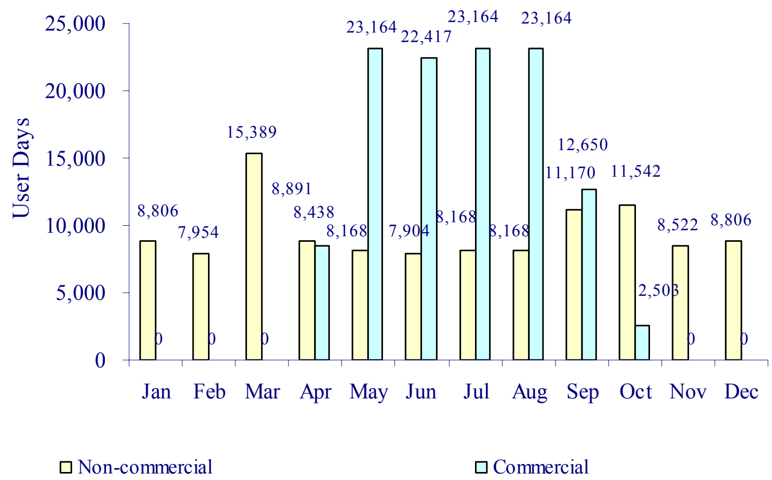

FIGURE 7 Whitewater boating user days, Grand Canyon, 2006.

Other characteristics of whitewater boating through Grand Canyon that may be affected by the proposal include wilderness values and safety. Wilderness characteristics of whitewater boating trips may be influenced by daily river fluctuations and by the conditions of beaches (Bishop et al. 1987; Shelby et al. 1992; Welsh et al. 1995). With no action taken by Reclamation, flows would vary within the constraints of the 1996 record of decision and daily change in flow would be no greater than 8,000 cfs. Reduced daily fluctuations of the 1996 record of decision makes the wilderness characteristics of a whitewater boating trip relatively high, but declines in sandbar area and volume reduce the overall recreational experience.

Whitewater boating safety depends on the type of craft, skill of the operator, the location, flow levels, and timing and variation of river stage (Brown and Hahn 1988; Jalbert 1992, 1996). Low flows make passage through some rapids difficult or impossible. High flows may create additional risks of flipping or capsizing.

The Hualapai Indian Reservation marks the southwestern end of the affected environment for this action. Diamond Creek is at about RM 227 and is a popular take out for many boating trips that begin at Lees Ferry. It is also the starting point for those commercial and noncommercial trips that originate on the Hualapai Indian Reservation. Private parties launching at this site pay launch and user fees to the Hualapai Indian Tribe. Commercial day and overnight trips run by Hualapai River Runners begin here and end at Quartermaster (RM 260) or Lake Mead (RM 277). The overnight trips make use of campsites (beaches) along the southern bank of the river (at RM 245) where the Hualapai Tribe has provided a composting toilet. There is also a concession pontoon boat operation, which uses helicopters to transport visitors into the canyon below, where they then walk down to a boat dock, and take a 20-minute, flat-water, river ride which launches and returns to Quartermaster.

Recreational use below Diamond Creek is managed in accordance with the NPS's new management plan. In 2007, the whitewater rafting season ran approximately from March 15 through October 31. During this past season, the Hualapai River Runners took over 19,000 visitors rafting on the Colorado River. The Hualapai River Runners pontoon boat operation is limited to five boats with a daily limit of 480 passengers on the water at any one time.[5] Approximately 175,200 passengers are expected annually.

3.3.2.4 Boating Under the Proposal

During the proposed 2008 high flow, no boats would be allowed to launch immediately below the dam. Day use rafting trips could still be launched from Lees Ferry and boats could move upstream under power. According to NPS estimates, approximately 190 boating user days would be lost during the proposed high flow. During the remainder of the year, day use rafting operations would be unaffected.

For the high flow portion of the proposal, the NPS studied river running risks and injuries during the 1996 experiment (Jalbert 1996). Jalbert reported that 45,000 cfs flows posed no greater risk of boating accidents than lower flows, in fact, the high flow enhanced visitor experience. She found the effects of the high flow on boaters were variable with location: the size of some waves and holes increased, others washed out.

Judging by NPS permit data, there are likely to be about 35 white-water boating groups on the river during a March high flow. The NPS is working closely with these permit holders to provide visitation flexibility to minimize adverse visitor impacts. Boaters on these trips would need to be cautious in selecting campsites, but the duration of the experiment relative to the length of a typical non-motorized trip (18 days), suggests effects on boaters would be limited. While fluctuations have been reported to decrease wilderness values, past high flows had beneficial effects on boater experiences.

The fall steady flows should have no measurable effect on visitor experiences in the canyon. As shown by Figures 6 and 7, visitation is relatively low during these months and the magnitude of change from no action should have no measurable effect on visitor experience.

Comments received from the Grand Canyon River Guides, Grand Canyon River Runners Association, and many individual guides and commercial rafting companies supported the proposal because of its potential to improve camping beaches and overall conditions in the river corridor.

3.3.2.5 Net Economic Use Value under No Action

Net economic use value is a measure of the value over and above the costs of participating in a recreation activity. The total net economic value is related to the number of recreationists who participate in each activity, the time of year in which they participate, and the value of each trip taken (King and Mazzotta 2007; National Research Council 2004).

The net economic value of recreation in Grand Canyon was estimated for a number of different flow scenarios by Bishop et al. (1987) and reported in Reclamation (1995, 1998).

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[5] This limit could be raised to 600 passengers/day if monitoring reveals no adverse impacts to resources.

Hammer (2001) later estimated the net economic value of whitewater boating using the (secondary) data collected by Stewart et al. (2000) and Hall and Shelby (2000).

Regional economic activity refers to expenditures and their impacts within the study area. River-based recreational users, such as anglers and white-water boaters, spend large sums of money in the region purchasing gas, food, lodging, guide services, and outdoor equipment during their visits. While these expenditures do not represent a benefit measure, they nonetheless are important because they support local businesses and provide employment for local residents.

The annual regional economic activity that results from nonresident anglers, whitewater boaters, and day rafters who visit Glen and Grand canyons has been estimated (Reclamation 1995) at approximately $25.7 million (1995 nominal dollars). Douglas and Harpman (1995) estimated that Glen Canyon and Grand Canyon recreational use in the region comprised of Coconino and Mojave Counties supported approximately 585 jobs. A more recent study by Hjerpe and Kim (2003) estimated that recreational use in Coconino County supports approximately 394 jobs.

3.3.2.6 Net Economic Value under the Proposal

The net effect of the proposed high flow on regional economic activity is likely to be negative due to the loss of angling and boating user days in the Lees Ferry reach during the high flow. With the high flow test preventing at least three to five days of use in March, incomes of local fishing guides and day use rafting guides and companies would be decreased.

Using data in Kaval and Loomis (2003:12), a fishing user day has an average value (through 2003) at $42 for the NPS Intermountain Region where Glen and Grand canyons are located. Using the minimum loss of 108 fishing days, this gives a value of $4,536 in losses due to the proposed high flow experiment, although this would likely be a higher figure using current economic data. However, recent communication between NPS and the trout guides revealed an estimated financial impact of $75,000 to $100,000 (Norm Henderson personal communication).

With the estimate of 190 boating user days lost during the proposed high flow, and again using Kaval and Loomis (2003:12), $56.42 is expended per boating day, resulting in a value of at least $107,198 from the high flow portion of the experiment. Current estimates of lost revenue communicated to the NPS were $15,000, so there is some uncertainty in these estimates.

As a result of the anglers and Lees Ferry boaters who would stay away during the high flow, local hotel and restaurant revenues would be reduced during or following the test, but there could be increases in visitor use associated with scientific and media activities surrounding the high flow test. In response to concerns expressed by local guides and business owners, Reclamation will assist in implementing the measures described in section 2.2.1. The fall steady flows should have no measurable effect on the economic values of Lees Ferry angling or boating.

No net change in whitewater boating use or significant change in trip value in the Lees Ferry reach is expected to result from the proposed high flow test or the steady fall flows. Therefore, net economic value is expected to be reduced less than one percent of the annual total revenues.

3.3.3 Indian Trust Assets

Indian trust assets are legal interests in property held in trust by the US government for Indian tribes or individuals. Examples of such resources are lands, minerals, or water rights. Review of the alternatives revealed that water rights would not be affected, but given that the action area is bounded on the east by the Navajo Indian Reservation and on the south by the Hualapai Indian Reservation, these tribes were consulted regarding potential effects of the proposal on their trust assets and reserved rights.

During consultation, both tribes were concerned that high flows could affect trust lands. Based on the 1883 Executive Order establishing the Hualapai Indian Reservation, the northern boundary of the reservation is the high water mark of the Colorado River (NPS 2005, Appendix M). Most of the Navajo Indian Reservation is more distant from the river bank, but the tribe is still concerned with adverse impacts of the proposal.

3.3.4 Environmental Justice

To implement Executive Order 12898, *Environmental Justice in Minority Populations and Low Income Populations*, the Council on Environmental Quality (1997) instructs agencies to determine whether minority or low-income populations or Indian tribes might be affected by a proposal, and if so, whether there might be disproportionately high and adverse human health or environmental effects on them. The affected area is bounded by the Navajo Indian Reservation and the Hualapai Indian Reservation. Hydropower and financial impacts to the Hualapai Tribe's recreational boating operations on the Colorado River were identified as potential environmental justice issues in this environmental assessment.

Hydropower impacts are a potential issue because electricity generated by Glen Canyon Dam or CRSP power is marketed to non-profit municipalities and Indian tribes, which are generally rural and small communities. As shown in Appendix D, over 50 Indian tribes now receive the benefits of CRSP power. Within the states receiving CRSP power, Table 5 shows the number of households requiring federal energy assistance for 2005 and 2006. The number of households receiving federal energy assistance is an indicator that environmental justice concerns may be present, particularly because these numbers appear to be increasing in the CRSP service area.

The Hualapai Tribe conducts recreational boating below Diamond Creek. Previous high flow tests have interrupted normal boating operations and have dislodged a boat dock near Quartermaster Rapid. Both of these impacts have had financial impacts to the tribe.

3.3.5 Environmental Justice under No Action

The need for federal energy assistance continues to grow rapidly due to a combination of rising energy costs and other economic factors affecting the US economy (Wolfe 2006, 2007). Table 5 shows the number of households in states served with CRSP power that required federal heating assistance in years 2005 and 2006. As shown, the minimum statewide increase is 12 percent, the maximum is 34 percent. While the table does not reflect the actual numbers of CRSP customers requiring energy assistance, it conveys the general increase in need for federal energy assistance in the states.

TABLE 5 Number of households per state requiring heating assistance, 2005 to 2006

State	2,005	2006	% Increase
Arizona	18,563	24,824	33.7
Colorado	96,127	107,500	11.8
Nebraska	32,514	39,000	19.9
Nevada	17,557	22,177	26.3
New Mexico	55,685	67,000	20.3
Utah	34,647	40,000	15.5
Wyoming	9,550	11,653	22.0

Source: Wolfe 2006, 2007.

3.3.6 Environmental Justice under the Proposal

The proposal might increase the number of households seeking energy assistance from the federal government if the action results in an increase in the CRSP power rate. In comparing the effects of the proposal with no action, rising electric costs could create an adverse economic impact among low-income households. This impact depends entirely on whether CRSP power rates would need to be increased as a result of the proposed action, which is determined by the financial status of the Basin Fund. Although power customers are currently involved in rate increase discussions, the potential for an additional rate increase due to the proposed action is uncertain.

The proposal for high flows could interrupt the boating and helicopter operations of Grand Canyon West, a wholly-owned and operated enterprise of the Hualapai Tribe. The Hualapai Tribe is concerned that the high flows have the potential to damage or dislodge recreational facilities such as the boat dock in the Quartermaster area. In addition, the high flows could damage the boating take-out at Diamond Creek. The financial impact to the tribe could be approximately $480,000 (based on lost revenue), with additional losses should facilities need to be repaired.

3.4 Other NEPA Considerations

In addition to reviewing direct, indirect and cumulative effects on resources in the preceding sections, section 102(2)(C) of NEPA requires consideration of unavoidable impacts, the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources. Bypassing the powerplant during the high flow test in 2008 would cause an unavoidable loss of power generation and a reduction of fishing guide and scenic day use rafting revenues. Steady flows in the fall would cause an increase in replacement power costs. However, timing of these elements of the proposal was designed to minimize economic and environmental justice impacts, while maintaining and enhancing the long-term productivity of the local environment.

Some endangered Kanab ambersnail could be inundated or displaced downstream under the proposed flood; however, these actions will be minimized or mitigated through the actions described in section 2.2.1. Non-essential foraging habitat for southwestern willow flycatcher might be impacted. However, no irreversible, long-term impact on any of these snail or bird populations is anticipated. Juvenile trout and young of year humpback chub could be displaced downstream and lost, but again, the effects to the long-term condition of the populations are not considered irreversible.

4.0 List of Agencies and Persons Consulted

Following requirements of 40 CFR 1508.9(b), this section lists agencies and persons consulted regarding this proposed federal action. Table 6 lists federally-recognized Indian tribes who have been or are being consulted regarding the proposal. On January 10, 2008, one multi-tribal meeting was held regarding the proposal. Formal government-to-government consultation letters and follow-up phone calls and face-to-face meetings with tribes listed in Table 6 are in progress. Table 7 lists agencies and persons and outside Reclamation who were consulted during the preparation of this environmental assessment. Of particular note is a conference call held on January 17, 2008 with members of the GCDAMP. One meeting sponsored by FWS was held with Lees Ferry fishing guides and local business owners on November 28, 2007. The report from that meeting, resulting recommendations, and FWS comments on the EA presented Reclamation with FWS input on the Lees Ferry trout fishery in lieu of a formal report under the Fish and Wildlife Coordination Act. The EA was mailed to agencies, organizations, and individuals concerned with dam operations and it was also made available on the internet at www.usbr.gov/uc/envdocs/index.html.

As of February 25, 2008, Reclamation had received 83 unique comment documents regarding the EA with the documents including written letters, e-mails, transcripts or notes of oral comments at consultation meetings (Appendix E). All comment documents received on the draft EA were reviewed and considered in preparing the final EA, with revisions made as appropriate in response to the comments. Some 20 comment documents supported the proposed action while 58 supported no action. In addition to expressing support or opposition to the proposal, most comment documents presented multiple comments.

Some 47 comments were received suggesting modifications of the proposed action. Of these 47 comments, 9 were requests to moderate the down ramp rate. There were roughly even numbers of requests to modify either the high flow portion of the proposal or the steady flow portion (7 and 8 comments respectively). There were also 6 requests to consider other ways to build beaches than through releases from the dam, including sediment augmentation. Another 35 comments were requests to supplement, improve, or modify analyses and 23 comments were requests to make factual corrections. Again, these comments were reviewed, and where possible, changes were made in the text.

TABLE 6 Federally-recognized Indian tribes being consulted

Federally Recognized Indian Tribe
Havasupai Tribe of the Havasupai Reservation, Arizona
Hopi Tribe of Arizona
Hualapai Indian Tribe of the Hualapai Indian Reservation, Arizona
Kaibab Band of Paiute Indians of the Kaibab Indian Reservation, Arizona
Las Vegas Tribe of Paiute Indians of the Las Vegas Indian Colony, Nevada
Moapa Band of Paiute Indians of the Moapa River Indian Reservation, Nevada
Navajo Nation, Arizona, New Mexico & Utah
Paiute Indian Tribe of Utah
San Juan Southern Paiute Tribe of Arizona
Yavapai-Apache Nation of the Camp Verde Indian Reservation, Arizona
Zuni Tribe of the Zuni Reservation, New Mexico

TABLE 7 List of federal and state agencies and private organizations consulted

Agencies
Arizona Department of Water Resources
Arizona Game and Fish Department
Bureau of Indian Affairs
Colorado Division of Water Resources
Colorado River Board of California
Colorado River Commission of Nevada
Colorado River Energy Distributors Association
Department of Energy, Western Area Power Administration
Federation of Fly Fishers, Northern Arizona Flycasters
Grand Canyon River Guides
Grand Canyon Trust
Grand Canyon Wildlands Council
National Park Service
New Mexico Interstate Stream Commission
US Fish and Wildlife Service
Utah Associated Municipal Power Systems
Utah Division of Water Resources
Wyoming State Engineer

5.0 References Cited

Ackmerman, M.W. 2007. *Native fish monitoring activities in the Colorado River, Grand Canyon.* Report to Grand Canyon Monitoring and Research Center from SWCA, Inc., Flagstaff, Arizona.

AGFD *see* Arizona Game and Fish Department

Arizona Game and Fish Department. 2007. Unpublished report on Lees Ferry fishery. Report to GCDAMP, Phoenix, Arizona.

Bishop, Richard C., K.J. Boyle, M.P. Welsh, R.M. Baumgartner, and P.C. Rathbun. 1987. Glen Canyon Dam releases and downstream recreation: an analysis of user preferences and economic values. Glen Canyon Environmental Studies Report No. 27/87. NTIS No. PB88-183546/AS. National Technical Information Service, Springfield, Virginia.

Blinn, D.W., L.E. Stevens, and J.P. Shannon. 1992. *The effects of Glen Canyon Dam on the aquatic foodbase in the Colorado River corridor in Grand Canyon, Arizona*. Glen Canyon Environmental Studies Technical Report. Report to USGS, Grand Canyon Monitoring and Research Center from Northern Arizona University, Flagstaff, Arizona.

Blinn, D.W., L.E. Stevens, and J.P. Shannon. 1994. Interim flow effects of Glen Canyon Dam on the aquatic food base in the Colorado River corridor in Grand Canyon, Arizona. Report No. GCES II – 02 Glen Canyon Environmental Studies. Report to Bureau of Reclamation, Salt Lake City, Utah.

Blinn, D.W., J.P. Shannon, K.P. Wilson, C. O'Brien, and P.L. Benanati. 1999. Response of benthos and organic drift to a controlled flood. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 259-272. American Geophysical Union Monograph No. 110. Washington DC.

Bond, G., W. Showers, M. Cheseby, R. Lotti, P. Almasi, P. deMenocal, P. Priore, H. Cullen, I. Hajdas, and G. Bonani. 1997. A pervasive millennial-scale cycle in North Atlantic Holocene and Glacial climates. *Science* 278:1257-1266.

Bowers, B. E., R. H. Webb, and E. A. Pierson. 1997. Succession of desert plants on debris flow terraces, Grand Canyon, Arizona, U.S.A. *Journal of Arid Environments* 36:67-86.

Brouder, M. J., D. W. Speas and T. L. Hoffnagle. 1999. Changes in number, sediment composition and benthic invertebrates of backwaters. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 241-248. American Geophysical Union Monograph No. 110. Washington DC.

Brown, B.T. 1988. Breeding ecology of a willow flycatcher population in Grand Canyon, Arizona. *Western Birds* 19:25-33.

——.1991. *Abundance, distribution, and ecology of nesting peregrine falcons in Grand Canyon National Park, Arizona.* Unpublished report. Grand Canyon National Park, Grand Canyon, Arizona.

——. 1992. The impact of fluctuating flows from Glen Canyon Dam on wintering bald eagles along the Colorado River in Grand Canyon National Park and Glen Canyon National Recreation area : biological assessment. Unpublished report. Accessed at http://www.gcmrc.gov/library/reports/biological/terrestrial/brown1992b.pdf.

Brown, B.T., R. Mesta, L.E. Stevens, and J. Weisheit. 1989. Changes in winter distribution of bald eagles along the Colorado River in Grand Canyon, Arizona. Journal of Raptor Research 23:110-113.

——. Brown, B.T., and L.E. Stevens. 1991. *Influences of fluctuating flows from Glen Canyon Dam and effects of human disturbance on wintering bald eagles along the Colorado River in Grand Canyon Arizona.* Unpublished report. Accessed at http://www.gcmrc.gov/library/reports/GCES/Biological/Terrestrial/Brown1991.pdf.

——. 1992. Winter abundance, age structure, and distribution of bald eagles along the Colorado River, Arizona. *Southwestern Naturalist* 37:404-435.

Brown, B.T., S.W. Carothers, and R.R. Johnson. 1987. *Grand Canyon birds: historical notes, natural history, and ecology.* University of Arizona Press, Tucson. 302 p.

Brown, C.A. and M.G. Hahn. 1988. The effect of flows in the Colorado River on reported and observed boating accidents in the Grand Canyon. Glen Canyon Environmental Studies Report. National Technical Information Service: Springfield, Virginia. NTIS No. PB88-183553/AS.

Carothers, S.W., and S.W. Aitchison. *eds*. 1976. An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, Arizona. Final report to U.S. Dept of Interior, National Park Service, Grand Canyon National Park, Arizona. 251 pp.

Carpenter, G.C. 2006. Herpetofauna. In: *Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of Grand Canyon*, ed. M.J. Kearsley, N. Cobb, H. Yard, D. Lightfoot, S. Brantley, G. Carpenter, and J. Frey, 108-125. Report to USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Clover, E.U., and L. Jotter. 1941. Floristic studies in the canyon of the Colorado River and tributaries. *American Midland Naturalist* 32:591-642.

Coggins, L.G. 2007. Abundance trends and status of the Little Colorado River population of humpback chub: an update considering 1989-2006 data. United States Geological Survey open file report 2007-1402.

Council on Environmental Quality. 1997. *Environmental justice: guidance under the National Environmental Policy Act.* Executive Office of the President, Washington DC.

Douglas, A.J. and D.A. Harpman. 1995. Estimating recreation employment effects with IMPLAN for the Glen Canyon Dam region. *Journal of Environmental Management* 44:233-247.

Drost, C.A. 2004. Population status and viability of leopard frogs (*Rana pipiens*) in Grand Canyon and Glen Canyon: annual report 2003. Report submitted to Bureau of Reclamation and Glen Canyon National Recreation Area and Grand Canyon National Park, National Park Service.

——. 2005. Population status and viability of leopard frogs (*Rana pipiens*) in Grand Canyon and Glen Canyon: annual report 2004. Report submitted to Bureau of Reclamation and Glen Canyon National Recreation Area and Grand Canyon National Park, National Park Service.

Elliott, J.M. 1973. The food of brown and rainbow trout (*Salmo trutta* and *Salmo gairdneri*) in relation to the abundance of drifting invertebrates in a mountain stream. Oecologia (Berlin) 12:329-347.

Frey, J. 2003. Small Mammals. 7-11 In *Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of Grand Canyon*, ed. M.J. Kearsley, N. Cobb, H. Yard, D. Lightfoot, S. Brantley, G. Carpenter, and J. Frey, 7-11. Report to USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Gerking, S.D. 1994. Feeding Ecology of Fish. Academic Press, Inc., San Diego, California. 416 p.

Gloss, S.P., J.E. Lovich, and T.S. Melis, eds. 2005. *The state of the Colorado River ecosystem in Grand Canyon: A report of the Grand Canyon Monitoring and Research Center 1991-2004.* USGS Circular 1282. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Goeking, S. A., J. C. Schmidt and M. K. Webb. 2003. Spatial and temporal trends in the size and number of backwaters between 1935 and 2000, Marble and Grand Canyons, AZ. Report submitted to USGS, Grand Canyon Monitoring and Research Center from Department of Aquatic, Watershed and Earth Resources, Utah State University, Logan.

Hall, T., and B. Shelby.2000. *1998 Colorado River boater study Grand Canyon National Park.* Report submitted to National Park Service, Grand Canyon National Park from Department of Forestry, Virginia Tech and Department of Forest Resources, Oregon State University.

Hammer, M.A. 2001. Applying the TCM with secondary data to white water boating in Grand Canyon National Park. Unpublished Masters thesis, Colorado State University, Fort Collins, Colorado.

Harpman, D.A. 1999. The Economic cost of the 1996 controlled flood. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 351-357. American Geophysical Union Monograph No. 110. Washington DC.

Hazel, J. E., M. Kaplinksi, R. Parnell, M. Manone and A. Dale. 1999. Topographic and bathymetric changes at thirty-three long-term study sites. P 161-183 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Hill, E.P. 1982. Beaver. 256- 281 In Wild mammals of North America: biology, management, and economics, ed. J.A. Chapman, and G.A. Feldhamer, 256-281. Johns Hopkins University Press, Baltimore, Maryland.

Hjerpe and Kim 2003. Regional economic impacts of Grand Canyon river runners. Unpublished report. Northern Arizona University, School of Forestry, Flagstaff, Arizona.

Hoffnagle, T.L., R.A. Valdez, and D.A. Speas. 1999. Fish abundance, distribution, and habitat use. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 343-350. American Geophysical Union Monograph No. 110. Washington DC.

Jalbert, L.M. 1992. *The Influence of discharge on recreational values including crowding, congestion and safety in Grand Canyon National Park*. Report. Grand Canyon National Park, Arizona.

Jalbert, L.M. 1996. *The effects of the 1996 beach/habitat building flow on observed and reported boating accidents on the Colorado River in Grand Canyon National Park*. Report. National Park Service, Grand Canyon Science Center, Grand Canyon National Park, Arizona.

Johnstone, H.C., and M.V. Lauretta. 2007. *Native fish monitoring activities in the Colorado River within Grand Canyon during 2004*. Report to USGS, Grand Canyon Monitoring and Research Center from SWCA, Inc., Flagstaff, Arizona.

Kaval, P., and J. Loomis. 2003. Updated outdoor recreation use values with emphasis on National Park Recreation. Department of Agricultural and Resource Economics, Colorado State Univeristy, Fort Collins, Colorado. Submitted to NPS, Fort Collins, Colorado.

Kearsley, M.J.C. and T. Ayers. 1996. The Effects of Interim Flows From Glen Canyon Dam on Riparian Vegetation in the Colorado River Corridor, Grand Canyon National Park, Arizona. USGS, Grand Canyon Monitoring and Research Center, Flagstaff.

Kearsley, L.H., R.D. Quartaroli, and M.J.C. Kearsley. 1999. Changes in the number and size of campsites as determined by inventories and measurement. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 147-159. American Geophysical Union Monograph No. 110. Washington DC.

Kearsley M.J.C., N.S. Cobb, H.K. Yard, D. Lightfoot, S.L. Brantley, G.C. Carpenter, and J.K. Frey, eds. 2003. *Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of Grand Canyon*: *an integrative approach*. Report. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Produced under Cooperative Agreement 01-WRAG 0034/0044. http://www.gcmrc.gov/library/reports/biological/terrestrial/Kearsley/01_WRAG044/Kearsley2003.pdf

Kearsley M.J.C., N.S. Cobb, H.K. Yard, D. Lightfoot, S.L. Brantley, G.C. Carpenter, and J.K. Frey, eds.. 2006. *Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of Grand Canyon*: *an integrative approach*. Unpublished report. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Produced under Cooperative Agreement 01-WRAG 0034/0044. http://www.gcmrc.gov/library/reports/biological/terrestrial/Kearsley/01_WRAG044/Kearsley2006.pdf

Kearsley, M.J.C., and T.J. Ayers. 1999. Riparian vegetation responses: snatching defeat from the jaws of victory and vice versa. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 309-328. American Geophysical Union Monograph No. 110. Washington DC.

King, D.M., and M. Mazzotta. Ecosystem valuation. *An online resource funded by several federal government agencies and maintained by the University of Maryland.* Accessed at http://www.ecosystemvaluation.org. Accessed on October 17, 2007.

Korman, J., M. Kaplinski, J.E. Hazel III, and T.S. Melis. 2005. Effects of the experimental fluctuating flows from Glen Canyon Dam in 2003 and 2004 on the early life history stages of rainbow trout in the Colorado River. Report to USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Koronkiewicz, T.J., M.A. McLeod, B.T. Brown, and S.W. Carothers. 2006. *Southwestern willow flycatcher surveys, demography, and ecology along the lower Colorado River and tributaries, 2005.* Report from SWCA Inc., Boulder City, Nevada to Bureau of Reclamation, Lower Colorado Region, Boulder City, Nevada.

Lauretta, M.V. and K.M. Serrato. 2006. *Native fish monitoring activities in the Colorado River within Grand Canyon during 2005.* Report. US Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Liebfried, B., K. Hilwig, K. Serrato, and M. Lauretta. 2006. *Restoring native fish habitat in selected tributaries of Grand Canyon National Park.* Report to National Park Service from SWCA, Inc., Flagstaff, Arizona.

McGuinn-Robbins, D.K. 1994. Comparison of the number and area of backwaters associated with the Colorado River in Glen and Grand Canyons, Arizona. Report. Arizona Game and Fish Department, Phoenix, Arizona.

McIvor, C.C., and M.L. Thieme. 1999. Flannelmouth suckers: movement in the Glen Canyon reach and spawning in the Paria River. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 289-296. American Geophysical Union Monograph No. 110. Washington DC.

McKinney, T., R.S. Rogers, A.D. Ayers, and W.R. Persons. 1999. Lotic community responses in the Lees Ferry reach. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 249-258. American Geophysical Union Monograph No. 110. Washington DC.

National Park Service, US Department of the Interior. 2005. *Final environmental impact statement, Colorado River management plan*, three volumes, Grand Canyon National Park, Arizona.

——. 2006. *Colorado River management plan environmental impact statement record of decision.* Intermountain Region, Denver, Colorado.

National Research Council. 2002 Riparian areas: functions and strategies for management. National Academy Press, Washington, D.C. 436 p.

——. 2004. *Valuing ecosystem services: toward better environmental decision-making.* National Research Council, Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems. National Academy Press, Washington, DC. 290 pp. ISBN: 0-309-54586-2, accessed at: http://www.nap.edu/catalog/11139.html

Nilsson, C., G. Grelsson, M. Johansson and U. Sperends. 1989. Patterns of plant species richness along river-banks. Ecology 70:77-84.

NPS *see* National Park Service.

Parnell, R. A. and J. B. Bennet. 1999. Mineralization of riparian vegetation buried by the 1996 controlled flood. In *The controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, pp. 225-239. American Geophysical Union Monograph No. 110. Washington DC.

Parnell, R. A. Springer and L. Stevens. 1997. Flood-induced backwater rejuvenation along the Colorado River n Grand Canyon, AZ: 1996 final report. Northern Arizona University, Flagstaff. 67 p.

Perry, R.H. Jr. 1982. Muskrats. In *Wild mammals of North America: biology, management, and economics*, ed. J.A. Chapman, and G.A. Feldhamer, 282-325. Johns Hopkins

University Press, Baltimore, Maryland.

Phillips, A.M. and L. Jackson. 1996. Evaluation and mitigation efforts for March, 1996 Colorado River test flow experiment. Hualapai Cultural Resources Division. Report to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, Arizona. 28 p.

Porter, M.E., 2002. Riparian vegetation responses to contrasting managed flows of the Colorado River in Grand Canyon, Arizona. Master's Thesis, Northern Arizona University, Flagstaff, Arizona.

Rakowski, C. L., and J. C. Schmidt. 1999. The geomorphic basis of Colorado pikeminnow nursery habitat in the Green River near Ouray, Utah. Report A in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Reclamation, US Department of Interior. 1988. *Colorado River simulation system user's manual.* Denver, Colorado.

——. 1998. Glen Canyon Dam beach/habitat-building flow draft environmental assessment. Salt Lake City, Utah.

——.1995. Operation of Glen Canyon Dam final environmental impact statement. Denver, Colorado.

——.1995a. Biological assessment of a one time test of beach/habitat-building flow from Glen Canyon Dam, spring 1996. Salt Lake City, Utah.

——.2007a. Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead. Boulder City, Nevada.

——. 2007b. Biological assessment on the operation of Glen Canyon Dam and proposed experimental flows for the Colorado River below Glen Canyon during the years 2008-2012: Bureau of Reclamation, Salt Lake City, Utah.

——. 2008a. Long-term Experimental Plan for the Operation of Glen Canyon Dam and Other Associated Management Activities. *Federal Register* 73(29):8062-8063.

——. 2008b. Colorado River basin hydrologic data base. Salt Lake City, Utah.

Rogers, R.S., W.R. Persons, and T. McKinney. 2002. *Effects of a 31,000-cfs spike flow* and low steady flows on benthic mass and drift composition in the Lees Ferry reach, draft report July 2002. Report. Arizona Game and Fish Department, Flagstaff, Arizona.

Schmidt, J.C., E.D. Andrews, D.L. Wegner, and D.T. Patten. 1999. Origins of the 1996 controlled flood in Grand Canyon. Pages 23-36 in R.H. Webb, J.C. Schmidt, G.R.

Marzolf, and R.A. Valdez (eds.). The controlled flood in Grand Canyon. Geophysical Monograph 110. American Geophysical Union, San Francisco, California.

Schmidt, J.C., and J.B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. US Geological Survey Professional Paper No. 1493. 74 p.

Schmidt, J. C., D. J. Topping, P. E. Grams, and J. E. Hazel. 2004. System wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, AZ. Final Report of the Fluvial Geomorphology Laboratory, Utah State University, Logan. 99 p.

FWS *see* US Fish and Wildlife Service.

Shafroth, P.B., G.T. Auble, J.C. Stromberg and D.T. Patten. 1998. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona. Wetlands 18(4):577-590. Dec 1998.

Shannon, J.P., D.W. Blinn, K.P. Wilson, P.L. Benenati, and G.E. Oberlin. 1996. *Interim flow and beach building spike flow effects from Glen Canyon Dam on the aquatic food base in the Colorado River in Grand Canyon National Park, Arizona.* Report. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Shannon, J.P., D.W. Blinn, T. McKinney, E.P. Benenati, K.P. Wilson, and C. O'Brien. 2001. Aquatic food base response to the 1996 test flood below Glen Canyon Dam, Colorado River, Arizona. Ecological Applications 11:672-685.

Shaver, M.L. J.P. Shannon, K.P. Wilson, P.L. Benenati and D.W. Blinn. 1997. Effects of suspended sediment and desiccation on the benthic tailwater community in the Colorado River, USA. *Hydrobiologia*. 357: 63-72.

Shelby, Bo. T.C. Brown, and R. Baumgartner. 1992. Effects of streamflows on river trips on the Colorado River in Grand Canyon, Arizona. *Rivers* 3:191-201.

Sogge, M.K. 1995. Southwestern willow flycatchers in the Grand Canyon. In *Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals and ecosystems*, ed. E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, 89-91. US Department of Interior National Biological Service, Washington, D.C.

Sogge, M.K., C. Van Riper III, T.J. Tibbitts, and T. May. 1995a. *Monitoring winter bald eagle concentrations in the Grand Canyon: 1993-1995*. National Biological Service Colorado Plateau Research Station, Northern Arizona University, Flagstaff, Arizona.

Sogge, M. K., T. J. Tibbitts, C. Van Riper III, and T. May. 1995b. *Status of the southwestern willow flycatcher along the Colorado River in Grand Canyon National*

Park - 1995. Report. National Biological Service Colorado Plateau Research Station, Northern Arizona University, Flagstaff, Arizona. 26 pp.

Speas, D.W., W.R. Persons, R.S. Rogers, D.L. Ward, A.S. Makinster, and J.E. Slaughter. 2004. *Effects of low steady summer flows on rainbow trout in the Lee's Ferry tailwater, 2000.* Report. Arizona Game and Fish Department, Phoenix, Arizona.

Spence, J.R. 1996. *The Controlled flood of 1996: effects on vegetation and leopard frogs (*Rana pipiens*) at RM - 8.8 Marsh, Colorado River, Glen Canyon*. Report. National Park Service, Glen Canyon National Recreation Area, Page, Arizona.

Spence, J.R. 2004. *The Riparian and aquatic bird communities along the Colorado River from Glen Canyon Dam to Lake Mead, 1996 - 2002*. Report. National Park Service, Glen Canyon National Recreation Area. Page, Arizona.

Stevens, L.E., and G.L. Waring. 1988. *Effects of post-dam flooding on riparian substrates, vegetation, and invertebrate populations in the Colorado River in Grand Canyon, Arizona.* Report to Reclamation, Glen Canyon Environmental Studies, Flagstaff, Arizona National Technical Information Series P688-183488/AS.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky, and J. Petterson. 1995. *The ecology of Kanab ambersnail (Succineidae:* Oxyloma haydeni kanabensis *Pilsbry, 1948) at Vaseys Paradise, Grand Canyon, Arizona.* Report. Glen Canyon Environmental Studies. Bureau of Reclamation, Flagstaff, Arizona.

Stevens. L.E., J.C. Schmidt, T.J. Ayers, and B.T. Brown 1995. Flow regulation, geomorphology, and Colorado River marsh development in the Grand Canyon, Arizona. *Ecological Applications* 5(4): 1025-1039

Stevens, L.E., and G.L. Waring. 1985. *Effects of post-dam flooding on riparian substrates, vegetation, and invertebrate populations in the Colorado River corridor in Grand Canyon, Arizona*. Glen Canyon Environmental Studies Technical Report. Bureau of Reclamation, Salt Lake City, Utah.

Stevens, L. E., F. R. Protiva, D. M. Kubly, V. J. Meretsky and J. Petterson. 1997a. The Ecology of Kanab ambersnail (*Succineidae: Oxyloma haydeni kanabensis pilsbry*, 1948) at Vaseys Paradise, Grand Canyon, Arizona: 1995 Final Report. Glen Canyon Environmental Studies Program Report. Flagstaff, Arizona: US Department of the Interior, Bureau of Reclamation, Glen Canyon Environmental Studies Program.

Stevens, L.E., J.P. Shannon, and D. W. Blinn. 1997b. Colorado River benthic ecology in Grand Canyon Arizona: USA; dam, tributary and geomorphic influences. *Regulated Rivers* 13:129-49.

Stewart, W.P., K. Larkin, B. Orland, D. Anderson, R. Manning, D. Cole, J. Taylor, and N. *Tomar. Preferences* of recreation user groups of the Colorado River in Grand Canyon.

Report to USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. Prepared under Cooperative Agreement No. 98-FG-40-0190. 2000. 231 pp.

Stromberg, J.C., R.Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications* 6:113-131.

Thieme, M. 1998. *Movement and recruitment of flannelmouth sucker in the Paria and Colorado Rivers, Arizona*. Master's Thesis. Department of Biology, University of Arizona, Tucson, Arizona.

Tippets, W.E. and P.B. Moyle. 1978. Epibenthic feeding by rainbow trout (*Salmo gairdneri*) in the McCloud River, California. *Journal of Animal Ecology* 47:549-559.

Topping et al. 2006. Comparison of Sediment-Transport and Bar-Response Results from the 1996 and 2004 Controlled-Flood Experiments on the Colorado River in Grand Canyon. Proceedings from the 8th Federal Inter-Agency Sedimentation Conference. Reno, Nevada.

Trammell, M.A., R.A. Valdez, S.W. Carothers, and R.J. Ryel. 2002. Effects of a low steady summer flow experiment in the Grand Canyon, Arizona. Report to USGS, Grand Canyon Monitoring and Research Center from SWCA Inc., Flagstaff, Arizona.

Turner, R. M. and M. M. Karpiscak. 1980. Recent Vegetation Changes Along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. In professional paper 1132. Flagstaff, AZ: US Department of the Interior, US Geological Survey.

Underhill, A.H., M.H. Hoffman, and R.E. Borkan. 1988. *An analysis of recorded Colorado River boating accidents in Glen Canyon for 1980, 1982, and 1984 and in Grand Canyon for 1981 through 1983.* Glen Canyon Environmental Studies Final Report. National Technical Information Service: Springfield, Virginia. NTIS No. PB88-195441/AS.

Unitt, P. 1987. *Empidonax traillii extimus*: an endangered subspecies. *Western Birds* 18 (1987): 137-62.

US Department of the Interior. 1996. Record of decision on the operation of Glen Canyon Dam. Washington, DC.

——. 1999. Proposed rule to remove the bald eagle in the lower 48 states from the list of endangered and threatened wildlife. *Federal Register* 64(128): 36453-36464.

——. 2005. Designation of critical habitat for the southwestern willow flycatcher (*Empidonax traillii extimus*), final rule. *Federal Register* 70:60886- 61009.

——. 2007. Endangered and threatened wildlife and plants; removing the bald eagle in the lower 48 states from the list of endangered and threatened wildlife, final rule. *Federal Register* 72:37346-37372.

——. 2008. Final biological opinion for the operation of Glen Canyon Dam. Phoenix, Arizona.

US Geologic Survey, Grand Canyon Monitoring and Research Center. 2007a. *Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam.* Report. Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

US Geological Survey, Grand Canyon Monitoring and Research Center. 2007b. Final August 2007 AMWG meeting sediment update. Report presented at Phoenix, Arizona.

US Geological Survey, Grand Canyon Monitoring and Research Center. In preparation. Final August 2007 AMWG meeting sediment update. Report presented at Phoenix, Arizona.

USGS *see* US Geologic Survey.

Valdez, R.A. 1994. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead : Phase I, final report to Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

——. 1999. Biological Implications of the 1996 Controlled Flood. Pages 342-350 in The controlled flood in Grand Canyon, R. H. Webb, J. C. Schmidt, G. R. Marzolf, and R. A. Valdez, eds. American Geophysical Union Monograph No. 110. Washington D.C. In *The Controlled flood in Grand Canyon*, ed. R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, 117-130. American Geophysical Union Monograph No. 110. Washington DC.

Valdez, R. A., and B. R. Cowdell. 1996. Effect of Glen Canyon Dam beach/habitat-building flows on fish assemblages in Glen and Grand Canyons, Arizona. Project completion report submitted to Arizona Game and Fish Dept. and Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R. A., B. R. Cowdell, and E. Pratts. 1995. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase II, final report to Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R. A., and T. L. Hoffnagle. 1999. Movement, habitat use, and diet of adult humpback chub. Pages 297–307 *in* R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez (eds.). The controlled flood in Grand Canyon. Geophysical Monograph 110. American Geophysical Union, San Francisco, California.

Valdez, R.A., and W.J. Masslich. 1999. Evidence of reproduction by humpback chub in a warm spring of the Colorado River in Grand Canyon, Arizona. *Southwestern Naturalist* 44:384-387.

Warren, P.L., and C.R. Schwalbe. 1985. Herpetofauna in riparian habitats along the Colorado River in Grand Canyon. In *Riparian ecosystems and their management: reconciling conflicting uses, first North American riparian conference, April 16-18, 1985, Tucson, Arizona*. Technical Report RM-120, pp. 347-354. US Forest Service.

Webb, R.H. 1996. *Observations of environmental change in Grand Canyon*. Report to Glen Canyon Environmental Studies Program, Bureau of Reclamation from USGS, Tucson, Arizona. Accessed at http://www.gcmrc.gov/library/reports/physical/Coarse_Sed_Webb/Webb1996.pdf.

Webb, R. H., R. Hereford, and G. J. McCabe. 2005. Climatic fluctuations, drought, and flow in the Colorado River Basin. *In* S.P. Gloss, J.E. Lovich, and T.S. Melis, editors. The State of the Colorado River Ecosystem in Grand Canyon. US Geological Survey Circular 1282, pp. 59-69.

Welsh, M.P., R.C. Bishop, M.L. Phillips, and R.M. Baumgartner. 1995. *Glen Canyon Dam, Colorado River Storage Project, Arizona—nonuse value study final report*. Hagler Bailly Consulting, Madison, Wisconsin. National Technical Information Service: Springfield, Virginia. NTIS No. PB98-105406.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins, eds. 1987. *A Utah Flora.* Great Basin Naturalist Memoirs No. 9. Brigham Young University, Provo.

Western Area Power Administration. 2008. CRSP Rate Brochure for Proposed Rates. Salt Lake City, Utah.

Whitmore, R.C. 1977. Habitat partitioning in a community of passerine birds. *Wilson Bulletin* 89:253-265.

Wiele, S.M., J.B. Graf, and J.D. Smith. 1995. *Sand deposition in the Colorado River in Grand Canyon from floods in the Little Colorado River.* Report to USGS, Grand Canyon Monitoring and Research Center, from USGS, Boulder, Colorado.

Wolfe, M. 2006. *States report highest level of households receiving energy assistance in 13 years, additional $1 billion appropriated for LIHEAP provides essential support, state-by-state results.* Press release. National Energy Assistance Directors' Association, Washington DC. Accessed at http://www.neuda.org/comm./press.

——. 2007. *State energy assistance directors call on congress to increase funding by $1 billion to address declining purchasing power and higher energy prices*. Press release. National Energy Assistance Directors' Association, Washington DC. Accessed at http://www.neuda.org/comm./press.

Yard, H., and J. G. Blake. 2004. Breeding bird assessment and surveys and monitoring. In *Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of Grand Canyon: an integrative approach*, ed. M.J.C. Kearsley, N. Cobb, H.

Yard, D. Lightfoot, S. Brantley, G. Carpenter, and J. Frey, 97-122. Report. USGS, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

6.0 Appendices

In cooperation with the Glen Canyon Dam Adaptive Management Program

Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam

Prepared by the Grand Canyon Monitoring and Research Center

December 27, 2007

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

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Executive Summary

This science plan describes proposed monitoring and research activities to be conducted by the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC), should the Secretary of the Interior approve an experimental high flow at Glen Canyon Dam in spring 2008. A high-flow release from the dam has been proposed in 2008, not only to rebuild sandbars and aid the endangered humpback chub, but also to benefit various downstream resources, including rainbow trout (*Oncorhynchus mykiss*), the aquatic food base, riparian vegetation, and archaeological sites. Additionally, the system is currently enriched with sediment as a result of repeated tributary floods from the Paria River in late 2006 and fall 2007; the current level of sand enrichment is greater than it has been since at least 1998.

The international prominence of Grand Canyon National Park and public concern about the impacts of Glen Canyon Dam resulted in Federal efforts to protect downstream resources. In 1992, the Grand Canyon Protection Act (GCPA) was enacted "to protect, mitigate adverse impacts to and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established." The 1996 Record of Decision on the Operation of Glen Canyon Dam Environmental Impact Statement established an adaptive management program, of which the GCMRC is a part, to ensure that the primary mandate of the GCPA is met.

Before the dam, the Colorado River swelled with spring snowmelt from the Rocky Mountains in most years, producing flood events and transporting large quantities of sediment that created and maintained sandbars in Grand Canyon. In Grand Canyon, sandbars provide camping beaches for river runners and hikers, serve as a source of sediment needed to protect archaeological resources from weathering and erosion, and create habitats used by native fish and other wildlife. Today, the river usually runs clear below Glen Canyon Dam, because Lake Powell traps all of the sediment upstream from the dam (Wright and others, 2005). As a result, Grand Canyon receives 6%–16% of its predam sand supply, which comes primarily from the Paria and Little Colorado Rivers when they enter the mainstem below the dam (Wright and others, 2005).

The native fish community found in Grand Canyon evolved in the large, turbid, and seasonally variable predam Colorado River. Today, three of the eight native fish species have been eliminated from the Colorado River in the study area and two are federally listed as endangered, razorback sucker (*Xyrauchen texanus*) and humpback chub (*Gila cypha*), under the Endangered Species Act of 1973. The razorback sucker is widely thought to no longer be present in Grand Canyon. Only six populations of humpback chub are known to exist, five in the Colorado River Basin above Lees Ferry, Ariz., and the one in Grand Canyon, Ariz., which is the largest population remaining in the basin.

Importantly, the design of the proposed 2008 high flow and the accompanying experimental studies outlined in this plan build on learning that occurred as the result of high-flow experiments conducted in 1996 and 2004. For example, from the 1996 high-flow, scientists learned that tributary-supplied sand does not accumulate on the riverbed over multiyear periods under typical dam operations. In fact, erosion of low-elevation sandbars caused by the 1996 high flow actually resulted in a net reduction in overall sandbar size. Approval of a supplemental environmental assessment (U.S. Department of the Interior, 2004) allowed scientists to evaluate the efficacy of conducting a high flow following tributary floods in 2004 for the first time and generated the following conclusions:

- The 2004 experiment resulted in an increase of total sandbar area and volume in the upper half of Marble Canyon, but further downstream, where sand was less abundant, a net transfer of sand out of eddies occurred that was similar to that observed during the 1996 experiment (Topping and others, 2006).
- More sand will be required than was available during the 2004 high flow (800,000 to 1,000,000 metric tons) to achieve increases in total sandbar area and volume throughout all of Marble and Grand Canyons in the future (Topping and others, 2006).
- Sandbars created by the 2004 high flow increased the windborne transport of sand toward some archaeological sites in Grand Canyon (Draut and others, 2005; Draut and Rubin, 2006). This led to the hypothesis that increased sand carried by the wind from restored sandbars may reduce erosion and increase preservation potential at some archaeological sites.

The sediment-related data that researchers propose to collect for a possible 2008 high flow would facilitate comparison with data collected during the two previous experiments. Proposed experimental studies will also generate new data that can be compared to previous tests on the physical processes regulating sandbar erosion and deposition during high-flow experiments, sediment deposition at archaeological sites and camping areas, ecosystem flux measurements related to organic tributary inputs, effects of flood disturbance on vegetation, and formation of backwater habitats used by native and nonnative fishes. These comparisons are required to determine whether greater and more geographically extensive sandbar rebuilding is possible with a future high flow than occurred in 1996 and 2004. The data are also needed to determine if consecutive high flows in the future might cause sand to accumulate through time to reverse erosion documented after the closure of Glen Canyon Dam in 1963.

Sandbar rebuilding is thought to be important in creating backwater habitat that may lead to increased production of young fish by native species. Overall, recruitment of humpback chub has been increasing from 1994 to 2002, a period that includes the 1996 high flow, though the uncertainty in these estimates is large. These data suggest that high flows have not been detrimental to humpback chub. It is also possible that high flows offer advantages to humpback chub, including the temporary displacement of nonnative fishes (Valdez and others, 2001) and the maintenance and construction of backwater habitats, which may offer growth advantages to humpback chub and other native fishes (Arizona Game and Fish Department, 1996).

The best timing to conduct a high flow to maximize resource benefits or to avoid undesirable impacts has yet to be determined. For 2007–08, the earliest practical time for a high flow would be early March 2008, given the logistical, administrative, and compliance requirements associated with conducting the research outlined in this plan.

The GCMRC proposes replication of the 2004 hydrograph in a potential 2008 high flow (41,500 cubic feet per second (cfs) for 60 hours). These conditions would allow scientists to determine whether the locally robust and consistent sandbar-building responses that occurred in upper Marble Canyon in 2004 can be repeated and possibly enhanced. However, a possible 2008 experiment would be different from the two high-flow experiments conducted previously in several important ways. In November 2007, for example, sand supplies in the main channel of the Colorado River were two to three times larger and distributed differently than in 2004. The system is currently enriched with sediment as a result of repeated tributary floods from the Paria River in October 2006 and August–September 2007 that delivered 2,500,000 metric tons (±500,000 metric tons) of sand into the Colorado River ecosystem below Glen Canyon Dam. Based on the entire period of record on the Paria River (1923–present), this annual magnitude of sand supply from the river occurs, on average, once in every 10 years. A second important difference is that a 2008 high flow would be followed by normal Record of Decision operations associated with annual release volumes, unlike previous experiments, which were followed by higher fluctuating flows than would have otherwise occurred.

Additionally, this science plan focuses on a wider range of research questions than previous high-flow experiments. For example, experimental study 1 (parts A–D) addresses questions related to sediment and seeks to determine not only if high-flow releases are an effective tool that will rebuild and maintain sandbars over time, but also if they have the ability to create additional backwater habitats for native fish and how new sand deposits affect archaeological sites. Experimental study 1 expands on work begun with the 2004 high flow to document the connection between high-flow releases and the transfer of sand to cultural sites by the wind and the formation and persistence of backwaters as the result of high flows. Additionally, data gathered as a result of a possible 2008 high-flow experiment would provide information to inform the continued development of a sediment model, which will help determine the optimum frequency, timing, duration, and magnitude of future high flows under varying sediment enrichment conditions. Experimental studies 2–5 address the impacts of high-flow experiments on riparian vegetation, the food base, rainbow trout, and Lake Powell water quality, respectively. Study 7 will provide a comprehensive synthesis of the results of all of the experimental studies conducted in association with a possible 2008 high-flow experiment. A well-calibrated, robust predictive sediment model will help minimize the impacts of high-flow tests on Glen Canyon Dam hydropower production.

The experimental studies outlined in this plan are designed to address strategic science questions identified in the Grand Canyon Monitoring and Research Center's monitoring and research plan; strategic science questions are designed to guide science activities over the next 5 years. Questions specific to the impacts of a high-flow flow are also identified for each study and would be addressed during the 2008 high-flow experiment, if it occurs.

The table that accompanies the executive summary briefly describes the various experimental studies and estimated costs. The total cost of the research activities associated with a possible 2008 high flow is approximately $3.73 million for fiscal years 2008–09. Thus, based on current and anticipated deposits into the experimental fund, additional support will be required to fully implement the science plan.

Based on the two previous high-flow experiments conducted to date, scientists cannot say at this time whether such experiments are an effective strategy for stopping the ongoing erosion of sand and sandbars in the Colorado River ecosystem. A long-term research strategy involving further high-flow experimentation and model development will be necessary to assess whether high flows can effectively conserve sediment and help achieve other related resource benefits (increased humpback chub recruitment, enhanced camping beaches, protection of cultural resource, minimized hydropower impacts, etc). At this time, it is not anticipated that a single high-flow release can answer all such relevant questions: accordingly, it is very likely that additional high-flow experiments will be needed to address the major uncertainties associated with the use such dam operations as an effective long-term management tool.

It is expected that a long-term experimental strategy, including the number and future frequency of high-flow experiments, will be determined through the Glen Canyon Dam Adaptive Management Program.

Table E.1. Description of experimental studies proposed by this science plan, including cost estimates for fiscal years (FY) 2008–09.

Experimental study	Description	FY 2008 cost estimate	FY 2009 cost estimate
	Sediment, archaeological sites, and backwaters		
1.A. Sand budgeting	Data will be collected to determine the amount of sediment available in the system and its availability for restoring sandbars and camping beaches, patterns of erosion and deposition, and changes in sediment grain size	$313,212	$94,102
1B. Eddy-sandbar studies	Data will be collected on the evolution of specific eddy sandbars before, during, and after a high flow. These data may be used to improve the predictive capabilities of the existing sediment model and determine the optimal peak flows of future high-flow experiments.	$103,797	$92,057
1.C. Response of sandbars and select cultural site	Data will be gathered to determine (1) if sandbars throughout the Colorado River ecosystem gain or lose sand as the result of a sand-enriched high flow, (2) if new sand can offset gully erosion, and (3) if enlarged sandbars provide source material for the windborne transport of sand upslope into archaeological sites.	$604,180	$360,374
1.D. Backwater habitats	Measure backwater habitats and sample them for fish in spring and fall to evaluate how (a) backwaters formed by a high flow change over time and (b) how fish, particularly humpback chub, use backwaters.	$851,461	$191,275
	Riparian vegetation		
2. Riparian vegetation studies	Study will document changes in riparian vegetation (native versus nonnative) following a high flow to determine if disturbances influence the success rate of nonnative species.	$42,709	$30,738
	Aquatic food base		
3. Food availability	Data will be collected to determine how high-flow experiments affect the quantity and quality of food available to invertebrates and, ultimately, fish.	$216,903	$44,175
	Rainbow trout		
4.A. Redds study	Data will be collected to determine how high-flow experiments affect spawning and survival of early-life stages of rainbow trout in Lees Ferry	$130,371	$100,861
4.B. Movement study	Study will collect data to determine if high-flow experiments displace rainbow trout from Lees Ferry and if displacement varies by fish length	$110,648	$2,057
	Lake Powell		
5. Lake Powell	Data to determine if a high flow results in higher nutrient releases and changes in the hypolimnion	$35,274	$5,022
	Conservation measures		
6. Kanab ambersnail	To minimize impacts to an endangered species, Kanab ambersnail habitat at Vaseys Paradise will be moved	$16,316	$0
	Knowledge synthesis		
7. Synthesis of knowledge	Data and knowledge gained as the result of the high-flows test will be synthesized in an attempt to address strategic science questions	$0	$258,000[1]
	Logistical support		
8. Logistical support	Logistical support costs not associated with specific research activities	$122,673	$0
Totals		**$2,547,543**	**$1,178,660**

[1] An additional $400,000 will be needed in FY 2010 to complete the synthesis of results from a possible 2008 high-flow test with previous high-flow tests

Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam

Prepared by the Grand Canyon Monitoring and Research Center

Part I: Introduction and Background

This science plan describes proposed monitoring and research activities to be conducted by the U.S. Geological Survey's (USGS) Grand Canyon Monitoring and Research Center (GCMRC), should the Secretary of the Interior approve an experimental high flow at Glen Canyon Dam in early 2008. The study area is the Colorado River ecosystem (CRE), the river corridor that extends from the forebay of Glen Canyon Dam to the western boundary of Grand Canyon National Park (fig. 1). This plan is designed to build upon existing scientific knowledge to inform managers about the efficacy of using high-flow releases from the dam, not only to rebuild sandbars and aid the endangered humpback chub (*Gila cypha*), but also to benefit various downstream resources, including rainbow trout (*Oncorhynchus mykiss*), the aquatic food base, riparian vegetation, archaeological sites, and water quality.

The GCMRC has responsibility for monitoring and research activities for the Glen Canyon Dam Adaptive Management Program (GCDAMP), a Federal initiative to protect and improve resources downstream of Glen Canyon Dam. Because of the lengthy lead time required to plan and execute a high flow, the Adaptive Management Work Group (AMWG)—the Federal Advisory Committee within the GCDAMP that provides recommendations to the Secretary of the Interior on the operation of the dam—recommended that the GCMRC prepare this plan in anticipation of a future experiment. Following this recommendation, the Department of the Interior directed the GCMRC to develop an "off-the-shelf" science plan to take advantage of potential high-flow research opportunities in the future. This plan has been adapted specifically to address a potential high-flow experiment in the spring of 2008; however, the plan may be considered generally applicable to any future high-flow experiment.

Although this science plan primarily focuses on potential experimental studies associated with a 2008 experimental high-flow release, the plan also addresses concerns expressed by GCDAMP participants about issues related to future high-flow experimental research, particularly associated costs and benefits. Issues of concern, relevant information about these issues gathered during the science-planning process, and an assessment of each issue prepared by GCMRC scientists are given in appendix A. Efforts have also been made to identify the pros and cons of a future high-flow experiment, especially related to the duration of the experiment (see appendix A, table A1).

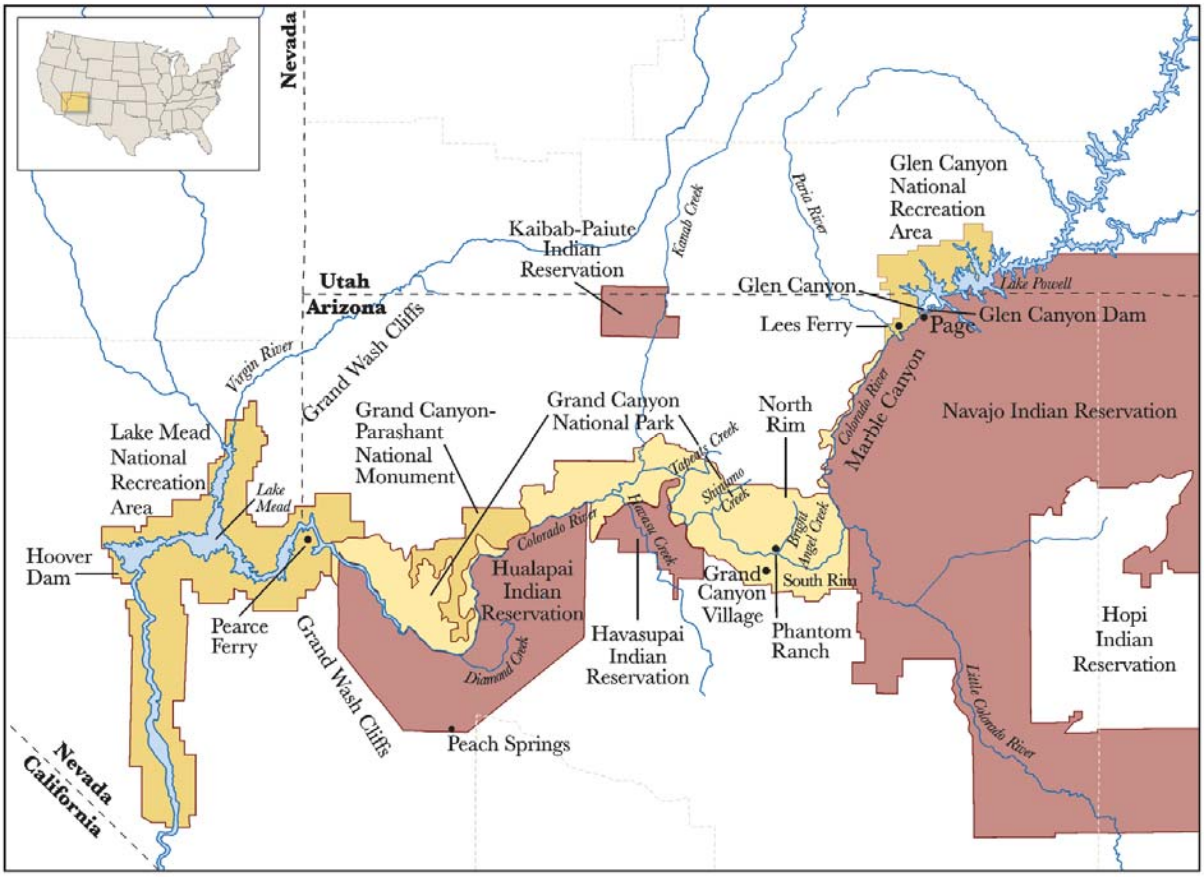

Figure 1. Map of the Colorado River ecosystem, the Colorado River corridor that extends from the forebay of Glen Canyon Dam to the western boundary of Grand Canyon National Park, Ariz.

Background

Glen Canyon Dam, one of the last major dams built on the Colorado River, is located in the lower reaches of Glen Canyon National Recreation Area, approximately 24 km upriver from Grand Canyon National Park. Before the dam, the Colorado River swelled with spring snowmelt from the Rocky Mountains in most years, producing flood events and transporting large quantities of sediment that created and maintained sandbars in Grand Canyon. The native fish community found in Grand Canyon, including species found nowhere else on Earth, evolved in the large, turbid, and seasonally variable predam Colorado River. Today, three of the eight native fish species have been eliminated from the Colorado River in the study area and two are federally listed as endangered, razorback sucker (*Xyrauchen texanus*) and humpback chub, under the Endangered Species Act of 1973. The razorback sucker is widely thought to no longer be present in Grand Canyon. Only six populations of humpback chub are known to exit, five in the Colorado River Basin above Lees Ferry, Ariz., and the one in Grand Canyon, Ariz., which is largest population remaining in the basin.

In Grand Canyon, sandbars supply camping beaches for river runners and hikers, provide sediment needed to protect archaeological resources from weathering and erosion, and create habitats used by native fish and other wildlife. For example, sandbars create backwaters—areas of stagnant or low-velocity flow—that are used as rearing areas by humpback chub and other native fishes. Today, the river usually runs clear below Glen Canyon Dam, because Lake Powell traps all of the sediment upstream from the dam (Wright and others, 2005). As a result, Grand Canyon receives 6%–16% of its predam sand supply, which comes primarily from the Paria and Little Colorado Rivers when they enter the mainstem below the dam (Wright and others, 2005).

The international prominence of Grand Canyon and public concern about the impacts of the dam resulted in Federal efforts to protect downstream resources. In 1992, the Grand Canyon Protection Act (GCPA) was enacted "to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established." The GCDAMP was established by the 1996 Record of Decision (ROD) on the Operation of Glen Canyon Dam Environmental Impact Statement (EIS) to ensure that the primary mandate of the GCPA is met (U.S. Department of the Interior, 1995). An adaptive management process—initiated following the 1996 Record of Decision—is being used to evaluate the effects of dam operations on the ecosystem below Glen Canyon Dam and to identify future modifications of dam operations to enhance resource conditions. Adaptive management is a systematic process that uses experimentation and monitoring to continually improve management practices.

Beach/Habitat-Building Flows and High-Flow Experimental Releases

One of the experiments identified by the 1995 EIS was the use of beach/habitat-building flows (BHBF) to rebuild high-elevation sandbars, deposit nutrients, and restore backwater channels. Replenishing sandbars requires both a sufficiently large upstream sand supply and higher than normal flows to deposit sand at higher elevations. In the EIS, a BHBF is defined as a release of water from Glen Canyon that is at least 10,000 cubic feet per second (cfs) greater than the allowable peak discharge (30,000 cfs) but not greater than 45,000 cfs. The EIS specified the testing of high-flow experiments prior to their implementation as a long-term management action.[2]

Importantly, the design of the 2008 high-flow experimental release and the accompanying experimental studies proposed in this plan build on learning that occurred as the result of previous high-flow experiments conducted in 1996 and 2004. For example, from the 1996 experiment, scientists learned that tributary-supplied sand does not accumulate on the riverbed over multiyear periods under typical dam operations, as had been hypothesized in the EIS. Additionally, the 1996 experiment was conducted when the Colorado River was relatively sand depleted, especially in Marble Canyon, and, as a result, the primary sources of sand for building high-elevation sandbars were the low-elevation parts of the upstream sandbars and not the channel bed (Andrews and others, 1999; Schmidt, 1999; Hazel and others, 2006). During the 1996 experiment, the erosion of low-elevation sandbars actually resulted in a net reduction in overall sandbar size. Sandbars that

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[2] The 1996 Record of Decision (ROD) and 1997 Glen Canyon Operating Criteria address the management framework for the operation of Glen Canyon Dam, including implementation of beach/habitat-building flows (BHBFs) as part of a long-term monitoring, research, and experimental program. The 1996 ROD established an adaptive management framework for future experimentation and management decision making, including experimentation designed to inform future operational changes. The high-flow experiment contemplated for March 2008 identified in this science plan utilizes the hydrologic release elements of a BHBF, but as described herein, would function as a single experimental action, rather than relying on the reservoir level-based triggers that are linked to management implementation of BHBFs. Implementation of this proposed experimental release is subject to completion of appropriate environmental compliance documentation by the action agency (Bureau of Reclamation). Further information regarding the approach and basis for the proposed experiment can be found in the biological assessment prepared for the proposed action by the Bureau of Reclamation (December 2007).

eroded during the 1996 experiment did not recover their former sand volume during the late 1990s, in spite of above-average sand supplies and the implementation of ROD operations.

These results indicated that high-flow releases conducted under sand-depleted conditions, such as those that existed in 1996, will not successfully sustain sandbar area and volume. Scientists and managers used this information to focus their efforts on the need to strategically time high-flow releases to better take advantage of episodic tributary floods that supply new sand, particularly sand input by the Paria River, to the Colorado River downstream of Glen Canyon Dam.

The Importance of Tributary Floods

In September 2002, the U.S. Department of the Interior approved the implementation of a new high-flow experimental approach linked to sand inputs from the Paria River (U.S. Department of the Interior, 2002). Significant sand inputs to Marble Canyon occurred during September–November 2004 that exceeded the sediment trigger established in 2002. Approval of a supplemental environmental assessment (U.S. Department of the Interior, 2004) allowed scientists to evaluate the efficacy of conducting a high-flow experiment following tributary floods for the first time. The second experimental high-flow release was conducted in November 2004 and generated the following conclusions:

- The 2004 experiment resulted in an increase of total sandbar area and volume in the upper half of Marble Canyon, but further downstream, where sand was less abundant, a net transfer of sand out of eddies occurred that was similar to that observed during the 1996 experiment (Topping and others, 2006).
- Substantial increases in total eddy-sandbar area are only possible when high flows are conducted following large tributary floods that enrich sand supplies in the main channel of the Colorado River (Rubin and others, 2002: Topping and others, 2006).
- More sand will be required than was available during the 2004 high-flow experiment (800,000 to 1,000,000 metric tons) to achieve increases in total sandbar area and volume throughout all of Marble and Grand Canyons in the future (Topping and others, 2006).
- Sandbars created by the 2004 high-flow experiment increased the windborne transport of sand toward some archaeological sites in Grand Canyon (Draut and others, 2005; Draut and Rubin, 2006). This led to the hypothesis that increased sand carried by the wind from restored sandbars may reduce erosion and increase preservation potential at some archaeological sites.

The sediment-related data that researchers propose to collect for a 2008 high-flow experiment will facilitate comparison with data collected during the two previous high-flow experiments conducted in 1996 and 2004. Proposed experimental studies will also generate new data that can be compared to previous experiments on the physical processes regulating sandbar erosion and deposition during high-flow releases, sediment deposition at archaeological sites and camping areas, ecosystem flux measurements related to organic tributary inputs, effects of flood disturbance on vegetation, and formation of backwater habitats used by native and nonnative fishes. These comparisons are required to determine whether greater and more geographically extensive sandbar rebuilding is possible with a future high-flow experiment than occurred during the 1996 and 2004 experiments. The data are also needed to determine if consecutive high-flow experiments in the future might cause sand to accumulate through time to reverse erosion documented after the closure of Glen Canyon Dam in 1963.

Humpback Chub Response

The 1996 high-flow experiment occurred in the spring (March 22 to April 8, 1996), which is approximately the same timing considered for a possible 2008 high-flow experiment (The 2004 high-flow experiment was conducted in the fall.). The fish community response to the 1996 high-flow release was studied and reported by Valdez and others (2001). These authors found that the native fish community, including humpback chub, did not experience decreased distribution or abundance as a result of the high-flow experiment; however, there was temporary displacement of nonnative fish species. During the November 2004 high-flow experiment, fisheries scientists attempted to sample the fish community before and after the experiment to further document the response of humpback chub and other fishes to high flows. Unfortunately, the sampling following the event was confounded by a natural flood event in the Little Colorado River, which greatly increased turbidity in the main channel and possibly reduced the efficiency of the sampling gear. Because of the timing and magnitude of the spate from the Little Colorado River, it cannot be determined whether the observed decline in catch rate following the 2004 high-flow experiment resulted from a decline in fish density or a decline in sampling gear efficiency.

The age-structured mark recapture model (ASMR) model (Coggins and others 2006) is used to assess the status and trends of the humpback chub population in Grand Canyon. The ASMR results for the years 1989–2006 indicate that the population of adult (age 4+) humpback chub in Grand Canyon declined to a modern low in 2001 but has been increasing since that time (fig. 2). This period of increasing population includes the November 2004 high-flow experiment. Although the exact cause of the increased population cannot be determined with certainty (Andersen, 2007), the November 2004 high-flow experiment does not appear to have been detrimental to the adult population of humpback chub.

The ASMR model also allows for an estimate of the abundance of recruitment of humpback chub (fig. 3), that is, how many young fish were produced in particular years. Overall, recruitment has been increasing from 1994 to 2002, a period that includes the 1996 experiment, though the uncertainty in these estimates is large. Considered together, these data suggest that high-flow experiments have not been detrimental to humpback chub. It is also possible that high-flow experiments offer advantages to humpback chub, including the temporary displacement of nonnative fishes (Valdez and others, 2001) and the maintenance and construction of backwater habitats, which may offer growth advantages to humpback chub and other native fishes (Arizona Game and Fish Department, 1996).

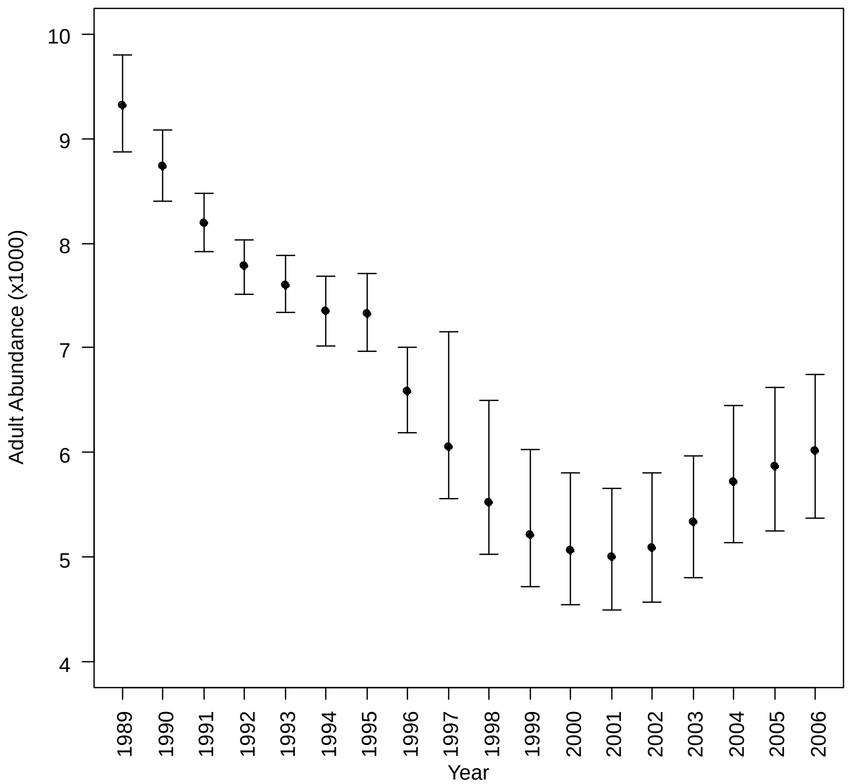


Figure 2. Trend of adult (age 4+) humpback chub population in Grand Canyon modeled by the age-structured mark recapture model of Coggins and others, 2006 (U.S. Geological Survey, unpub. data, 2007). Error bars represent 95% profile confidence intervals.

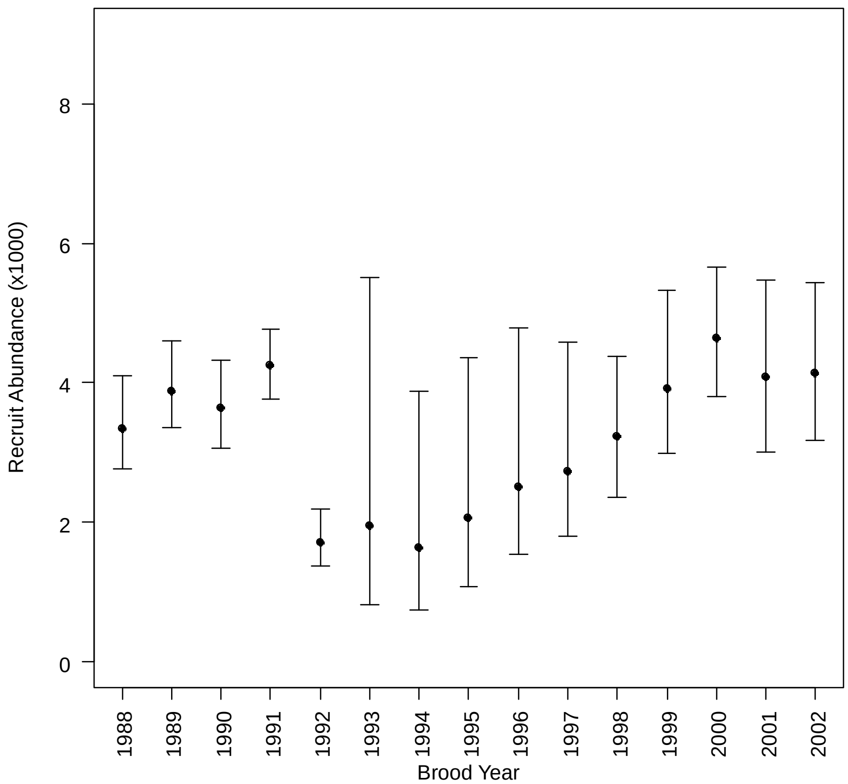


Figure 3. Estimated recruitment to the Little Colorado River humpback chub population from brood years 1988–2002 (U.S. Geological Survey, unpub. data, 2007). Error bars represent 95% profile confidence intervals.

2008 Potential High-Flow Experiment

Timing

The best timing to conduct a high-flow experiment to maximize resource benefits or to avoid undesirable impacts has yet to be determined. For 2007–08, the earliest practical time for a high-flow release would be early March 2008, given the logistical, administrative, and compliance requirements associated with conducting the research outlined in this plan. March 2008 is an appropriate time frame for a high-flow experiment for the following reasons:

1. The system is currently enriched with sediment as a result of repeated tributary floods from the Paria River in October 2006 and August–September 2007 that delivered 2,500,000 metric tons (±500,000 metric tons) of sand into the Colorado River ecosystem below Glen Canyon Dam. As a result, sand supplies in the upper reaches of Grand Canyon National Park now contain approximately two to three times the minimum sand volume that was previously needed to trigger the last high-flow experiment in 2004. Sand production by the Paria River in Water Year 2007 has been twice the long-term average and the current level of sand enrichment is

greater than it has been since at least 1998. Based on the entire period of record on the Paria River (1923–present), this annual magnitude of sand supply from the Paria River occurs, on average, once in every 10 years. Most of this new sand is still retained in Marble Canyon at present because downstream transport of the new sand has been suppressed under minimum dam operations associated with modified low fluctuating flows combined with 8.23 million acre-feet annual release volume.

2. A March experimental release would be expected to be compatible with the life cycles and life histories of many native Colorado River organisms. For example, humpback chub historically spawned on the ascending limb of the spring hydrograph when water temperatures would approach 17°C.
3. High flows that occur when sand supply is abundant in the channel are known to form backwater habitats (Goeking and others, 2003) where young native fish can find refuge from predation and benefit from warmer water temperatures that encourage growth. A March high flow would create backwaters at the onset of the spawning season increasing the likelihood that they would be available for use by larval and juvenile fishes
4. March is before the flowering of the nonnative tamarisk (*Tamarix ramosissima*), and so would reduce the potential for increasing its distribution. Controlling the spread of tamarisk in the CRE is a priority of the National Park Service.
5. A March high-flow experiment is expected to have moderate to low impact on the production of algae and diatoms between the dam and Lees Ferry and, as a result, should not limit the availability of these food sources for the rainbow trout fishery and native fishes. Rather, a March high-flow experiment has the potential to crop off senescent or dead algae and to encourage fresh, new growth as increased solar radiation is available from March through October as compared to other times of the year.
6. A March experimental high-flow release will maximize the potential for newly created sandbars to contribute additional sand to nearby archaeological sites. A March high-flow experiment would create sandbars just before the onset of the spring windy season (April–June).

Peak Flow Magnitude and Duration

The GCMRC proposes replication of the 2004 high-flow hydrograph in a similar experiment in 2008 (41,500 cfs for 60 hours). Flows immediately preceding and following a potential March 2008 experiment are anticipated to be similar to normal modified low fluctuating flow (MLFF) patterns typically released in the transition month of March during 8.23 million acre-feet (maf) release years. The daily range of flows would likely be 6,000 cfs with diurnal peaks flows of 12,000–13,000 cfs. These operations would probably be very similar to the December 2004 MLFF patterns that followed the November 2004 experiment. No experimental fluctuating flows or steady flows are recommended to proceed or follow a possible 2008 high-flow experiment.

A possible 2008 experiment would allow scientists to determine whether the locally robust and consistent sandbar-building responses that occurred in upper Marble Canyon in 2004 can be repeated and possibly enhanced. By reproducing the 2004 hydrograph, scientists would also be able to evaluate whether there are cumulative benefits to sandbar conservation in lower Marble and Grand Canyons each time a sand-enriched high-flow experiment occurs.

The GCMRC and its science cooperators recently evaluated the limitations and benefits of a shorter duration peak at 41,500 cfs. Exact predictions about the outcome of a high-flow experiment with a shorter duration are not possible at this time without field experimentation because current sediment models have limited utility for estimating sandbar responses over long reaches, and there are many factors to consider related to peak-flow duration and peak magnitudes for high-flow experiments. Scientists acknowledge that a potential 2008 high-flow release lasting not less than 30 hours might also result in sandbar-building benefits and would also advance learning about high flows and sediment dynamics. The GCMRC compares the pros and cons associated with a 60-hour versus 30-hour peak high-flow duration in appendix A.1.

Fall dam releases that preceded the 2004 high-flow experiment (5,000 to 10,000 cfs daily range) were very effective in limiting downstream sand transport between September and late November 2004. However, because these releases caused most of the new sand to be stockpiled in the upper section of Marble Canyon, the flood wave's higher velocity took it downstream of the new sand supply by the time the flood reached lower Marble Canyon and beyond. A March 2008 experiment would allow sediment scientists to evaluate whether normal dam operations following the input of new sand effectively redistributes new sand throughout Marble and Grand Canyons. Allowing the sand to be redistributed before a high-flow experiment might produce more optimal sandbar building than occurred during the 2004 experiment. Currently, the sand that has been deposited in the Colorado River by tributary flooding since August 2006 has been subjected to 5–19 months of normal MLFF flows.

2008 Test Includes Important Differences

A 2008 experiment would be different from the two high-flow experiments conducted previously at Glen Canyon Dam in several important ways. As noted above, the 1996 experiment was conducted when sand supplies in the Colorado River were relatively depleted. The 2004 experiment occurred shortly after Paria River flooding had enriched the sand supply in Marble Canyon; however, the amount of sand present in 2004 was insufficient to achieve increases in total sandbar area and volume throughout both Marble and Grand Canyons. In November 2007, sand supplies in the main channel of the Colorado River were two to three times larger and more evenly distributed longitudinally than in 2004. Conducting a high-flow release under current sediment conditions would allow scientists to evaluate the effectiveness of conducting high flows under much enriched conditions that have been followed by 5–19 months of normal MLFF operations.

A second important difference is that a 2008 high-flow experiment would be followed by normal springtime Record of Decision operations associated with annual release volumes, unlike previous experiments, which were followed by higher fluctuating flows than would have otherwise occurred. The daily range of flows would likely be 6,000 cfs with diurnal peaks flows of 12,000 to 13,000 cfs (specific flows would be determined by the Bureau of Reclamation). These operations would probably be very similar to the December 2004 flow patterns that followed the November 2004 high flow and preceded the experimental fluctuating flows of January–March 2005. The 2008 experiment would allow a unique comparison of the relative stability of sandbars and backwaters under the relatively low fluctuating flows associated with normal spring operations versus higher summer monthly operations during a minimum release year (8.23 maf).

Experimental Studies to Address a Variety of Scientific Questions

In December 2005, the AMWG identified concerns and questions about the effects of high flows on a variety of resources. In addition, in August 2007, the AMWG approved the GCMRC monitoring and research plan (MRP), which includes a series of strategic science questions (SSQs) that will guide science activities over the next 5 years. Table 1 describes the SSQs from the MRP and high-flow science questions that would be addressed during the 2008 high-flow experiment, if it occurs. The high-flow science questions are specifically designed to address concerns and questions identified by the AMWG.

For example, this science plan proposes to determine how high flows affect sediment resources and sandbars, backwater habitats used by the endangered humpback chub and other native fishes, the aquatic food base, rainbow trout recruitment and emigration, riparian vegetation, and archaeological resources in close proximity to the Colorado River. For example, experimental study 1 (parts A–D) addresses questions related to sediment and seeks to determine not only if high flows are an effective tool to rebuild and maintain sandbars over time, but also if such experiments have the ability to create additional backwater habitats for native fish and how new sand deposits affect archaeological sites. Experimental study 1 expands on work begun with the 2004 experiment to document the connection between high-flow releases and the transfer of sand to cultural sites by the wind and the formation and persistence of backwaters as the result of high flows. Experimental studies 2–5 address the impacts of high-flow experiments on riparian vegetation, food base, rainbow trout, and Lake Powell water quality, respectively. Study 7 would provide a comprehensive synthesis of the results of all of the experimental studies conducted in association with a possible 2008 high flow.

Table 1. Strategic science questions from the GCMRC monitoring and research plan (MRP), related high flow science questions, and the experimental studies that would address in part or in whole individual questions.

Question	Experimental Studies
Sediment and related resources	
MRP strategic science question: Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?	
High flow science question: How do conditions of suspended sediment concentration and grain size evolve and vary through time and by reach below Glen Canyon Dam during replication of the 2004 hydrograph under more highly enriched sand supply conditions; and how do these data compare with similar data collected at similar locations during the 1996 and 2004 high-flow experiments? Is the net mass balance of sand following the high flow net positive, negative, or neutral?	1.A
High flow science question: What is the minimum duration for high-flow experiments needed to build and maintain sandbars under sand-enriched conditions?	1B
High flow science question: Can the next high flow increase campable areas at sandbars on a sustainable basis?	1.C
High flow science question: Following a high flow, how Record of Decision (ROD) operations under 8.23 million acre-feet annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?	1.D
Humpback chub	
MRP strategic science question: How important are backwaters and vegetated shoreline habitats to the overall growth and survival of young-of-year and juvenile native fish? Does the long-term benefit outweigh short-term potential costs?	
High flow science question: Do high-flow experiments result in creation of backwater habitats that may benefit humpback chub and other native fishes? To what extent are backwater habitats created by a high flow used by humpback chub and other native fishes?	1.D
Cultural resources	
MRP strategic science question: How effective are various treatments in slowing rates of erosion at archaeological sites over the long term?	
High flow science question: Do sandbars deposited by high-flow experiments contribute to preservation of archaeological sites in the river corridor?	1.C
High flow science question: Do high-flow experiments contribute to added stability or erosion of archaeological sites located in close proximity to the river?	1.C

Table 1. Strategic science questions from the GCMRC monitoring and research plan (MRP), related high flow science questions, and the experimental studies that would address in part or in whole individual questions.—Continued.

Other priority resource issues	
Strategic science questions: What Glen Canyon Dam operations maximize trout fishing opportunities and catchability? Do rainbow trout immigrate from Glen to Marble and eastern Grand Canyons, and if so, during what life stages?	
High flow science question: How will a high flow affect spawning, survival of early life history stages of rainbow trout (BBT) in the Lees Ferry reach? Will a high flow stimulate downstream migration of age-1 RBT?	4.A, 4.B
Strategic science questions: How is invertebrate flux affected by water quality and dam operations?	
High flow science question: How will a future high flow affect food production and availability for rainbow trout in the Lees Ferry reach? What are the effects of high-flow experiments on aquatic food production? How do these effects impact native fishes?	3
Strategic science questions: How is invertebrate flux affected by water quality and dam operations?	
High flow science question: Will the next high flow result in higher nutrient releases and shrinking of the hypolimnion? Will the operation of the river outlet works and the penstocks at capacity measurably alter Lake Powell hydrodynamics or stratification, or alter release water quality?	5
Strategic science questions: Do dam controlled flows affect rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?	
High flow science question: Are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation following a disturbance?	2

One of the concerns managers have with the possible 2008 high flow is its potential to affect aquatic food resources at lower trophic levels, thereby indirectly affecting native and nonnative fishes. However, the exact effects of these events have not been well studied, so conclusions about them remain speculative. The study of the aquatic food base anticipates monitoring the effects of the 2008 high flow on the primary and secondary producers below Glen Canyon Dam. Monitoring before and after the 2008 high flow would be an important link in the ongoing research and data collection that is being conducted throughout the river corridor to help determine what changes, if any, result from the 2008 high flow.

Other biological activities also build on ongoing scientific research to address key strategic science questions. For example, experimental study 1.D is being used not only to help develop methods for mapping backwater habitats to better understand their creation and persistence in the months following the 2008 high flow, but also is intended to build on existing efforts by expanding the fall sampling of backwater habitat for small-bodied fish to include sampling during the spring. Spring sampling for small-bodied fishes would complement the fall sampling and provide additional insights into the persistence of backwaters and use of backwater habitats by native and nonnative fishes. The GCDAMP is undertaking a diverse program of monitoring for native and nonnative fishes to help evaluate potential longer term effects of the 2008 high flow.

Relation of a Potential High Flow to Sediment Modeling Activities

Besides answering pressing scientific questions, a 2008 high-flows test would provide information to inform the continued development of a sediment model, which would help determine the optimum frequency, timing, duration, and magnitude of future high-flows tests under varying sediment enrichment conditions. Model construction has not been possible with the currently available information. Experimental study 1.B in this science plan is intended to provide the key data on eddy sandbar evolution that is needed to advance modeling within eddies and sand exchanges between eddies and the main channel.

Research on the development of flow and sediment-transport modeling and development have occurred within the previous Glen Canyon Environmental Studies and current GCMRC science programs. Much of the previous effort has been focused on developing models that accurately route dam discharges through the Colorado River channel downstream, as well as simulating sandbar evolution within eddies under varied flow and sand-supply conditions; including fluctuations and high-flow releases. Research efforts have also focused on predicting sand production from key tributaries, such as the Paria River, on the basis of streamflow and river geomorphology. Despite much progress in these areas, only the tributary flow and sediment models, and main-channel flow routing and average temperature models have progressed far enough to provide reliable predictions.

Future advancement of sediment transport models can allow managers and scientists to more efficiently evaluate a range of flow and sediment-supply conditions in the river to identify high-flows options that might meet management objectives for sand conservation. A well-calibrated, robust predictive sediment model would help minimize the impacts of high flows on Glen Canyon Dam hydropower production.

Cost of 2008 High Flow

As shown in table 2, the cost of the research activities associated with the next high flow is approximately $3.73 million for fiscal years 2008–09; the total cost of this science plan is dependent on the scope of studies that are eventually implemented. In 2003, the GCDAMP established an experimental fund to pay for experimental research studies such as the proposed high flow, so that they could be conducted without financially impacting other ongoing aspects of the science program. The balance of the experimental fund in fiscal year (FY) 2008 is approximately $1,450,000. In FY 2009, an additional $500,000 is planned to be deposited into the experimental fund. Thus, based on current and anticipated deposits into the experimental fund, additional support would be required to fully implement this science plan.

In addition to the cost of studies, some portion of the flows needed for a possible 2008 experiment would bypass the powerplant at Glen Canyon Dam. The Western Area Power Administration has estimated that approximately $2 million of replacement power costs would be incurred as a result of a high flow. The extent of these costs would depend on the magnitude, duration, and timing of a possible high flow. It has also been suggested that a high flow could have a negative impact on the Marble Canyon economy, which is dependent on the Lees Ferry trout fishery. However, these economic impacts and the economic benefits associated with potential improvements to resources and recreation in the Colorado River ecosystem have not been fully evaluated or quantified. An assessment of the economic impacts of dam operations, including a potential high-flows test, is outside the scope of this document.

Table 2. Description of experimental studies proposed by this science plan, including cost estimates for fiscal years (FY) 2008–09.

Experimental study	Description	FY 2008 cost estimate	FY 2009 cost estimate
	Sediment, archaeological sites, and backwaters		
1.A. Sand budgeting	Data will be collected to determine the amount of sediment available in the system and its availability for restoring sandbars and camping beaches, patterns of erosion and deposition, and changes in sediment grain size	$313,212	$94,102
1B. Eddy-sandbar studies	Data will be collected on the evolution of specific eddy sandbars before, during, and after a high flow. These data may be used to improve the predictive capabilities of the existing sediment model and determine the optimal peak flows of future high-flow experiments.	$103,797	$92,057
1.C. Response of sandbars and select cultural site	Data will be gathered to determine (1) if sandbars throughout the Colorado River ecosystem gain or lose sand as the result of a sand-enriched high flow, (2) if new sand can offset gully erosion, and (3) if enlarged sandbars provide source material for the windborne transport of sand upslope into archaeological sites.	$604,180	$360,374
1.D. Backwater habitats	Measure backwater habitats and sample them for fish in spring and fall to evaluate how (a) backwaters formed by a high flow change over time and (b) how fish, particularly humpback chub, use backwaters.	$851,461	$191,275
	Riparian vegetation		
2. Riparian vegetation studies	Study will document changes in riparian vegetation (native versus nonnative) following a high flow to determine if disturbances influence the success rate of nonnative species.	$42,709	$30,738
	Aquatic food base		
3. Food availability	Data will be collected to determine how high-flow experiments affect the quantity and quality of food available to invertebrates and, ultimately, fish.	$216,903	$44,175
	Rainbow trout		
4.A. Redds study	Data will be collected to determine how high-flow experiments affect spawning and survival of early-life stages of rainbow trout in Lees Ferry	$130,371	$100,861
4.B. Movement study	Study will collect data to determine if high-flow experiments displace rainbow trout from Lees Ferry and if displacement varies by fish length	$110,648	$2,057
	Lake Powell		
5. Lake Powell	Data to determine if a high flow results in higher nutrient releases and changes in the hypolimnion	$35,274	$5,022
	Conservation measures		
6. Kanab ambersnail	To minimize impacts to an endangered species, Kanab ambersnail habitat at Vaseys Paradise will be moved	$16,316	$0
	Knowledge synthesis		
7. Synthesis of knowledge	Data and knowledge gained as the result of the high-flows test will be synthesized in an attempt to address strategic science questions	$0	$258,000[3]
	Logistical support		
8. Logistical support	Logistical support costs not associated with specific research activities	$122,673	$0
Totals		**$2,547,543**	**$1,178,660**

[3] An additional $400,000 will be needed in FY 2010 to complete the synthesis of results from a possible 2008 high-flow test with previous high-flow tests

Long-term Strategy for Future High-Flow Experimentation and Frequency

The data gathered as the result of the experimental studies proposed in this science plan would feed into the GCDAMP adaptive management process. Figure 4 depicts how information derived from the proposed 2008 high-flow experiment would be used by the GCDAMP to improve decision making and refine predictive models.

Based on the two previous high-flow experiments conducted to date, scientists cannot say at this time whether such experiments are an effective strategy for stopping the ongoing erosion of sand and sandbars in the Colorado River ecosystem. A long-term research strategy involving further high-flow experimentation and model development will be necessary to assess whether high flows can effectively conserve sediment and help achieve other related resource benefits (increased humpback chub recruitment, enhanced camping beaches, protection of cultural resource, minimized hydropower impacts, etc). At this time, it is not anticipated that a single high-flow release can answer all such relevant questions: accordingly, it is very likely that additional high-flow experiments will be needed to address the major uncertainties associated with the use such releases as an effective long-term management tool. For example, additional experiments will likely be needed to further define environmental conditions that affect or contribute to the maintenance of humpback chub habitat and other important ecosystem components, particularly beaches, backwaters, and other nearshore habitat.[4]

Additional experiments will be needed partly because high-flow releases are believed to build sandbars with less efficiency than historical floods, owing to the shorter duration and smaller volume of experimental releases compared to predam floods, as well as the significant loss of upstream sand supplies in the postdam era. And, ROD-based intervening flows export sand from the system. The rate of those exports depends on the volume of flow and the magnitude of daily fluctuations from Glen Canyon Dam. As a management strategy, it is believed that the frequency of high-flow releases would need to be frequent enough so that more sand can accumulate than is being eroded by intervening flows. In addition, sand supplies are greatly reduced over what was available historically, and sand is replenished only from tributary floods that occur on irregular intervals.

Replication is also needed to provide sufficient observations of high flow results under the range of natural conditions that are most likely to occur in the future. It is believed that in addition to future high flow tests, by developing and calibrating additional sediment transport and deposition models, scientists will be better able to interpolate between observed effects and help rule out scenarios that are unlikely to yield positive, sustainable results. Some of the data needed to develop a model could be obtained through laboratory studies or field studies conducted during normal flow conditions. Data from the anticipated 2008 high-flow test would also be very important for the development of additional predictive models. Such an approach would likely reduce the overall research costs and help minimize impacts to hydropower.

It is expected that a long-term experimental strategy, including the number and future frequency of high-flow experiments, will be determined through the Glen Canyon Dam Adaptive Management Program.

[4] Further information regarding the approach and basis for the proposed experiment can be found in the Biological Assessment prepared for the proposed action by the Bureau of Reclamation (December 2007).

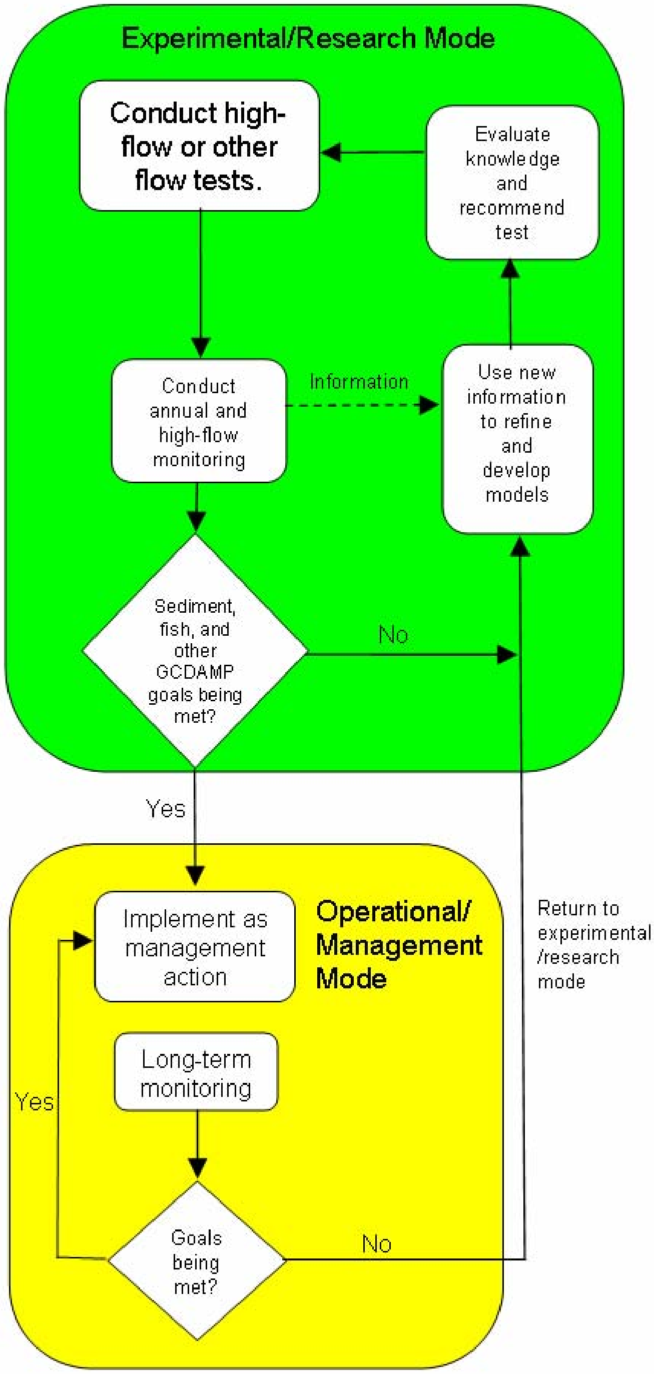


Figure 4. Flow chart showing how field data and modeling information are fed into the adaptive management process and used to improve management of resources downstream from Glen Canyon Dam. Experimental operations must be evaluated over a timeframe sufficient to take into account of natural variability (e.g., decadal scale). (GCDAMP=Glen Canyon Dam Adaptive Management Program)

Part 2: Experimental Study Descriptions

Experimental Study 1.A: Reach-scale changes in the fine-sediment mass balance and grain size during a future high flow

Duration

20 months

Principal Investigators

David Topping, U.S. Geological Survey, Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center and David M. Rubin, U.S. Geological Survey, Geologic Division, Western Coastal and Marine Geology

Geographic Scope

River miles 0 through 226

Abstract

The study intends specifically to answer the following two questions: How would conditions of suspended sediment concentration and grain size evolve and vary through time and by reach below Glen Canyon Dam during a March 2008 replication of the 2004 high-flow hydrograph under more highly enriched sand supply conditions, and how would these data compare with similar data collected at similar locations during the 1996 and 2004 high-flow experiments? Would the net mass balance of sand following the 2008 high flow be positive, negative, or neutral? To answer these questions, a series of continuous measurements of suspended sediment concentration and grain size shall be collected before, during, and after the high flow at seven fixed measurement sites throughout the Colorado River ecosystem (between river miles 30 to 226). Simultaneously, two river trips shall collect the same type of data between fixed measurement points from boats whose downstream movement will be timed such that two separate packets of river water and suspended sediment will be repeatedly monitored for changes in suspended sand concentration and grain size. Fixed location and moving location data shall then be compared to sandbar data from experimental study1.C—a study focused mainly on documenting changes in channel storage of sand and eddy sandbars.

Study Goals

This study documents the following: (1) reach-based sediment budgeting during a future high flow, (2) longitudinal patterns of net erosion and deposition of sand, and (3) temporal and spatial changes in sediment grain size related to enrichment and depletion of sediment during a future high flow.

Need for Study

Detailed measurements of sediment flux and grain size are required to evaluate whether a future high flow conducted under sand-enriched conditions can be used to maintain eddy sandbars in the Colorado River ecosystem. These data are also required for continued development and verification of predictive physically based sediment-transport models.

Strategic Science Question

> **SSQ 4.1**—Is there a "flow-only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs [high-flow experiments], without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal time scales?

High flow Science Question

How would conditions of suspended sediment concentration and grain size evolve and vary through time and by reach below Glen Canyon Dam during a March 2008 replication of the 2004 high-flow hydrograph under more highly enriched sand supply conditions; and how do these data compare with similar data collected at similar locations during the 1996 and 2004 high-flow experiments? Is the net mass balance of sand following the 2008 high flow positive, negative, or neutral?

Working Hypotheses

Future high-flow experimentation conducted under magnitudes and longitudinal distributions of sand enrichment similar to those that existed before the 2004 high flow will result in sandbar building comparable to that observed during the 2004 high flow. If this is the case, the sand budget computed under this study will be positive between river miles 0 and 30 for the period bracketing the tributary inputs of sand and a future high flow. If reaches downstream from river mile 30 are sand enriched relative to their condition before the 2004 high flow, then sandbar building in these downstream reaches will be greater than was observed in these reaches during the 2004 high flow.

Methods

Hydrodynamic, sediment transport, grain size, temperature, conductivity, and turbidity data are to be collected at five locations (Lees Ferry gaging station, river mile 30, river mile 61, Grand Canyon gaging station, and above Diamond Creek gaging station) and on two Lagrangian river trips (tracking the water between river miles 0 and 226). Suspended-sediment data are collected using both conventional and laser-acoustic methodologies. Stage, discharge, and water quality data are to be collected using standard USGS methodologies. Similar work conducted during the 1996 and 2004 high-flow experiments and 2000 low summer steady flow experiment is described in Konieczki and others (1997), Rubin and others (1998, 2002), Topping and others (1999, 2000a, 2000b, 2006a, 2006b), Rubin and Topping (2001), and Hazel and others (2006). Analyses as described in Rubin and others (1998) and Topping and others (1999, 2006b) of sediment-transport and sand-grain-size data, and analyses of reach-based sand budgets will be used to evaluate the results of a future high flow relative to the high-flow experiments conducted in 1996 and

2004. If the working hypotheses are supported by these analyses, then rebuilding and maintenance of sandbars might be possible through a future high flow conducted under sand-enriched conditions. If the working hypotheses are rejected by these analyses, then flow and nonflow strategies in addition to high-flow experiments may be needed to restore and maintain sandbars in the Colorado River ecosystem (i.e., further constraint of operations, sediment augmentation, or a combination of both).

Relation to Existing Work and Other Studies

This study builds on the large quantity of previous published work on sediment transport, erosion, and deposition in the Colorado River ecosystem downstream from Glen Canyon Dam. It is also linked to several high flow-related physical, sociocultural, and biological studies, including experimental studies 1.B (Studies of eddy-sandbar hydrodynamics, sediment transport, and bathymetry during a future high flow), 1.C (Response of sandbars and selected cultural sites to a future high flow conducted under sediment-enriched conditions), 2 (Evaluation of the effect of a future high flow on riparian plant community development at multiple surface elevations and depositional environments), and 3 (evaluation of high-flow effects on lower trophic levels in the CRE). Work conducted under this study will also be used by the USGS's Lew Coggins, Scott Wright, and Nick Voichick for a study relating fish-catch rates to suspended-sediment concentration and grain size.

Information Needs Addressed

The study will directly address multiple information needs as follows:

> **EIN 8.1.1** How do fine sediment abundance, grain size, and distribution in the main channel below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?
>
> **EIN 8.3.1** How does fine sediment abundance, grain size, and distribution, within eddies below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?
>
> **RIN 8.5.2** What is the reach-scale variability of fine-sediment storage throughout the main channel?
>
> **RIN 8.1.3**, **RIN 8.2.1, RIN 8.3.1**, **RIN 8.5.6** What fine sediment abundance and distribution, by reach, is desirable to support GCDAMP ecosystem goals? [Note: Definition of "desirable" will be derived from targets for other resources and managers goals.]
>
> **RIN 7.3.1** Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

Products/Reports

Several peer-reviewed journal article(s) and/or USGS report(s) will be produced based on the findings of a future high flow within 12–24 months of the next high flow.

Budget Summary

FUNDING PROPOSAL		
Experimental study 1.A: Reach scale changes in the fine-sediment mass balance and grain size during a future high flow (Sand Budgeting)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	35,600	46,500
GCMRC Study Related Travel/Training (19.1% burden)	11,000	5,000
GCMRC Operations/Supplies/Publishing (19.1% burden)	8,100	15,000
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	7,000	0
AMP Logistical Support (19.1% burden)	99,225	0
Outside GCMRC & Contract Science Labor (In this project, sub-allocated - no additional burden charged)	121,550	14,900
Cooperative/Interagency Agreements (6.09% burden)	0	0
Study Sub-Total	**$282,475**	**$81,400**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	30,737	12,702
Study Total (including burden)	**$313,212**	**$94,102**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	61%	18%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 1B: Studies of eddy-sandbar hydrodynamics, sediment transport, and bathymetry during a future high flow

Duration

20 months

Principal Investigators

Scott Wright, U.S. Geological Survey, Water Resources Division, California Water Science Center; Mark Schmeeckle, Arizona State University; and Matt Kaplinski, Northern Arizona University

Geographic Scope

Middle Marble Canyon around Eminence (river mile 45)

Abstract

The study intends specifically to answer the following question: What is the minimum duration for high-flow experiments needed to build and maintain sandbars under sand-enriched conditions? To answer this question a series of high-resolution measurements of eddy sandbar depositional rates will be made within a subset of six to eight study sites throughout Marble Canyon and the eddy bar responses will be evaluated during the proposed 60-hour duration of the hydrograph. The variability in depositional rates between sites will be evaluated and the total sandbar responses will be compared to the duration of the test to determine whether or not the duration of the flow test was appropriate relative to sandbar deposition and evolution. These measurements, along with those made for studies 1.A, 1.C, and 1.D, may also be used to support ongoing and future sediment model research; particularly those focused on improvement of multi-dimensional, large-eddy simulations and their verification.

Study Goal

The goal of this study is to improve our understanding of the time evolution of eddy sandbars during a future high flow. Knowledge of the rate of deposition or erosion of eddy sandbars during a future high flow will assist in the determination of the optimal high-flow hydrograph shape for a given sand-supply condition to achieve sandbar resource management goals, while minimizing negative impacts to other resources (e.g., hydropower).

Need for Study

The development of predictive capabilities for the evolution of eddy sandbars, a primary recommendation of the August 2006 sediment protocol evaluation panel (Wohl and others, 2006), has been limited by a lack of information on hydrodynamics, sediment transport, and bathymetry during a high flow. The lack of predictive capability has in turn limited our ability to provide definitive recommendations related to experimental high-flow peak discharge and duration. The existing eddy model (Wiele and others, 1996; Wiele, 1998) has been tested only with before and after bathymetry downstream from the Little Colorado River following floods in 1993. Also, initial investigations of eddy hydrodynamics and sediment transport during the November 2004 high flow indicated that some of the assumptions in the existing model are not supported by the data (Wright and Gartner, 2006). Thus, detailed data are needed on eddy hydrodynamics and morphology during a future high flow, if we are to improve our predictive capabilities and thus improve our ability to identify future high-flow characteristics that can most effectively rebuild and maintain available sand resources and related habitats.

Strategic Science Questions

> **SSQ 4.1-1—**Is there a "flow-only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs [high-flow experiments], without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal time scales?
>
> **SSQ 4.1-1a—**What are the short-term responses of sandbars to BHBFs [high-flow experiments]?
>
> **SSQ 4.1-1b—**What is the rate of change in eddy storage (erosion) during time intervals between BHBFs [high-flow experiments]?
>
> **SSQ 4.1-1c—**What are the effects of ramping rates on sediment transport and sandbar stability?

High Flow Science Question

What is the minimum duration needed for high-flow experiments to build and maintain sandbars under sand-enriched conditions?

Working Hypotheses

Sand deposition rates in eddies during a future high flow are regulated by (1) the interaction of the flow field with the antecedent bed topography and (2) the upstream sand supply. At a given location for a given high-flow hydrograph, an eddy sandbar will grow over time if the upstream sand supply is sufficiently large; conversely, if the upstream sand supply is insufficient, an eddy sandbar will erode over time.

Methods

This study collects hydrodynamic, sediment transport, bathymetric, and load-cell data at several eddy sandbars in middle Marble Canyon in order to improve our understanding of eddy-sandbar hydrodynamics and evolution during a future high flow.

We will use two separate methods to collect information on (1) the detailed temporal evolution of eddy sandbars at a sparse spatial resolution and (2) the detailed spatial structure of hydrodynamics, sediment transport, and bathymetry at a sparse temporal scale. Ideally, sites throughout Marble and Grand Canyons would be studied during a single high flow, but this is not logistically feasible. As a compromise, sites in middle Marble Canyon will be studied because results from the November 2004 high flow indicate that eddies in this reach may provide varied responses, and several eddy sandbars close to each other have been studied previously by the Integrated Fine-Sediment Team (FIST) and through long-term sandbar monitoring conducted by Northern Arizona University.

The detailed temporal evolution of eddy sandbars at a sparse spatial resolution will be measured by deploying an array of load sensors in three eddy sandbars in the reach around river mile 45 (Eminence). The load sensors proposed for use here were used successfully for this purpose in Grand Canyon during the 1996 high flow (Carpenter, 1996) and for monitoring the infilling of spawning gravels with fine sediment (see http://www.rickly.com/ss/scoursensor.htm for a product description). The study team proposes to bury three to four load sensors within each eddy sandbar at different elevations to capture deposition or erosion that occurs during the rising limb, peak, and falling limb of the experimental high-flow hydrograph.

The detailed spatial structure of hydrodynamics, sediment transport, and bathymetry at a sparse temporal scale will be measured with a sonar system and an acoustic doppler current profiler (ADCP) using automated shore-based boat position tracking. The study area is within a FIST study reach, so the survey control is already established. The team will map the eddy sandbars where the load sensors are deployed as frequently as possible under the logistical constraints. At minimum, we plan to obtain a map of each eddy sandbar before a future high flow, during the rising limb, on the peak, during the falling limb, and after a future high flow. The ability to get multiple maps during a given segment will depend on the timing of the next experimental high flow (i.e., mapping will only be possible during daylight hours) and the peak duration. Each survey will result in a bathymetric map of the eddy sandbar and a map of the time-averaged three-dimensional velocity structure of the eddy. Additionally, the team will collect sediment samples and attempt to calibrate the acoustic backscatter from the ADCP to suspended-sand concentration (we have had success with this in the past; see Topping and others, 2006b). If successful, we will further develop maps of time-averaged suspended-sand concentration within each eddy for each survey, which, when combined with the velocity maps, will allow us to generate maps of the time-averaged flux of suspended-sand within the eddy.

Relation to Existing Work and Other Studies

This study is linked closely to previous and ongoing work related to numerical modeling eddy-sandbar morphology. The data acquired through this initiative have the potential to significantly enhance ongoing and potential future developments of numerical models of eddy-sandbar responses to high-flow releases from the dam. The study is also linked to several other experimental high flow-related physical, sociocultural, and biological studies by providing sediment-transport data, eddy-sandbar bathymetry, and eddy-sandbar hydrodynamics and morphology, including experimental study 1.A (Reach-scale changes in the fine-sediment mass balance and grain size during a future high flow), experimental study 1.C (Response of sandbars and selected cultural sites to a future high flow conducted under sediment-enriched conditions), experimental study 2 (Evaluate effect of a future high flow on riparian plant community development at multiple surface elevations and depositional environments), and experimental study 3 (evaluation of the effects of high flow on lower trophic levels in the Colorado River ecosystem).

Information Needs Addressed

The study will directly address several experimental and research information needs, as follows:

EIN 8.3.1 How does fine sediment abundance, grain size, and distribution within eddies below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 8.4.1 How does fine sediment abundance, grain size, and distribution within eddies between 5,000 to 25,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

RIN 8.5.1 What elements of Record of Decision operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine-sediment inputs, and stabilizing sediment deposits above the 25,000 cfs stage?

RIN 7.3.1 Develop simulation models for Lake Powell and the Colorado River to predict water quality conditions under various operating scenarios, supplant monitoring efforts, and elucidate understanding of the effects of dam operations, climate, and basin hydrology on Colorado River water quality.

Products/Reports

One or more peer-reviewed journal article(s) or USGS report(s) will be produced during a 12- to 24-month period following a future high flow on findings from this study.

Budget Summary

FUNDING PROPOSAL		
Experimental study 1B: Studies of eddy-sandbar hydrodynamics, sediment transport, and bathymetry during a future high flow (Sandbar Deposition Rates)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Study Related Travel/Training (19.1% burden)	1,000	2,000
GCMRC Operations/Supplies/Publishing (19.1% burden)	11,000	2,000
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	0	0
AMP Logistical Support (19.1% burden)	19,325	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	62,672	82,210
Study Sub-Total	**$93,997**	**$86,210**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	9,800	5,847
Study Total (including burden)	**$103,797**	**$92,057**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	77%	95%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 1.C: Response of sandbars and selected cultural sites to a future high flow

Duration

20 months

Principal Investigators

Jack Schmidt, Utah State University, and Amy Draut, U.S. Geological Survey, Geologic Division, Western Coastal and Marine Geology

Cooperating scientists: Joe Hazel, Matt Kaplinski, and Rod Parnell, Northern Arizona University, Department of Geology; David Topping and Helen Fairley, U.S. Geological Survey Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center; and David Rubin, U.S. Geological Survey, Geologic Division, Western Coastal and Marine Geology.

Geographic Scope

Numerous fan-eddy complexes, with associated campsites, and selected cultural sites between river miles 0 and 226.

Abstract

This study intends to answer the following interrelated questions concerning the effects of high flow sediment transport on sandbars and associated resources: (1) Following a high flow, how do Record of Decision (ROD) operations under 8.23 million acre-feet annual release volumes affect the persistence of sandbars compared to non-ROD operations that followed the 2004 high flow? (2) Can the next high flow increase campable areas at sandbars on a more sustainable basis than occurred in conjunction with the 1996 and 2004 high-flow experiments? and (3) Do sandbars deposited by high-flow experiments contribute to preservation of archaeological sites in the river corridor? To answer these questions, a series of sandbars shall be surveyed at 46 long-term study sites and assessed with respect to changes in sandbar topography, area, volume, and net camping area before and after the high flow. Rates of aeolian sand transport and gully incision at selected cultural sites will also be quantified before and after the high flow to evaluate the effects of measured sandbar changes on physical processes affecting cultural sites.

Study Goal

The principal goal of this study is to determine whether a future high flow conducted under sediment-enriched conditions can be used to rebuild/maintain eddy sandbars and associated campsites in the Colorado River ecosystem. This goal is to be achieved during a future high flow through (1) evaluation of whether sandbars throughout the Colorado River ecosystem gain or lose sand above and below the stage associated with a discharge of 8,000 cfs and (2) comparison of the topographic response of sandbars with those observed during two previous high-flow experiments conducted in 1996 and 2004. Secondary objectives of this study include further evaluation of whether (1) sediment deposited in arroyo mouths can offset/reduce gully erosion (Yeatts, 1996) and (2) enlarged sandbars produced during the next high flow result in increased aeolian transport of sand upslope into archaeological sites, thereby offsetting/reducing wind deflation and rill erosion of sediment in and around these sites (Draut and Rubin, 2006).

Strategic Science Questions

In 2007, the Grand Canyon Monitoring and Research Center produced, and the Adaptive Management Working Group subsequently approved, a FY 2007–FY 2011 Strategic Science Plan and an associated Monitoring and Research Plan (MRP) that identified a series of strategic science questions (SSQs).

> **SSQ 4.1**Is there a "flow-only" operation (i.e., a strategy for dam releases, including managing tributary inputs with BHBFs [high-flow experiments], without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal time scales?
>
> > **4.1a**What are the short-term responses of sandbars to BHBFs [high-flow experiments]?
> >
> > **4.1b**What is the rate of change in eddy storage (erosion) during time intervals between BHBFs [high-flow experiments]?
>
> **SSQ 2.1** Do dam-controlled flows increase or decrease rates of erosion at archaeological sites and TCP sites, and if so, how?
>
> **SSQ 2.3** If flows contribute to archaeological site and TCP erosion, what are the optimal flows for minimizing impacts to these cultural resources?
>
> **SSQ 2.4** How effective are various treatments in slowing rates of erosion at archaeological sites over the long term?
>
> **SSQ 3.9** How do varying flows positively or negatively affect campsite attributes that are important to the visitor experience?

High Flow Science Questions

High flow science questions were subsequently identified as a means of bridging the research and monitoring work that will be conducted in conjunction with a future experimental high-flow test with the strategic questions previously identified in the 5-year science plans. For study 1.C, the underlying strategic science questions and associated high flow science questions are as follows:

> Following a high flow, how do ROD operations under 8.23-maf annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?
>
> Do sandbars deposited by high-flow experiments contribute to preservation of archaeological sites in the river corridor?
>
> Do high-flow experiments contribute to added stability or erosion of archaeological sites located in close proximity to the river?

Can the next high flow increase campable areas at sandbars on a more sustainable basis than occurred in conjunction with the 1996 and 2004 high-flow experiments?

Need for Study

This study is required to document whether a high flow conducted under sediment-enriched conditions can be used to rebuild/maintain eddy sandbars and associated campsites and add sand to archaeological sites in the Colorado River ecosystem, thereby contributing to the sustainability of these valued resources, in keeping with the intent of the Grand Canyon Protection Act and the stated goals of the Glen Canyon Dam Adaptive Management Program.

Working Hypotheses

A future high flow conducted under magnitudes and longitudinal distributions of sand enrichment similar to those before the 2004 high flow will result in sandbar rebuilding and low-elevation gully infilling comparable to that observed during the 2004 high flow. If reaches downstream from river mile 30 are sand enriched relative to their condition before the 2004 high flow, then sandbar building and gully infilling in these downstream reaches will be greater than was observed in these reaches during the 2004 high flow. In addition, if the sandbars produced during a future high flow are (1) larger during the subsequent spring windy season than in the spring windy season preceding the next high flow and (2) dry during the spring windy season following the next high flow, then the aeolian flux of sand derived from these sandbars will be greater than it was before this test (as observed by Draut and Rubin, 2006).

Methods

This study will collect and analyze topographic, bathymetric, sedimentologic (grain-size), campable area, meteorological, geomorphic, and aeolian sand-transport data at fan-eddy complexes and selected cultural sites. Analyses similar to those described in Rubin and others (1998), Hazel and others (1999, 2006), Schmidt and others (1999b), Topping and others (1999, 2006a), and Draut and Rubin (2005, 2006, 2007) of sandbar topographic response, sandbar stratigraphy, grain-size data, aeolian sand-transport data, and aeolian topographic response at cultural sites will be used to evaluate the results of a future high flow relative to the two previous high-flow experiments conducted in 1996 and 2004.

If the working hypotheses are supported by these analyses, then rebuilding and maintenance of sandbars might be possible through release of additional high-flow experiments that are also implemented under sand-enriched conditions. Furthermore, if the working hypothesis specific to the aeolian sand-transport component of this study is supported by these analyses, preservation of certain archaeological sites might be increased through a strategy of repeated high-flow experiments in the future under sand-enriched conditions. If the working hypotheses are rejected by these analyses, then additional flow and nonflow treatments (i.e., further constraints on dam operations, sediment augmentation, or a combination of both) in association with any future high-flow experimentation may be needed to rebuild and maintain sandbars throughout the Colorado River ecosystem.

Geomorphic mapping, scour-chain installation, and associated interpretive work will be conducted using established methods by scientists from Utah State University (Schmidt and others, 1999). Topographic and multibeam bathymetric surveys will be collected before and after a future high flow using established methods by scientists from Northern Arizona University (Hazel and others, 1999, 2000, in review; Kaplinski and others, 2000, 2007, in review). These data will be collected at numerous fan-eddy complexes located throughout Marble and Grand Canyons and at selected cultural sites. Analog cameras will be used at 29 selected sandbars and cultural sites to document the topographic evolution by fluvial and aeolian processes of these sites during and after a future high flow. River-based arroyos associated with selected cultural sites will also be surveyed as part of this study (see table 3 for locations of various study components).

Previous work has shown that the grain size of the underwater part of eddy-sandbar surfaces is the most important regulator of sand transport in the Colorado River over multiyear timescales (Topping and others, 2005) and that the coarsening of the channel bed and sandbar surfaces reduces the subsequent export of sand from the system (Rubin and others, 1998; Topping and others, 2007). Grain size on the riverbed and on sandbar surfaces will be studied using an underwater microscope (Chezar and Rubin, 2004; Rubin and others, 2006, 2007) and digital image processing (Rubin, 2004). Grain size in flood deposits on sandbars will be measured by sampling vertical profiles (Rubin and others, 1998) and using standard lab analyses. Sedimentary structures in flood deposits will be examined by installation and excavation of scour chains, by trenching, and by inspection of natural cut banks.

Weather instrument stations will measure wind, rainfall, and aeolian sand transport at the targeted cultural sites listed below. Weather monitoring instruments have already been deployed (during February and March 2007) at most of the proposed study sites, in conjunction with the previously funded Cultural Monitoring Research and Development Project. For the possible 2008 high-flow experiment, additional instruments will be deployed at Malgosa, lower Palisades, and in the vicinity of Basalt Canyon. The aeolian monitoring component of study 1.C will build on the findings of Draut and Rubin's 2003–06 study on the role of aeolian sediment in the preservation of cultural sites (Draut and others, 2005; Draut and Rubin, 2005, 2006, 2007), specifically, the finding from the 2004 experiment that high-flow releases in the CRE can increase wind-blown transport of sand toward some of the aeolian deposits that contain archaeological material, thereby increasing their preservation potential.

Table 3. Locations of various study components for experimental study 1.C (All river miles are generalized to protect the confidentiality of archaeological site locations).

Day on river trip	Sandbar topography, campsite area, scour chains	Bathymetry, underwater microscope	Aeolian sand transport work	Surveys of arroyos at selected cultural sites	Cameras
0	-6R				-9 Mile
1	1R, 3L, 8L, 16L	3L, 16L			2.6R, 8.2R
2	22R, 24L, 29L, 30R	22R, 30R	24		16.7R,22.0L, 24.5L
3	32R, 33L, 35L	32R, 35L			30.8L
4	41R, 43L, 44L	41R, 43L, 44L			41.3L,44.5R
5	45L, 47R, 50R, 51L	45L, 47R, 51L			47.6R, 50.1L
6	55R, 56R, 62R, 63L	55R, 63L	58, 60		55.9L, ~58L
7	65R, 68R	65R, 68R	66, 70	66L	66R
8				72R	70L, 72L
9	81L, 84R, 87L, 88R				81.7R,87.6R
10	91R, 93L, 104R				
10	119R, 122R, 123R	122R			104.4L, 119.3L, 123.2R
11	137L, 139R, 145L	139R	135		137.7R, 145.8R
12	166L, 172L, 183R	172L			172.6R, 183.3L
13	194L, 202R	194L			194.6L, 202.3L
14	213L, 220R, 225R	225R	203, 223		213.3R, 225.5L
15	46 sites	22 sites			29 camera sites

Relation to Existing Work and Other Studies

This integrated sediment study builds on the large quantity of previous published work on sediment erosion and deposition in the Colorado River ecosystem downstream from Glen Canyon Dam. Study 1.C is a integral part of study 1, which is focused on sediment responses from a high flow, and as such, it is closely linked to the other proposed experimental studies that are part of study 1, including experimental study 1.A (reach-scale changes in the fine-sediment mass balance and grain size during a future high flow), experimental study 1.B (studies of eddy-sandbar hydrodynamics, sediment transport, and bathymetry during a future high flow), and experimental study 1.D (formation and persistence of backwaters following a high flow). In addition, the data collected by study 1.C will be directly relevant to the interpretation of experimental study 2 (evaluation of the effect of a future high flow on riparian plant community development at multiple surface elevations and depositional environments) and experimental study 3 (evaluation of the effects of a high flow on lower trophic levels in the Colorado River ecosystem). Bed sediment grain-size data collected as part of this study will be used to help interpret shifts through time in the sediment rating-curve data collected as part of experimental studies 1.A and 1.B. Similarly, grain-size grading of flood deposits will be compared to temporal changes in suspended-sediment grain size observed during high flows (components of experimental studies 1.A and 1.B). Subsequent evolution of the backwaters will be determined through surveying as part of this study will be evaluated in the spring and fall of 2008, in conjunction with backwater seining trips identified under study 1.D.

The science activities described in this study explicitly integrate several important cultural concerns in recognition of the close interrelationship between physical and biological processes and cultural resource condition outcomes. Specifically, in addition to evaluating high-elevation sand storage resulting from a high flow, the proposed science activities in study 1.C are designed to evaluate (1) the size and distribution of sandbars and open sand areas used as camping sites, and their persistence over time, (2) the potential effect of a future high flow on sediment transport and deposition at archaeological sites and consequent effects on site stability or erosion, and (3) formation and persistence of backwaters associated with eddy-sandbar complexes that may be important habitats for native fish.

The proposed 1.C study activities build upon monitoring data that are already being collected to assess the rate and extent of changes occurring to the ecosystem under ROD operations. Data from focused science activities proposed as part of this experimental study would be analyzed in relation to these previously collected monitoring data. For example, the GCMRC collects data annually on the area, volume, and extent of sandbars and associated campable area at selected sandbar sites distributed throughout the Colorado River ecosystem; additional survey data and documentation collected in conjunction with a future high flow will build on these previous studies and utilize the previous results (as well as future monitoring data) in evaluating how campable area changed in response to a high flow conducted under enriched sediment conditions, compared to results measured in 1996–97 and 2004–05. Likewise, in conjunction with developing an ecosystem-based approach to monitoring archaeological site condition, the GCMRC has established weather monitoring stations at several locations and is collecting aeolian transport and gully erosion data at a sample of archaeological sites within the Colorado River ecosystem. Extension of the aeolian/archaeological site study supplements ongoing weather monitoring, aeolian transport, and gully-erosion monitoring work. It also extends the applications of the study by Draut and others on the role of aeolian sediment in the preservation of archaeological sites. The 2003–06 study collected similar data (Draut and Rubin 2005, 2006, 2007), and therefore will provide valuable comparison data between the 2004 and a future high flow. In addition, this work will contribute to and complement ongoing investigations by Joel Pederson and Gary O’Brien from Utah State University on geomorphic processes affecting gully incision in Colorado River sediment deposits.

Information Needs Addressed

The study will address various information needs and research information needs, as follows:

> **EIN 8.3.1** How does fine sediment abundance, grain size, and distribution, within eddies below 5,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 8.4.1 How does fine sediment abundance, grain size, and distribution, within eddies between 5,000 to 25,000 cfs change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 8.5.1 How does fine sediment abundance, grain size, and distribution on shorelines between 25,000 cfs and the uppermost effects of maximum dam releases change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 9.3.1 How do the size, quality, and distribution of camping beaches change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 11.1.1 Determine the effects of experimental flows on historic properties.

RIN 8.5.1 What elements of Record of Decision operations (upramp, downramp, maximum and minimum flow, MLFF, HMF, and BHBF) are most/least critical to conserving new fine-sediment inputs and stabilizing sediment deposits above the 25,000 cfs stage?

RIN 8.5.4 What is the significance of aeolian processes in terrestrial sandbar reworking?

RIN 11.1.1a What and where are the geomorphic processes that link loss of site integrity with dam operations as opposed to dam existence or natural processes?

RIN 11.1.5 What are appropriate strategies to preserve resource integrity?

Products/Reports

Several peer-reviewed journal article(s) and/or USGS report(s) will be produced based on the findings of this study within 12 to 24 months of a future high flow.

Budget Summary

FUNDING PROPOSAL		
Experimental study 1.C: Responses of sandbars and selected cultural sites to a future high flow (Sandbar Fate: Topographic and Grain-size Responses)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Study-Related Travel/Training (19.1% burden)	4,800	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	6,600	19,500
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	14,200	0
AMP Logistical Support (19.1% burden)	127,100	0
Outside GCMRC & Contract Science Labor (In this study, suballocated - no additional burden charged)	147,435	80,200
Cooperative/Interagency Agreements (6.09% burden)	259,100	242,200
Study Subtotal	**$559,235**	**$341,900**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	44,945	18,474
Study Total (including burden)	**$604,180**	**$360,374**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	84%	94%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 1.D (pilot study): Monitoring of biological and physical aspects of backwater habitats

Duration

Monitoring sites at specific times through September of year one; data analysis in year two

Principal Investigators

U.S. Geological Survey, Southwest Biological Research Center, Grand Canyon Monitoring and Research Center scientist to be determined

Geographic Scope

Colorado River in Marble and Grand Canyons

Abstract

This study will investigate the creation and persistence of backwater habitats controlled by sandbars. It will also investigate fish use of these backwater habitats in the spring and fall when fish are most likely to be attracted by backwater warming and when they are most likely to be captured. This study will allow for some comparison of different surveying methods by employing different measurement methods and comparing results. This study will conduct measurements of aquatic primary productivity to assess relative productivity of backwater habitats. Temperature measurements and photography of the backwaters will also be conducted in this study. Resultant information will be important for understanding where and when backwaters created by sandbars occur, information which in turn will help increase understanding of where and when such habitats may be available as habitat for native fishes.

Study Goals

The goals of this study are to increase understanding of how backwater habitats respond to flow changes in Grand Canyon (an issue of fluvial geomorphology) and the use of backwater habitats by native and nonnative fishes (a biological issue). This study seeks to develop and initiate an interdisciplinary approach to the study of backwater habitats in Grand Canyon.

Need for Study

The condition of stagnant flow in a return-current channel in the lee of an emergent reattachment bar is called a “backwater” by aquatic ecologists and fisheries biologists, although this term has no relation to the more long-standing term “backwater” used by hydraulic engineers and geomorphologists to describe flow conditions of the mainstem channel upstream from debris fans. Through the rest of this proposal, the term “backwater habitat” is used in reference to the low-velocity feature defined by ecologists. To increase understanding of backwater habitat availability and persistence, this work will study geomorphic processes that create reattachment bar and eddy return-current channel relief, the processes that rework the initial high-flow-created relief, the volume of water that fills the stagnant eddy return-current channel, thermal insolation of the water in the backwater, and how fish use these sites and whether there is a relation between occupation and physical site characteristics.

In the Colorado River in Grand Canyon, lateral separation eddies downstream of debris fans serve as “sinks,” where suspended sediment is deposited during high flows. Smaller embayments caused by the irregularities of talus and bedrock banks also create small areas of stagnant flows that induce sand deposition. High flows are known to increase the amount of sand deposition in return flow eddies (Goeking and others, 2003). Upon flood recession, the reattachment bar becomes emergent and blocks flow into the return-current channel, creating an area of nearly stagnant flow in the formerly active return-current channel.

Although stagnant flow in eddy return-current channels are the largest and most numerous backwater habitats, these features can also form anywhere mainstem flow is blocked, velocities become low, and temperatures have a chance to warm, attracting age-0 fish as nursery and rearing sites. Schmidt and Brim-Box (2004) identified several backwater habitat situations in alluvial parts of the Green River that occasionally occur in Grand Canyon, and the formative geomorphic processes that create these backwater habitats are unrelated to primary eddy return-current channels. Thus, sampling strategies must recognize that different geomorphic processes may lead to different process response models for different types of backwater habitats. Backwater habitats studied as part of this study will be identified by geomorphologic classifications. This study will focus on those backwater habitats created by sandbars.

Backwater habitats have been hypothesized to offer benefits to humpback chub (*Gila cypha*) and other native fishes because of greater food availability and warmer water temperatures relative to mainstem habitats, (Arizona Game and Fish Department 1996). Arizona Game and Fish Department (1996) observed a higher percent of benthic organic matter and higher densities of zooplankton and benthic invertebrates in backwaters relative to adjacent sandy beach facies. Primary and secondary production represent a better measure of food availability than static measures of biomass. Primary or secondary production is a function of biomass and growth rates (i.e., annual production = biomass*growth). Growth rates for both algae and invertebrates are strongly and positively related to water temperature. Water temperatures in backwaters are typically warmer than the mainstem CRE. Therefore, food availability (i.e., annual algae and invertebrate production) may be considerably higher in backwaters relative to mainstem habitats. Converse and others (1998) found higher densities of subadult humpback chub in low-velocity habitats, such as occur in backwaters and in other habitats, although they found the highest densities of subadult humpback chub in association with vegetated shorelines. Protected backwater habitats are a relatively small portion (approximately 5% or less, depending on conditions and flows) of the nearshore habitat in the Colorado River in Marble and Grand Canyons. The relatively shallow, isolated backwater habitats warm more than the mainstem during summer months. When backwaters are warm, they may offer advantages to humpback chub and other native fishes for increased growth because they foster both higher metabolic and growth rates (e.g., Petersen and Paukert, 2005) and greater available food (e.g., Arizona Game and Fish Department, 1996; Rader and others, 2007).

These advantages may be so important to native fishes that these ephemeral habitats (Goeking and others, 2003; Korman and others, 2004) are of high value in spite of their limited distribution and potential to attract nonnative fishes that compete with, and/or prey on, native fishes (but see

Paukert and Petersen, 2007). The relative value of backwaters for native fishes as compared to other habitats is not evaluated with this study, but this study does endeavor to evaluate (1) the construction and persistence of such habitats in response to a high flow, (2) food availability in backwaters relative to other nearshore habitats, and (3) the presence or absence of fish in these habitats.

Review of previous drafts of this study plan by the GCMRC Science Advisors and by the GCDAMP Technical Work Group resulted in recommendations that investigations conducted in association with any high flow should provide information about the physical characteristics of backwater aquatic habitats formed by a high flow, the persistence of those habitats following the high flow under normal MLFF operations, food availability in these habitats relative to other nearshore environments, and the use of these habitats by native and nonnative fishes. In response to these recommendations, increased physical measurements of backwaters before and after the high flow, investigation of the processes that create and rework backwater habitats, and measurements of food availability have been incorporated into this science plan with study 1.D. Integration of this study with study 1.C should provide information regarding the response of backwater habitats to various flow regimes. This study is will serve as a pilot study that will inform the development of a request for proposals for a broader nearshore ecology study that will evaluate food availability and the use and relative importance of a variety of nearshore habitats by native and nonnative fishes.

This study will monitor as many of the backwaters as possible, with the goal of conducting a complete, or nearly complete, census of these habitats in 2008. The census will be conducted in association with sampling for fishes in the spring and fall, bracketing the summer season of higher fluctuating dam releases. We will assess food availability in a subset of backwaters by measuring, among other things, primary and secondary production. This will yield data that are comparable to the primary and secondary production information being collected by the GCMRC's food base research study. These measurements will take 4–5 hours per site, so we will only be able to measure production on a single backwater each day of the river trips. To increase the information available to study processes, a subset of these habitats will also be surveyed immediately before and after the high flow, and also in October. The focus of the more intensely surveyed subset will be backwater habitats downstream of known humpback chub aggregations. Multiple methods will be employed to allow for assessment of the habitats as well as assessment of the methods.

Strategic Science Questions

Strategic science questions are taken from the GCMRC Strategic Plan.

> Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?
> How is invertebrate flux affected by water quality and dam operations?
> How important are backwaters and vegetated shoreline habitats to the overall growth and survival of young-of-year and juvenile native fish? Does the long-term benefit outweigh short-term potential costs?

High Flow Science Questions

High flow science questions are high flow-specific questions that would be addressed with the actions described in this study to help achieve answers to the broader strategic science questions.

> Do high-flow experiments result in creation of backwater habitats that may offer physical benefits to humpback chub and other native fishes? To what extent are backwater habitats created by a high flow used by humpback chub and other native fishes?
>
> What are the effects of high-flow experiments on aquatic food production? How do these effects impact native fishes?
>
> Following a high flow, how do Record of Decision (ROD) operations under 8.23 million acre-feet annual release volumes affect the persistence of sandbars and related backwaters compared to non-ROD operations that followed the 2004 high flow?

Working Hypotheses

Previous work by Goeking and others (2003) found that backwater area increases in response to high-flow releases, a conclusion partially supported by the modeling of Korman and others (2004). This study anticipates verifying that finding. We hypothesize that the spring flow operations will only slightly erode the sandbars that constrain backwaters. We also hypothesize that high summer flows associated with MLFF operations will overtop or erode the sandbars that constrain backwater habitats, decreasing the area and volume of these habitats by the time of the return to lower flows, assumed to begin September 1 under MLFF. Backwater habitats may also begin to fill with sediment, reducing their area and volume. The modeling of Korman and others (2004) provides support for the hypotheses regarding changes in backwater habitats with time and various flows. We hypothesize that algal and invertebrate production in backwaters is higher relative to other nearshore environments. We also hypothesize that small-bodied fishes, native and nonnative, will occupy backwater habitats in the spring and fall. A variety of age classes and species is predicted.

Methods

This study will employ a suite of methods to investigate the creation, maintenance, and use of backwater habitats. Four methods will be used: total station surveying, tape surveying, level surveying, and photography (survey record and repeat/fixed). A summary of their relative strengths and weaknesses is presented in table 3, below.

Table 3. Comparison of physical habitat measurement methods for study 1.D.

Method	Relative data collection rate	Backwater area calculated	Backwater volume calculated	Compare results to other flow regimes?	All backwater sites surveyed?
Total station	Slower	Yes	Yes	Yes	No
Tape/level	Faster	Yes	Some	No	Yes
Survey record photography	Faster	No	No	No	Yes
Repeat/fixed photography	Constant	No	No	Yes	No

By combining these methods, GCMRC and cooperating scientists hope to maximize the amount of information collected and learning achieved in association with the high flow.

Total station measurements are more detailed and automated and allow for calculation of the area and volume of the measured backwater not only at the stage discharge encountered, but also at other discharges. Total station measurements include measurement of the site bathymetry (underwater topography). Total station measurements can be referenced to allow for comparison with similar data taken in previous years. Tape and laser level surveys are simpler measurements, using less automated equipment. Tape and level measurements could easily allow for comparison to other tape and level measurements made within the same year, but may be harder to apply to different years and stage discharges because they are more difficult to reference. One of the functions of the study 1.D multiple method deployments will be to assess how comparable these different habitat measurements are. To allow for geo-referencing of the sites, one control trip will be launched in 2009 to geo-reference those sites that are surveyed with the total station.

For the nonreferenced tape and level measurements, the backwater area is defined by measuring the backwater width and length with a tape at multiple locations. The number of width measurements is dependent on the length of the backwater; generally, widths are taken approximately every meter of length. Backwater volume is defined by measuring backwater depth relative to water surface and adjacent bar crest relative to water surface with a level. These measurements are made at each width-measurement location.

For the referenced total station surveys, a stable reference point is established. On the first survey at each site, two stable elevation reference points are established. These may be a mark etched in a rock or an easily defined tip of a rock. Each reference point must be described in notes and photographed, and surveyed to the best possible precision with available GPS.

Two total station survey crews will be deployed on four study trips in an effort to assess as many of the backwaters as possible. These trips are currently anticipated in: February, March, May, and September. The February and March trips will assess a subset of backwater habitats, emphasizing those locations that are downstream of known humpback chub aggregations (Valdez and Ryel, 1995). The May and September trips will conduct a more complete backwater habitat inventory, emphasizing the tape and laser level method, supported at a subset of the sites with total station surveys. Tape and level measurements will be taken at every backwater encountered, as these can be taken more quickly. Tape and level measurements will also be taken in conjunction with GCMRC/GCDAMP sampling trips currently scheduled for the summer months.

Water temperatures will be taken at all backwater habitats sampled. Water temperatures will also be taken in the mainstem river adjacent to the backwaters. During a trip following the high flow, additional water temperature sensors will be deployed to collect continuous temperature data at the subset of backwaters where food production measurements are made (12–15 backwaters). Continuous temperature data will be critical for estimating annual primary and secondary production. Additional water temperature sensors will also allow us to enhance our current sites by including the measurement of lateral thermal gradients, and water-temperature data collection in other nearshore habitats (i.e., talus slopes, low-angle sandy shorelines, and cobble bars), as well as to expand the overall number of nearshore sites. These data will be used to further develop temperature models, improving the capability of assessing the relative value of backwaters for fishes.

At least one photograph will be taken of each backwater in association with the habitat measurements to augment records of site condition. Repeat photography will be taken at 10 preselected sites. At the repeat sites, fixed cameras will be deployed. These cameras will be programmed to take weekly photos of the sites. This will allow for important visualization of the quantitative results, especially to help assess habitat suitability for fishes. Repeat photography will also assist in visualization of the rate of change at these sites, to be correlated with changes in flows. Because of the difficulty and expense of deploying repeat photography cameras, because they are subject to malfunction and vandalism, and because we are trying to deploy the least amount of equipment possible to minimize impacts to Park visitors, approximately 10 sites will be photographed repeatedly during the year, but not more. The number of sites for repeat photography will be dependent, in part, on equipment availability. Site selection for repeat photography will emphasize backwaters where fishes have been captured in previous years.

Habitat monitoring associated with this study will be conducted shortly before and after the high flow in February and March. Because of the difficulty in collecting fishes and interpreting those data, backwater seining will not be conducted in February and March. The habitat sampling for this study will be conducted in association with seining backwaters for fishes, now to be conducted in both May and September/October, so that assessments of fish use of these habitats is conducted immediately before and after the period of high summer flows.

Food production measurements will be collected during the February, March, May, and September trips. We will assess water column chlorophyll, phytoplankton, and zooplankton concentrations in backwaters on all trips. We will measure benthic organic matter, chlorophyll, and invertebrate biomass and density on all trips. During the March, May, and September trips we will measure water column and benthic primary production using light and dark bottles and chambers. During the March, May, and September trips we will also measure invertebrate growth rates for use in secondary production estimates. We will also determine the principal food items consumed by fishes occupying backwaters by analyzing the gut contents for small numbers of native and nonnative fishes. Collectively, these data will allow us to determine food availability in backwaters and the feeding habits of fishes occupying these habitats. These data will be compared with identical data being collected as part of the food base research study to determine whether food production in backwaters is greater than other nearshore habitats.

Sampling for fishes in backwater habitats has been conducted in September and October since 2002, providing an estimate of the extent of these habitats in the fall, as well as an estimate of fish presence or absence in these habitats. This sampling will be maintained for the foreseeable future. If increased load-following flows are initiated on June 1, this study proposes to also sample backwater habitats for fish in May, in advance of the higher summer flows and fluctuations of the current MLFF schedule, developing important information for temporal comparisons. If higher load-following flows are not implemented until July 1, GCMRC would propose delaying this sampling and habitat assessment until June. Sampling in June increases the survivorship of young native fishes encountered because they have had additional time to grow and increase their resistance to the stress caused by handling. Table 4 provides a summary of the schedule for measurements and samples

Table 4. Summary schedule for measurements and samples for study 1.D.

Method	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.
Total Station		X	X		X				X	
Tape & Level		X	X		X		X	X	X	
Survey Photos		X	X		X				X	
Repeat Photos		X	X	X	X	X	X	X	X	X
Temp.		X	X		X				X	
Seining					X				X	

Links/Relationship to Existing Work and Other Studies

Because studies 1.C and 1.D will be deployed to some of the same sites, sampling sites will be compared in advance to help ensure efficient deployment of personnel and equipment. If measurements are scheduled to be taken at a study 1.C site, that site will be dropped from the data collection list for study 1.D. Study 1.C seeks to evaluate sandbar construction and maintenance, factors that are important for this study. 1.D Data collected from this study are anticipated to be useful in the development of a new GCMRC study to study the ecology of nearshore habitats and their relative value for native fishes, especially humpback chub. Overflight imagery, scheduled to be taken in 2009, will allow for comparison of 2005 and 2002 backwater habitat distribution and abundance.

The food base research study is determining whether food availability limits populations of native and nonnative fishes. Study 3 of this science plan will determine whether a high flow has a negative, neutral, or positive effect on food available to fishes. Study 1.D will complement both of the above studies by providing detailed measurements of food production in backwaters.

In support of ongoing water-temperature-modeling efforts, the GCMRC has been collecting continuous water temperature data at 6 backwater sites distributed throughout the river corridor for the last year and a half. Water temperature sensor strings have been deployed in a manner that allows for the calculation of both vertical and longitudinal thermal gradients over time within these backwater habitats. These data are being utilized in the calibration and testing of nearshore water temperature models and are a critical component of the overall thermal modeling work. Additional water temperature sensors will allow us to enhance our current sites by including the measurement of lateral thermal gradients, water temperature data collection in other nearshore habitats (i.e., talus slopes, low-angle sandy shorelines, and cobble bars), as well as to expand the overall number of nearshore sites.

Information Needs Addressed

RIN 2.1.4. What habitats enhance recruitment of native fish in the LCR and mainstem? What are the physical and biological characteristics of those habitats?
RIN 7.4.4. How does flow rate and fluctuation affect habitat availability and utilization by fish and other organisms?

Products/Reports

After the completion of data collection for this study in October (assuming a March 2008 high flow), data will be analyzed and at least one report will be prepared summarizing the data analysis. Data analysis will be focused on answering the following questions:

- Were backwater habitats created and/or expanded at the monitoring sites following the high flow?
- Where they were created, were they maintained until June 1? Were they maintained until September 1? Were they maintained through the final monitoring trip in October?
- What were the area and volume of the backwater habitats monitored? What were the area/volume ratios at various flows encountered during the year?
- What were the temperatures in these habitats throughout the range of flows encountered during the year?
- How does food production in the habitats compare with other nearshore habitats?
- Were native fishes present in these habitats in the spring and/or the fall?
- Were nonnative fishes present in these habitats in the spring and/or the fall?
- Are there any significant correlations between the fishes present and the physical habitat measurements, such as area, volume, area/volume ratio, and temperature?

This study will inform the development of a request for proposals (RFP) to initiate a 2-year study to investigate the relative value of nearshore habitats for native fishes. The RFP will be subjected to review by the Science Advisors and/or other qualified personnel in advance of release. Once responses to proposals are received, these, too, will be subjected to critical technical review. A cooperator will be selected on the basis of technical merit and productivity record. The selected entity will be responsible for conducting the work in future years and providing annual reports on this activity.

Study Site List

To be completed in advance of the first trip; however, the list is subject to modification depending on sites and conditions encountered.

Budget Summary

FUNDING PROPOSAL		
Experimental study 1.D: Monitor physical and biological aspects of backwater and other nearshore habitats in June (Spring Backwater Monitoring)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	11,351	8,727
GCMRC Study Related Travel/Training (19.1% burden)	7,000	2,000
GCMRC Operations/Supplies/Publishing (19.1% burden)	0	500
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	178,500	65,000
AMP Logistical Support (19.1% burden)	205,680	37,136
Outside GCMRC & Contract Science Labor (19.1% burden)	10,407	0
Cooperative/Interagency Agreements (6.09% burden)	340,880	51,000
Study Subtotal	**$753,818**	**$164,363**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	97,643	26,912
Study Total (including burden)	**$851,461**	**$191,275**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	60%	42%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Relation of Potential 2008 High Flow to Long-Term Sediment Monitoring Activities

This science plan was prepared with science integration as an objective. Despite the fact that this science plan is a stand-alone document intended to describe research tied specifically to a 2008 high flow, the GCMRC has specifically designed the study 1 (experimental studies 1.A–1.D) so that they are also supported by four long-term sediment-monitoring protocols that have been recently approved for implementation below Glen Canyon Dam. These long-term sediment monitoring tasks include (1) continuous measurements of flow and suspended-sediment transport at five locations between mid-Marble Canyon and Diamond Creek (river miles 30, 61, 87, 166 and 226), (2) annual measurements of 45 long-term sandbar study sites through the CRE (above the 8,000 cfs stage elevation), (3) below 8,000 cfs, annual topographic mapping of long segments of the river channel between fixed measurement points listed above in 1 (excepting years when a high flow is implemented), and (4) systemwide, orthorectified, digital overflights of the entire CRE (sand and vegetated areas above the 8,000 cfs stage elevation)—missions that are flows once every 4 years. Together, these monitoring data sets provide key information about topographic changes in the river channel related to changes in sand storage at all elevations, as well as the suspended-sand flux (positive, negative, or neutral) that continually influence those topographic changes through the ecosystem. Topographic data throughout the river channel are critical to understanding the evolution and fate of sandbar habitats, such as backwaters, camping areas, marshes, terrestrial environments for vegetation, benthic organisms, and cultural sites. The sand-transport data provide information about constantly changing water quality conditions (turbidity) that are controlled by suspended sand and finer sediment.

The data that would be collected during a 2008 high flow, in combination with these longer term sediment monitoring data, can provide the information that is required to fully address the strategic science question for sediment. This is possible owing to the fact that the four elements of long-term monitoring directly relate to research measurements that will be made during the test under elements A, C, and D of study 1 (sand transport and net flux, plus detailed topographic measurements of the channel bed and shorelines across the full range of elevations). Evaluation of topographic changes and sand-flux data collected during the test, along with similar measurements repeated annually over several years, allows scientists and managers to evaluate (1) how long rebuilt sandbars persist following the 2008 high flow, and (2) whether or not sandbar increases from high-flow experiments are sustainable. These data will allow constraints to be placed on the frequency of high-flow experiments for a given sand supply. Owing to the fact that topographic measurements are made throughout the channel at all elevations and the data cover entire reaches between fixed sediment-transport measurement points, it is possible to determine the net mass balance of sand throughout long reaches of the CRE.

Experimental Study 2: Evaluate effect of a future high flow on riparian plant community development at multiple surface elevations and depositional environments: Following a disturbance, are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation?

Duration

24 months

Principal Investigator

Barbara Ralston, U.S. Geological Survey, Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

Geographic Scope

Glen Canyon Dam to Diamond Creek

Abstract

Determining the relationship between native and nonnative species richness and site susceptibility is important for long-term resource management. A high flow provides a unique opportunity to compare riparian vegetation composition (i.e., native/nonnative ratios) in established vegetation monitoring sites subject to disturbance with large bare sites made available from sediment reworking. Compositional change data (native vs. nonnative species) and soil samples in established and newly bare depositional environments across multiple surface elevations immediately following a high flow and in subsequent months will be collected to test hypotheses about exotic species establishment and expansion. The study addresses a strategic science question about the effects of high flows on traditional cultural properties, which include riparian plants. Data are incorporated into long-term monitoring of riparian vegetation for the Glen Canyon Dam Adaptive Management Program.

Study Goals

The study goals are to document community compositional changes (native vs. nonnative species) in established and newly bare depositional environments across multiple surface elevations following a future high flow. The study goal addresses a subcomponent of a larger question posed in the knowledge assessment (Melis and others, 2006b): To what extent and in what respects can high-flow experiments (magnitude and frequency) achieve reduction of exotic species?

Need for Study

Riparian areas are highly susceptible to exotic species introductions and expansions (Graf, 1978; Thébaud and Debussche, 1991; Naiman and others, 2005). Furthermore, the successful establishment of an invasive species may be affected by the degree to which a community is developed at a site. Two competing hypotheses exist regarding site susceptibility to invasive species. Darwin (1859), Elton (1958), Moulton and Pimm, (1983), Case (1990), and Case and Bolger (1991) suggest that invasion success decreases as community size and structural complexity increase. Stohlgren and others (1998, 1999) postulate the opposite hypothesis, arguing that species-rich sites, such as riparian zones, are more susceptible to exotic species introductions than upland areas that may have lower species richness. The latter argues for temporarily increased resource availability associated with disturbance, while the former argues that fewer exploitable habitats are available, thus preventing new species introductions (MacArthur and Wilson, 1967; Pimm, 1991).

In human-impacted systems, determining the relationship between native and nonnative species richness and site susceptibility is important for long-term resource management. A high-flow event provides a unique opportunity to compare riparian vegetation community composition (i.e., native/nonnative ratios) in established vegetation sites subject to disturbance with large bare sites made available from sediment reworking during a future high flow. By comparing established and new bare sites at multiple surface elevations, scientists should be able to identify the sites that are most susceptible to nonnative species introductions and expansion. Identification of susceptible sites provides managers the opportunity to focus resources when considering nonnative species control measures following a large disturbance event.

Strategic Science Question

> **SSQ 2.1—**Do dam controlled flows affect rates of erosion and vegetation growth at archaeological sites and TCP sites, and if so, how?

High Flow Science Question

Are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation following a disturbance?

Working Hypotheses

Hypothesis 1: Native/nonnative species richness ratios are the same across all habitats and surface elevations up to 60,000 csf.

Alternative hypothesis: The ratio between native/nonnative richness and cover at sites with established vegetative communities will not change following disturbance because resource availability is limited by the presence of existing species. Bare areas will have ratios of native/nonnative richness and cover values similar to those of established sites. Surface elevation will not have an affect on native/nonnative richness and cover values.

Alternative hypothesis: The ratio between native/nonnative richness and cover at sites with established vegetative communities will shift toward an increase in nonnative richness and cover because of the increased nutrient availability associated with the disturbance caused by a high flow.

Native/nonnative richness and cover ratios will change by surface elevation with nonnative species decreasing with increasing surface elevations in relation to available soil nutrients. Bare areas will favor nonnative species across all surface elevations.

Methods

Plots established by Kearsley (2006) as a part of riparian vegetation monitoring will be used to assess native/nonnative foliar cover. These plots occur at specific river miles (table 5) and include data collected from 2001 to 2005. Reassessment of these locations provides an opportunity to examine native/nonnative cover and richness ratios across years and relative to a large scale disturbance within a year. These plots are also linked to the following surface elevations: 8,000, 15,000, 25,000, 35,000, 45,000, and 60,000 cfs. At each location, surveys of foliar cover of all species found with four 1 m^2 plots located at each surface elevation will be recorded. Many of these sites occur in channel margin locations and will likely experience some disturbance but would be unlikely to be completely bare following a future high flow.

Percent foliar cover will be determined by using 10-cm grids on 1-m frames. Field readers will count the number of cross-sectional grid points that coincide with the presence of a given species. This is more accurate than field crews estimating percent cover visually. All species encountered in a plot will be recorded and those species that have <1% cover will be identified as a trace and assigned a value of 0.01. All sites will be visited before a future high flow as a part of monitoring. Sampling following a future high flow will take place in association with post-flood sandbar monitoring trips, which will occur in midsummer at the height of plant productivity, in the fall in association with regular monitoring, and 1 year following a future high flow.

Bare ground sites: Similarly sized plots will be established in newly identified depositional environments (e.g., sandbars, return current channels). In most cases, these bare ground sites will be the same sites that are identified in experimental study 1.C. Established vegetation plots that are close to sandbar survey beaches will be surveyed. Surface elevations will be determined for these sites, and data collection will follow that of the established vegetation sites.

Soil collection: To determine how soil constituents and grain size affect species composition, soil samples will be collected at each site and analyzed for available nitrogen, total carbon, and particle size. Four soil samples will be taken at each site and at each surface elevation. One sample will be taken from the midpoint of each 1-m^2 plot. The sample will be external to the plots so as not to disturb the plots. Standing litter will be removed before sampling and sample depths will be at least 15 cm. A soil sampler will be used to collect the soil cores. Samples will be combined into a single soil sample for each surface elevation per site. Analysis will be conducted by an external lab, which is to be determined. Samples will be collected before and after a future high flow at the established vegetation plots to determine if soil constituents and grain sized changed as a result of the high flow.

Analysis: Species cover data from each surface elevation will be pooled to determine total cover and richness, as well as richness and cover values for native and nonnative species. Native/nonnative values will be compared using a one-way analysis of variance (ANOVA) F-test. Established and bare ground sites will be compared using Multiple Response Permutation Procedures (MRPP) (McCune and Grace, 2002). MRPP is a nonparametric test for the hypothesis of no difference between two or more groups; in this case, richness and cover would be compared between bare ground and vegetated sites before and after a high flow. Indicator species analysis would also be used to describe which species might distinguish each group, if differences exist, and, more importantly, identify which species in bare plots may be more successful as invaders. Stepwise regression will be used with soil data to determine the effect of soil constituents and particle size on native/nonnative cover and richness values. Comparisons using MRPP will also be made between sites located above and below the LCR to see how distance may affect compositional differences.

Table 5. Established vegetation sites and corresponding experimental study 1.C sandbar sites by river mile (R=river right and L=river left)

Established vegetation sites	Corresponding study 1.C sandbar sites by river mile
002.7L	3L
008.1L	8L
035.1L	35L
037.7R	35L
041.2R	41R
043.9L	43L
047.0L	47R
053.2R	56R
056.1R	56R
062.0L	62R
065.4R	65R
068.2R	68R
119.9L	119R
121.1R	122R
122.8L	123R
132.8L	137L
139.1R	139R
143.5R	145L
171.5L	172L
182.7L	183R
193.3R	194L
202.3L	202R
220.1R	220R

Links/Relationships to Existing Work and Other Studies

This study augments general riparian vegetation monitoring because it incorporates existing monitoring locations into data collection efforts. By using surface elevations as site location criteria, the study also links species richness and cover to operational effects on riparian vegetation across surface elevations. In terms of integrating research across resources, this study will produce data that supports experimental study 1.C (Response of sandbars and selected culture sites to future high-flow experiments) by sampling reworked and bare sandbars and return current channel substrates, collecting and analyzing soil samples for grain-size information, and identifying plant species components in marsh and riparian habitats. The locations for sampling are associated with those sites designated for research associated with sandbar topography, campsite area, and scour chains (experimental study 1.C). This study will also help to answer a cultural research information need 11.2.3 (Determine acceptable methods to preserve or treat traditionally important resources within the Colorado River ecosystem) by providing data relevant for improving our understanding of how high-flow experiments may affect culturally important native plant species composition and distributions relative to invasive nonnative species.

Information Needs Addressed

This study directly addresses and experimental information need for M.O. 6.5 associated with riparian vegetation.

> **EIN 6.5.1** How does the abundance and distribution of nonnative species change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Budget Summary

FUNDING PROPOSAL		
Experimental Study 2: Evaluate effect of future high-flow experiments on riparian plant community development at multiple surface elevations and depositional environments: are open patches more susceptible to exotic species colonization and establishment than sites with existing vegetation following a disturbance? (Riparian Vegetation Studies)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Study Related Travel/Training (19.1% burden)	3,000	3,000
GCMRC Operations/Supplies/Publishing (19.1% burden)	3,036	500
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	0	0
AMP Logistical Support (19.1% burden)	15,750	7,875
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	15,800	16,000
Study Sub-Total	**$37,586**	**$27,375**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	5,123	3,363
Study Total (including burden)	**$42,709**	**$30,738**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	63%	73%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 3: Effects of high flow on lower trophic levels in the Colorado River ecosystem

Duration

19 months

Principal Investigators

Theodore Kennedy, U.S. Geological Survey, Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center; Wyatt Cross and Robert Hall, University of Wyoming; and Emma Rosi-Marshall, Loyola University

Geographic Scope

Glen Canyon, the confluence of the Little Colorado River, and Diamond Creek (river miles -15 to 226)

Abstract

We will evaluate whether a high flow on the Colorado River has a negative, neutral, or positive impact on the amount of food available to fishes by making intensive measurements of (1) algal and invertebrate biomass and species composition, (2) invertebrate and fish feeding habits, and (3) invertebrate and fish growth indicators. Because a high flow is likely to alter the systemwide carbon budget we are currently describing, we will also intensively measure transported organic matter during a high flow. This research will take place at Glen Canyon, at Diamond Creek, and in the mainstem Colorado River near the confluence with the Little Colorado River.

Study Goal

The goal of this study is to measure how a future high flow will affect the quantity, quality, and types of food available for invertebrates, and ultimately fish.

Need for Study

Previous food base research has demonstrated that a high flow causes short-term reductions in primary producer and invertebrate biomass (Blinn and others, 1999; McKinney and others, 1999). Blinn and others (1999) and McKinney and others (1999) focused on static measures (e.g., algal biomass, invertebrate biomass) at a relatively coarse temporal scale (i.e., monthly measurements following a high flow). Although biomass of algae and invertebrates will be temporarily reduced following a high flow, it is possible the post-high flow algal assemblage will be faster growing and of higher quality, leading to higher invertebrate growth rates (note: production=biomass* growth). Higher invertebrate growth rates following high-flow experiments could compensate for short-term reductions in invertebrate biomass. That is, short-term (i.e., weeks) negative effects of a future high flow on biomass may be offset by longer term (i.e., months to 1 year) increases in invertebrate growth rates, which would result in more food available to higher trophic levels.

A future high flow is likely to alter the systemwide carbon budget that we are currently constructing. Consequently, we will quantify fluxes of transported organic matter before, during, and after the future high flow experiment. Although these types of measurements have been taken during previous high-flow experiments, none of the data have been linked to whole-system carbon budgets. This information will be critical for ultimately measuring the effect of a future high flow on inputs, retention, and export of organic matter that fuels river food webs.

There is evidence that disturbances that might occur during future a high flow could lead to an algal assemblage dominated by fast-growing and nutritious taxa. Brock and others (1999) measured production of algae-covered rocks in Glen Canyon before and after the 1996 high flow. They demonstrated that rates of net primary production and production to respiration ratios were both higher after the high flow, although algal biomass on rocks was lower following the high flow. They attributed these changes to the removal of detritus and senescent algal biomass. Because rapidly growing and young algae are more nutritious than senescent algae or detritus, the study by Brock and others (1999) suggests that the post-high flow algal assemblage was of higher quality for invertebrates than the pre-high flow algal community. Numerous studies in Sycamore Creek, a desert stream in southern Arizona, have demonstrated that following a scouring flood the algal assemblage shifts towards more nutritious and faster growing taxa (e.g., diatoms), invertebrates readily consume these new food resources, and that invertebrate biomass rapidly recovers to pre-flood levels (Fisher and others, 1982; Grimm and Fisher, 1989; Peterson and others, 1994).

Strategic Science Question

> **SSQ 5-2—**Is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?

High Flow Science Question

How will a future high flow affect food production and availability for rainbow trout in the Lees Ferry reach? What are the effects of high-flow experiments on aquatic food production?

Working Hypotheses

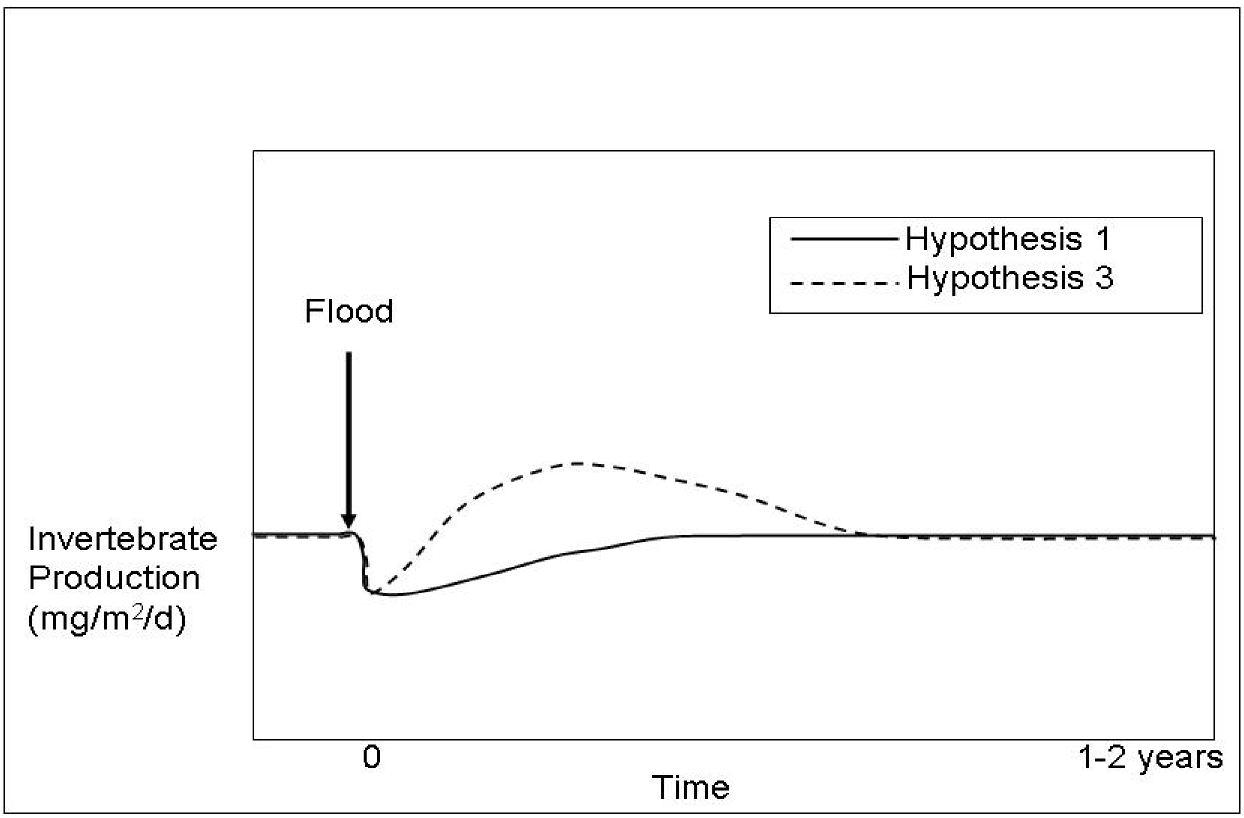
Hypothesis 1: A short-duration high flow in late winter scours the benthos, causing short-term reductions in algal and invertebrate biomass, and results in an overall decrease in annual invertebrate production (see fig. 4).

Hypothesis 2: A short-duration high flow in late winter scours the benthos, causing reductions in algal biomass, but the new successional community of primary producers is of higher quality, more productive, and is assimilated more efficiently by invertebrates, leading to no change in annual invertebrate production.

Hypothesis 3: A short-duration high flow in late winter initially scours the benthos, causing reductions in algal biomass, but the new successional assemblage of primary producers is of higher quality, more productive, and is assimilated more efficiently by invertebrate consumers, thereby increasing annual invertebrate production (see fig. 4).

Our research will test these competing hypotheses of recovery following a high flow. Direct measurements of invertebrate and fish growth before and after a high flow are intractable. However, we may be able to infer how invertebrate or fish growth rates are affected by future high-flow experiments by measuring indices of growth (ribosomal RNA; Elser and others, 2003) and by quantifying invertebrate and fish diets and using literature values to determine the assimilation efficiencies of principal food resources. We will also measure whether a high flow changes the quality (i.e., C:N, C:P) of algal assemblages. Collectively, the proposed research will measure how a high flow affects the quantity and quality of food available for fishes and whether indicators of rainbow trout growth are affected by changes in food resources.

Figure 5. Potential effects of a high flow on invertebrate production.



Methods

We will measure biomass of lower trophic levels (i.e., algal and invertebrate biomass, cover and canopy height of submerged aquatic vegetation, organic drift) coupled with dynamic process-oriented measures (e.g., nutrient content of basal resources, ribosomal RNA of invertebrates and fish, open-channel metabolism measurements) to test how a high flow affects annual invertebrate production. Methods described briefly below are presented in more detail in our original food base proposal (Hall and others, 2005).

We will sample algae, submerged aquatic vegetation, and benthic organic matter with appropriate area-specific sampling devices (e.g., Ponar and Hess samplers, rock scrapes, modified suction sampler); the samples will be dried to a constant mass, weighed, ashed in a muffle furnace (at 450°C), and reweighed to determine total dry mass and organic mass. Dried samples of these food base components will also be analyzed for carbon, nitrogen, and phosphorus content following standard methodology (CHN analyzer, acid digestion and spectrophotometry, APHA 1998). Open-channel metabolism in the Glen Canyon reach will be quantified before and after the high flow with continuously deployed Yellow Springs Instruments (YSI) data sondes (with optical probes), using a two-station diel oxygen change method corrected for re-aeration (e.g., Hall and Tank, 2003; Hall and others, 2005). Downstream in Grand Canyon, we will measure metabolism using a one-station technique as part of the food base study (Hall and others, unpublished). Metabolism will be measured continuously at Diamond Creek for a period of a week before, and several months after, a high flow. At the LCR, metabolism will be measured continuously for 1 week before, and 2 weeks after, a future high flow. Coarse and fine organic drift will be quantified using depth-integrated Miller net and grab samples, before, during, and after a future high flow at each site. Invertebrates will be quantified on multiple substrate types (i.e., cliff faces, talus slopes, cobble bars, depositional areas) with appropriate area-specific sampling devices (e.g., modified suction sampler, rock grabs, Hess sampler, ponar dredge). Dietary analysis will be conducted on invertebrates before and on multiple occasions after (days 1, 3, 7, 14, 30) a high flow using digital imaging software (Image Pro 3.0). Dominant dietary items can be easily identified with this method (e.g., diatoms, amorphous detritus, leaves, animal prey; Benke and Wallace, 1980; Hall and others, 2000). Ribosomal RNA analysis will be conducted on dominant invertebrates and fishes as a proxy for growth rate and condition (Elser and others, 2003).

Tasks

1. Measure how a high flow alters the carbon budget for the CRE.
    - Measure the composition, biomass, and nutrient content of basal resources (algae, submerged aquatic vegetation, benthic organic matter)
    - Quantify whole system metabolism, a measure of primary production and resource consumption
    - Prior to high flow, quantify standing mass of leaf litter between 20-41 k cfs stage elevation
    - Measure organic drift during high flow
2. Measure how a high flow affects invertebrate biomass and production

- Quantify invertebrate composition, abundance, and biomass
- Quantify invertebrate diets and growth indicators (i.e., ribosomal RNA)

3. Measure impact of a high flow on growth and condition indices (i.e., ribosomal RNA) for rainbow trout in Lees Ferry (in collaboration with Korman and others)

We will compare the above measures before and after a future high flow, and again in the following year at the same time when no high flow occurs. Frequent measurements before and after a high flow (i.e., -7d, -1d, +1d, +3d, +7d, +14d), ongoing quarterly sampling at the LCR confluence, and monthly sampling at Glen Canyon and Diamond Creek will allow us to measure the short- and long-term effects of a high flow on food quantity and quality.

Relation to Existing Work and Other Studies

One of the main goals of the food base research effort is to determine whether rainbow trout in Lees Ferry and native fishes downstream, particularly humpback chub, are food limited. To answer this question we are quantifying food production at each of six sites and comparing that with fish demand for food. At the time of this writing we are nearing 2 years of data collection on these efforts, both of which have been 8.23 M acre-feet years with no experimental flows or tests. We anticipate that many of the measurements we are making to determine food production would be useful in a future food base monitoring program. A high flow in March 2008 is likely to provide a large contrast in food production relative to the first 2 years of data collection—this should allow us to test the sensitivity of potential food base monitoring measurements that we are currently making as part of our research on food production. Further, the 2 years of data collection under 8.23 M acre-feet hydrology will serve as a valuable baseline for determining whether a high flow has a negative, neutral, or positive impact on food production.

This study is linked to experimental study 1B (Studies of eddy-sandbar hydrodynamics, sediment transport, and bathymetry during future a high flow). We will share transported sediment samples and analyze them for both sediment and organic matter and determine what effect a high flow has on organic matter transport.

Information Needs Addressed

Experimental effects information needs (EIN) addressed by the proposed research include the following:

EIN 1.1.1 How does primary productivity for the reach between Glen Canyon Dam and the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 1.2.1 How do benthic invertebrates in the reach between Glen Canyon Dam and the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 1.3.1 How does primary productivity in the Colorado River ecosystem below the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 1.4.1 How do benthic invertebrates in the Colorado River ecosystem below the Paria River change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

EIN 1.5.1 How does drift in the Colorado River ecosystem change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Budget Summary

FUNDING PROPOSAL		
Experimental Study 3.: Aquatic Food Base Studies (Lower Trophic Levels)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% burden)	30,130	31,508
GCMRC Project Related Travel/Training (19.1% burden)	2,000	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	0	5,000
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	30,000	0
AMP Logistical Support (19.1% burden)	46,500	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	82,500	0
Project Sub-Total	**$191,130**	**$36,508**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	25,773	7,667
Project Total (including burden)	**$216,903**	**$44,175**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	55%	0%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Studies 4.A and 4.B: Rainbow Trout Studies

Introduction

The Adaptive Management Program includes the maintenance of a rainbow trout sport fishery above the Paria River (Lees Ferry) in its 12 program goals. There are conflicting hypotheses regarding how a beach/habitat-building flows test may affect this fishery. In general, there are those who believe that experimental high flows are an unequivocal detriment to this fishery. Others believe that short-term negative impacts to the fishery are overshadowed by gains, including a rejuvenation of the primary producers in the Lees Ferry reach and a compensatory response of the remaining rainbow trout that can exhibit increased growth in response to reduced intraspecific competition.

To support evaluation of some of the competing claims regarding the effects of a high flow on the rainbow trout fishery, the GCMRC proposes that three studies be conducted in association with a high flow. One of these is the ongoing monitoring of the adult rainbow trout population that the Arizona Game and Fish Department conducts several times each year. Because this work occurs with or without a high flow, it is not described further in this document. The remaining two studies, specific to a high flow, are described in the following text. These studies address early life stages of rainbow trout (study 4.A) and the movement/displacement of young and adult rainbow trout (study 4.B), both in association with a high flow. Together, all three studies of the Lees Ferry rainbow trout population help increase understanding of how high-flow experiments do or do not affect the sport fishery. They also offer opportunities to apply new study methods, especially remote tracking methods and occupancy modeling of fish populations. These two new methods may potentially be applied to native fish populations downstream if either is proven to be effective and useful.

Experimental Study 4.A: Effects of future high-flow experiments on rainbow trout early life stage survival, and the distribution, mortality, and potential downstream movement of age-1 fish in the Lees Ferry reach

Duration

24 months

Principal Investigator

J. Korman, Ecometric, Inc., Vancover, British Columbia, Canada (GCMRC cooperator)

Geographic Scope

Glen Canyon Dam to Lees Ferry

Abstract

The goal of this study is to determine how high flows affect rainbow trout spawning and incubation survival, and examine the influence of high-flow experiments on age-1 mortality, downstream migration, and habitat use in the Lees Ferry reach. This work will expand upon the Rainbow Trout Early Life Stage Survival (RTELSS) research conducted by Korman and others (2005). Redd and age-0 and juvenile abundance surveys will be conducted pre- and post-experiment. This study provides a robust evaluation of factors affecting growth, survival, and habitat choice of age-0 rainbow trout, including flow, juvenile density, adult density and the associated predation risk, and food availability.

Study Goals

This study seeks to determine how high flows affect spawning and incubation survival of rainbow trout in the Lees Ferry reach, and the potential of high-flow experiments to influence age-1 mortality and habitat use in the Lees Ferry reach and downstream migration. Hypotheses that will be evaluated are (1) high flows will scour redds (spawning nests), but the effect on the juvenile population will be limited because of compensatory survival responses, and (2) high flows will change in the distribution of age-1 fish within the Lees Ferry reach, and increase mortality and/or result in downstream migration out of the reach.

Need for Study

The size of the adult rainbow trout population in the Lees Ferry reach is very likely regulated by the survival rate and dynamics of early life stages (Houde, 1987). This study would increase our understanding of these dynamics and therefore contribute to better management of the Lees Ferry trout fishery. Trout from Lees Ferry may migrate downstream and have negative effects on native fish (Korman et al. 2005, L. Coggins, unpublished data). The extent of downstream migration may be density dependent (Clone and Anderson 1992), a normal ontogenetic habitat shift (Elliott 1986), and/or stimulated by high flows (Heggenes and Traaen 1988, Jensen and Johnsen 1999, Mitro et al. 2003). A better understanding of the dynamics of the Lees Ferry population and the effects of high flows, therefore, has implications for the control of trout densities downstream.

Understanding the effects of flow on the vital rates (e.g., growth and survival) of young fish requires an understanding of their habitat use. Certain flow regimes may be harmful in one habitat type (e.g., fluctuating flows in low angle shorelines or backwaters) but inconsequential in others (e.g., steep talus shorelines). The most feasible way to understand habitat use is to compare catch rates across habitats (e.g., Converse et al. 1998); however, this approach requires an understanding of differences in capture probability among habitats (or among habitats sampled by different gear types), and the extent to which capture probability is influenced by fish density, fish size, flow, flow history, and other factors. Such an analysis has already been undertaken for age-0 rainbow in the Lees Ferry reach in 2006 and 2007 (Korman, Walters, Coggins, and Yard, unpublished data). This study would expand that analysis by repeating it for the more challenging age-1 life stage. Lessons learned from this component may assist in understanding nearshore habitats and their ecology in Grand Canyon.

Strategic Science Question

> **SSQ 3.2** To what extent could predation impacts by nonnative fish be mitigated by higher turbidity or dam-controlled high-flow releases?

High Flow Science Questions

How will a high flow affect spawning and survival of early life history stages of rainbow trout (BBT) in the Lees Ferry reach? To what extent is the adult population of rainbow trout controlled by survival rates during incubation and age-0/juvenile rearing stages, or by changes in growth and maturation in the adult population influencing egg deposition?

Working Hypotheses

To evaluate these hypotheses, we will compare (1) the number of redds before and after the high-flow event to compute the potential loss of redds due to high flows; (2) the ratio of the density of newly emerged fry to the total number of redds constructed with ratios determined in 2003, 2004, 2006, and 2007 (Korman and others, 2005, work in progress); and (3) the abundance and distribution of age-1 fish before and after the high-flow event. We predict that (1) redd numbers will be reduced by the flood due to scour; (2) the ratio of fry-to-redds will be similar to other years (2006/7=ROD, 2003/4=experimental flows) because of strong compensatory mechanisms that occur shortly after emergence (Elliott, 1994); and (3) distribution of age-1 fish in Lees Ferry fish will be different after the flood and there will be a reduction in abundance due to mortality or downstream movement (Korman and others, 2005; U.S. Geological Survey, unpub. data). It may be possible to determine whether mortality or movement was the cause for change in abundance if age-1 fish are tagged as part of the proposed GCMRC sonic telemetry program (see study 4.B).

Methods

The RTELSS study associated with the high flow will include (1) ten redd surveys to provide a more accurate and detailed estimate of redd numbers and timing of spawning; (2) four juvenile fish surveys to compute the age-0 to redd ratio (July sample) and to describe the change in abundance and distribution of age-1 fish (sampling before and after high flow); (3) support for physical modeling to develop a depth and velocity map for a range of discharges for the entire Lees Ferry reach; and (4) two age-1 surveys, one before the high flow and one after the high flow. The juvenile fish survey should occur in the late fall to provide an annual index of age-0 abundance (altering the timing of this survey from previous efforts disrupts the time series).

With regard to item (3) above, as fish grow they use deeper and faster habitats (Gaudin, 2001). Previous age-0 surveys have been restricted to generally quite slow water (but sometimes deep) that is broadly distributed along the shoreline in the Lees Ferry reach. However, larger age-0 and age-1 fish appear to concentrate in the limited number of shorelines with faster water where food availability is higher (Korman and Yard, unpublished data). These habitat types will be sampled to provide a representative description of how high flows change abundance and distribution. The physical model would allow us to design a representative sampling regime for age-1 fish and scale up density samples to estimate age-1 population size before and after a high flow. Predictions of depth and velocity in Lees Ferry reach would also be useful for assessing redd scour, which we will evaluate in the field by before and after mapping of redds as part of our regular survey, and burial of existing spawning areas with sand (as apparently occurred at 6 and 8 mile sandbars as a result of the 1996 high flow). Data collected from past RTELSS efforts and a complete topographical map of the Lees Ferry reach developed by the GCMRC would be integrated into an existing 2-D hydrodynamic modeling framework developed by the USGS.

Data collection during 2009 will allow for a more robust evaluation of the factors that affect growth, survival, and habitat choice of age-0 rainbow trout, including flow, juvenile density, adult density and the associated predation risk, and food availability. Further, 2009 data collection will allow for a comparison of potential future flow tests to ROD flows.

RTELSS-Basic

This program would exclusively address hypothesis 1 and be repeated in 2009. Ten redd surveys (January–June) averaging 1.5 days in duration (two crew) and four age-0 surveys (June, August, September, and November) of 4 days length would be completed (two crew plus two boatmen for each survey). The 40 RTELSS index sites would be surveyed for age-0 fish on each fry survey trip (single pass), and, if time allowed, limited mark-recapture (two passes) would be conducted.

Age-1 Parr

This program would exclusively address hypotheses 2 and 3 and be repeated in 2009. Two substantial age-1 surveys would be completed (one before and one after). Each survey would be 8 days duration (two 4-day blocks) and require four crew (and two boatmen). Multipass mark-recapture would be conducted at a series of sites in different habitat types on each survey. In addition, the 40 RTELSS index sites would also be sampled (single pass).

Links/relationship to Existing Work and Other Studies

Food base information will be useful in interpreting changes in age-0 survival estimated from RTELSS-Basic compared to survival rates measured in non-high flow years. Downstream migration of trout from the Lees Ferry reach resulting from high flows will be studied by GCMRC. Trout captured as part of the proposed study could be used as part of GCMRC's downstream movement assessment and their data would be very useful for interpreting our reach-wide assessment of downstream movement/mortality (and the age-1 parr data will be useful for interpreting the telemetry information). Development of techniques and results from capture probability estimates from the age-1 Parr study component is potentially transferable to the upcoming nearshore habitat use study in Grand Canyon.

Determination of how the food web dynamics influence the density and growth of rainbow trout in the Lees Ferry reach is also important. Downstream migration of trout from the Lees Ferry reach resulting from a high flow will be studied by the GCMRC. Trout captured as part of the proposed study will be used as part of GCMRC's downstream movement assessment (see experimental study 4.B). These data will be very useful for interpreting downstream movement/mortality.

Information Needs Addressed

> **RIN 4.2.7—**What dam release patterns most effectively maintain the Lees Ferry rainbow trout trophy fishery while limiting rainbow trout survival below the Paria River?
>
> **EIN 4.1.1—**How does rainbow trout abundance, proportional stock density, length at age, condition, spawning habitat, natural recruitment, whirling disease and other parasitic infections change in response to an experiment performed under the Record of Decision, unanticipated event, or other management action?

Budget Summary

FUNDING PROPOSAL		
Experimental Study 4.A: Effects of future high-flow experiments on rainbow trout early life stage survival, and the distribution, mortality and potential downstream movement of age-1 fish in the Lees Ferry reach (Rainbow Trout Redds Study)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Project Related Travel/Training (19.1% burden)	0	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	3,000	3,000
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	0	0
AMP Logistical Support (19.1% burden)	34,000	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	81,350	91,650
Project Sub-Total	**$118,350**	**$94,650**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	12,021	6,211
Project Total (including burden)	**$130,371**	**$100,861**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	83%	0%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 4.B: Evaluate effects of a future high flow on adult rainbow trout distribution in Glen and Marble Canyons

Duration

19 months

Principal Investigator

K.D. Hilwig, U.S. Geological Survey, Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

Geographic Scope

Glen and Marble Canyons (river miles -15 to 225)

Abstract

This study will address strategic science questions and information needs associated with the impacts of flow management on emigration of rainbow trout from Lees Ferry and potential management options to reduce their impact on native species. This study will use abundance indices in combination with acoustic technologies to evaluate the possible displacement of rainbow trout from Lees Ferry during a high flow.

Study Goals

The goals of this experimental study are to (1) determine the effects of a high flow on rainbow trout abundance in Lees Ferry, (2) determine if a high flow causes displacement of rainbow trout of approximately 120-mm total length (TL) and larger from the Lees Ferry reach into Marble Canyon and eastern Grand Canyon; (3) determine if such displacement is experienced differentially among fish of different length; and (4) provide a platform for Grand Canyon scientists to develop skills with acoustic technologies that can be applied to answering questions about native and nonnative fish movement and distribution and sampling efficiencies.

Need for Study

Native fishes of the Colorado River evolved in a system with a seasonally variable hydrograph, with winter base flows as low as ~1,000 cfs and annual spring floods routinely exceeding 100,000 cfs, and with other large floods often occurring during the summer and early fall (Topping and others, 2003). Although a high flow of ~40,000 cfs would likely not disadvantage these native species, it is commonly observed in other systems that a naturally flashy hydrograph can disadvantage nonnative species (Meffe, 1984). It is currently unclear whether a moderate high-flow event of ~40,000 cfs could affect the nonnative fish community of the Colorado River and provide a management tool. During the high flow of 1996, Valdez and Cowdell (1996) observed an increase in catch rates of rainbow trout <152-mm TL in the Little Colorado River (LCR) inflow reach of the Colorado River. They hypothesized that displacement of fish from Lees Ferry and Glen Canyon into Grand Canyon by the high flow was likely responsible for these increased catch rates. They did not, however, observe any changes in the catch rates of other species of the nonnative fish community. After the 2004 high flow, Korman (pers. com.) observed a decrease in the catch rates of juvenile trout in Lees Ferry, which supports the Valdez and Cowdell (1996) hypothesis of displacement in 1996. Once again, however, direct observation of the fate of the fish could not be made. Currently, we do not know if short-duration high-flow experiments displace young trout from Lees Ferry and cannot infer this from experiments using abundance indices alone. This experimental study would employ the additional technology of acoustic telemetry to make direct observations of movement patterns of rainbow trout greater than approximately 120-mm total length during a future high flow. This information in combination with relative-abundance measures will allow for a stronger inference to be drawn during a future high flow about the fate of rainbow trout greater than approximately 120-mm TL. This experimental study also provides an opportunity for scientists to gain skills and experience with acoustic technologies that may prove important for addressing broader questions about Lees Ferry trout dispersal, movement dynamics, and sampling efficiency of other native and nonnative fish species in the Grand Canyon. Information and experience gained in this study is potentially useful in evaluating and structuring future telemetry-based observations of native fishes dispersal associated with a high flow in downstream sections (e.g., near the LCR confluence) of the Colorado River.

Strategic Science Question

> **SSQ 1.3—**Do rainbow trout emigrate from Glen to Marble and eastern Grand Canyons, and, if so, during which life stages?

High Flow Science Question

Will a high flow stimulate downstream migration of age-1 rainbow trout?

Working Hypotheses

A future high flow will result in displacement of young rainbow trout from the Lees Ferry reach into Marble Canyon and eastern Grand Canyon. This trout redistribution will be inversely related to the size of fish.

Methods

This experimental study will use abundance indices and sonic technologies to evaluate the possible age-specific displacement of rainbow trout larger than approximately 120-mm TL from the Lees Ferry reach during a future high flow. Abundance indices will be established for adult and juvenile rainbow trout before and after the high flow for comparison. Before the high flow, the GCMRC will execute a trout sampling trip following the protocol developed by the Arizona Game and Fish Department (AZGFD) for long-term monitoring of adult trout in Lees Ferry (Speas and others, 2002). The post-high flow evaluation of adult trout abundance will include the use of AZGFD catch-rate information from reoccurring long-term rainbow trout monitoring in the Lees Ferry reach. Additional electrofishing catch-rate information collected by Ecometric, Inc. (experimental study 4.A) will be used for abundance comparisons of pre- and post-high flow juvenile trout abundance. In combination, these catch data will be used to infer changes in the abundance of adult and juvenile rainbow trout associated with a future high flow.

Relative-abundance indices will be combined with direct observations of location and movement from acoustic telemetry to draw inferences about the effects of a future high flow on the Lees Ferry trout population. The Colorado River upstream of Lees Ferry will be divided into three strata: upper (river mile -15 to -10), middle (river mile -10 to -5), and lower (river mile -5 to 0). Ten fish of age 1, 2, and 3 will be collected from each strata and tagged via intraperitoneal implantation for a total sample size of 90 implanted individuals. The minimum size fish implanted with a transmitter will be 120-mm TL. With the appropriate acoustic transmitter, this represents a tag to fish body weight ratio of 5%, which has been demonstrated to have little to no effect on swim performance of juvenile hatchery-reared rainbow trout (Brown and others, 1999). Tagged fish will be held in net pens for 24 hours to allow recovery from surgeries. Recovery of all fish will be evaluated and individuals recovering poorly will be removed from the experiment. Fish will be released in their river stratum of origin. Released fish will be manually tracked daily for 1 week to evaluate movement patterns and longer term response to surgeries. We expect to observe a dispersal pattern after release that stabilizes over the period of tracking. Movement downstream of Lees Ferry will be detected with three acoustic receiver gates. These will be deployed at Lees Ferry, Marble Canyon Bridge, and Badger Creek. Fish in the Lees Ferry reach will then be tracked for an additional 3 days to assure data accuracy of the stationary receiver gates. A post-high flow electrofishing sampling protocol will be employed 1 week after the high flow to detect changes in the relative abundance of trout in the Lees Ferry trout fishery.

Caveats on expected study findings: To clarify how this study will address the strategic science questions listed above and the information needs listed below, note that this study will not answer all questions associated with rainbow trout emigration from the Lees Ferry reach because it will only be observing movement of fish larger than approximately 120-mm TL. However, it will potentially provide insight into whether or not larger size classes of rainbow trout are vulnerable to high-flow-related displacement. In addition, the study will provide insight into the vulnerability of rainbow trout larger than approximately 120-mm TL to displacement associated with a BHBF. This information is clearly related to potential management actions that might be considered under strategic science questions 1.4 and 3.2. Additionally, this study will provide only a partial answer to RIN 4.2.1 (below) because the fish under study will be greater than approximately 120-mm TL and observed movement will be associated with a BHBF. Therefore, no direct information will be acquired on smaller sizes of rainbow trout nor associated with routine dam operations. This study will not determine the most effective way (RIN 4.2.2) to detect emigration of rainbow trout from the Lees Ferry reach. However, it will provide insight into how well a combination of catch-rate metrics and telemetry will perform for rainbow trout greater than approximately 120-mm TL. This study will only partially address RIN 4.2.3, since it will be mainly focused on a specific hydrologic event (i.e., a high flow) and the emigration rate of rainbow trout larger than approximately 120-mm TL.

Links/Relationships to Existing Work and Other Studies

This experimental study has direct linkage to experimental study 4.A, the long-term Lees Ferry trout monitoring effort, the FY 2007 sonic tag/gear efficiency evaluation, the FY 2007 warmwater nonnative fish research, and future native fish research. Experimental studies 4.A and 4.B are interrelated because of data and logistics sharing. Conducting these studies in concert will strengthen the inferences drawn from each about the fate of age-1 trout in the Lees Ferry reach in relation to a high flow. This study also relies on Lees Ferry long-term trout monitoring data collected by the AZGFD on relative abundance of adult trout in the Lees Ferry reach after a future high flow. Additionally, this study provides a platform for Grand Canyon scientists to gain valuable experience using sonic technologies to address a broader set of biological question. The experience gained from a future high-flow study will be employed in ongoing investigations of gear efficiencies and warmwater nonnative fish. These tools are also expected to be invaluable for future investigations of native fish in the Grand Canyon ecosystem.

Information Needs Addressed

The experimental study will generally address the following research information needs (RIN):

> **RIN 4.2.1** What is the rate of emigration of rainbow trout from the Lees Ferry reach?
>
> **RIN 4.2.2** What is the most effective method to detect emigration of rainbow trout from the Lees Ferry reach?
>
> **RIN 4.2.3** How is the rate of emigration of rainbow trout from the Lees Ferry reach to below the Paria River affected by abundance, hydrology, temperature, and other ecosystem processes?

Products/Reports

A peer-reviewed journal article and/or USGS report will be produced based on the findings of this study.

Budget Summary

FUNDING PROPOSAL		
Experimental Study 4.B: Evaluate effects of a future high flow on adult rainbow trout distribution in Glen and Marble Canyons (Rainbow Trout Studies - Juvenile and Adult Distribution)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Project Related Travel/Training (19.1% burden)	9,539	1,200
GCMRC Operations/Supplies/Publishing (19.1% burden)	500	500
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	43,930	0
AMP Logistical Support (19.1% burden)	30,100	0
Outside GCMRC & Contract Science Labor (19.1% burden)	3,000	0
Cooperative/Interagency Agreements (6.09% burden)	6,550	0
Project Sub-Total	**$93,619**	**$1,700**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	17,029	357
Project Total (including burden)	**$110,648**	**$2,057**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	26%	0%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 5: Evaluate effects of a future high flow on water quality of Lake Powell and Glen Canyon Dam releases

Principal Investigator

William S. Vernieu, U.S. Geological Survey, Biological Resources Division, Southwest Biological Science Center, Grand Canyon Monitoring and Research Center

Geographic Scope

Lake Powell forebay to upstream limit of the hypolimnion (~Oak Canyon, 90 km above the dam), Glen Canyon Dam, and the tailwaters to Lees Ferry

Abstract

This study will monitor water-quality parameters above and below the dam to assess any changes in these parameters that may occur because of the high flow. It will provide additional information to compare to the status of these parameters in the context of the ongoing Lake Powell water-quality monitoring study.

Study Goal

The goal of this experimental study is to determine how the addition of jet tube and full powerplant releases from the dam will alter water quality in the Glen Canyon Dam tailwaters and the hydrodynamics and stratification patterns in Lake Powell. This effort will entail installation of an additional water-quality multiparameter sonde (MPS) at the ring follower gates in the dam and at the inlet port of the river outlet works. It may require another MPS located below Glen Canyon Dam at a point where full mixing of combined discharges is achieved. In addition to the regularly scheduled monthly profiling in the Glen Canyon Dam forebay, additional monitoring locations will be added to include the upstream extent of the hypolimnion, between 45 and 90 km above the dam. Additional surveys of these locations will take place immediately before and immediately after a future high flow. During a future high flow, additional chemical samples will be taken in the dam, at Lees Ferry, and at the river outlet works depth in the reservoir before and after a high flow.

Need for Study

Use of the river outlet works, 30 m below the penstocks, draws water from deeper layers of the reservoir than normal powerplant releases. This water is cooler, has higher concentrations of dissolved minerals and nutrients, and has lower concentrations of dissolved oxygen.

Given the most probable timing of late fall to early spring for a high flow, this study is likely to occur concurrently with an annual event in the reservoir that has been documented by the Lake Powell monitoring program. During this event, an upwelling of the hypolimnion of the reservoir, driven by winter underflow density currents, is observed at Glen Canyon Dam and influences powerplant releases in the early spring. During a future high flow, the operation of the river outlet works, combined with full powerplant releases, could evacuate large volumes of this hypolimnetic water, causing mixing to deeper layers of the reservoir and reduction of the volume of stagnant hypolimnion. For this reason, the high flow of 1996 significantly mixed and diminished the stagnant water in the hypolimnion (Hueftle and Stevens, 2001). Development of stagnation of the hypolimnion can produce hypoxic (low oxygen) conditions in the reservoir, which may in turn be discharged below the dam into the tailwaters.

The 2004 high flow occurred in November when convective mixing and reduced reservoir elevations brought upper lake layers closer to the release structures. Consequently, net releases during the 2004 high flow were drawn primarily from the surface layers and had little effect on hypolimnetic waters. The February/March timing for a future high flow is more likely to release colder, saline, and hypoxic water from the hypolimnion.

In summary, a future high flow has the potential to entrain deeper layers of the reservoir, which could cause enhanced mixing of those layers and reduced stagnation and hypoxia. Releases downstream may deliver more nutrients to the aquatic ecosystem, and the river outlet works would re-aerate hypoxic releases.

Strategic Science Question

SSQ 5.2—How is invertebrate flux affected by water quality and dam operations?

High Flow Science Question

Will the next high flow result in higher nutrient releases and shrinking of the hypolimnion? Will the operation of the river outlet works and the penstocks at capacity measurably alter Lake Powell hydrodynamics or stratification, or alter release water quality?

Methods

Existing methodologies associated with the Lake Powell water-quality core monitoring program will be used to accomplish the objectives. Additional MPS will be calibrated and deployed according to past standards. Additional chemical samples will be collected and processed with monitoring samples; profiles will be conduced using existing equipment and methods.

Links/Relationships to Existing Work and Other Studies

Use of the river outlet works is likely to increase the export of nutrients and ions during the experimental flows and could alter hypolimnetic mixing patterns and result in the increased evacuation of hypolimnetic water. This could provide additional nutrients to the aquatic food base in Grand Canyon in the recovery period following the experiment (Parnell and others, 1999; Shannon and others, 2001; Stevens and others, 2001; Schmidt and others, 2001). The data collected for this study will be provided to the ongoing aquatic food base study to establish baseline values for system nutrient loading. Any changes as a result of the high flow will be important for understanding nutrient levels made available for organisms downstream of the dam. These data are also important for the ongoing Lake Powell monitoring study.

Information Needs Addressed

The following information needs will be addressed by this study:

> **RIN 7.3.1.a** Determine the status and trends of chemical and biological components of water quality in Lake Powell as a function of regional hydrologic conditions and their relation to downstream releases.
>
> **RIN 7.3.1.b** Determine stratification, convective mixing patterns, and behavior of advective currents in Lake Powell and their relation to Glen Canyon Dam operation to predict seasonal patterns and trends in downstream releases.

Products/Reports

A post-experiment report will summarize findings of data collection efforts and a discussion of changes to the stratification and water quality in Lake Powell and changes to the water quality of the Glen Canyon Dam tailwaters as a result of the experimental action.

Budget Summary

FUNDING PROPOSAL		
Experimental Study 5: Evaluate effects of a future high flow on water quality of Lake Powell and Glen Canyon Dam releases (Lake Powell)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	16,350	4,150
GCMRC Study Related Travel/Training (19.1% burden)	2,640	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	2,627	0
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	8,000	0
AMP Logistical Support (19.1% burden)	0	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	0	0
Study Sub-Total	**$29,617**	**$4,150**
	5,657	872
Study Total (including burden)	**$35,274**	**$5,022**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	0%	0%

Note: Cost estimates for FY2008 are from current year projections; FY2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 6: Kanab ambersnail habitat conservation

Compliance Monitoring (contingent on need only)

In the event of a 2006–07 high-flow experiment, the Arizona Game and Fish Department (AZGFD) can conduct necessary onsite monitoring and compliance at Vaseys Paradise (VP), Grand Canyon, to meet legal and regulatory requirements for the endangered Kanab ambersnail—in coordination with the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and/or National Park Service. Compliance and mitigation efforts will follow stipulations outlined in the most recent Biological Opinion regarding the operation of Glen Canyon and its effects on the Kanab ambersnail population and habitat at VP. We anticipate using the same methods from the November 2004 high flow habitat mitigation effort for VP KAS habitat (referenced in the December 6, 2002 Biological Opinion, which proposes the temporary removal and replacement of 25%–40% of ambersnail habitat).

This proposal outlines the objectives, schedule, and budget summary for an AZGFD-led survey/mitigation team to meet the needs of compliance monitoring for this mollusk for a high flow. We would require boat support (oar or motor) for the proposed activities—either a dedicated trip or passenger space on another science trip (for 3–4 researchers).

Objectives

Conduct a pre-experiment topographical survey of the low-zone affected habitat and work with cooperators to determine estimated incidental take due to a 41,000-cfs high flow (GCMRC survey staff time permitting).

Conduct mitigation efforts for the ambersnails and habitat as necessary—based on recommendations of wildlife regulatory agencies and suggestions from the Kanab Ambersnail Working Group.

Observe the actual flood line along the stage discharge elevation at VP during the peak of the high flow; document loss of snails and habitat with digital photos.

Deliverables

Onsite compliance monitoring and mitigation efforts for ambersnails and habitat following criteria outlined in Biological Opinion.

Trip summary report including photo documentation, which will be followed up after the biannual surveys.

Budget Summary

FUNDING PROPOSAL		
Conservation Measure 6: Kanab ambersnail compliance monitoring and mitigations for ambersnails and habitat following criteria outlined in the USFWS Biological Opinion.		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 19.1% Burden)	0	0
GCMRC Study Related Travel/Training (19.1% burden)	0	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	0	0
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	0	0
AMP Logistical Support (19.1% burden)	8,600	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	5,725	0
Study Subtotal	**$14,325**	**$0**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	1,991	0
Study Total (including burden)	**$16,316**	**$0**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	70%	0%

Note: Cost estimates for FY 2008 are from current year projections; FY 2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

Experimental Study 7: Synthesis of Knowledge—Integrated interdisciplinary reporting on high-flow tests

Duration

The development of the synthesis of knowledge report on the 2008 high flow will be initiated during FY 2009, with completion of the report as a comprehensive chapter in The State of the Colorado River Ecosystem in Grand Canyon (SCORE) 2010 report (proposed USGS circular report) summarizing knowledge about high-flow experiments conducted in 1996, 2004, and 2008

Principal Investigators

Science staff of the U.S. Geological Survey, Southwest Biological Research Center, Grand Canyon Monitoring and Research Center in collaboration with cooperating researchers involved in the 2008 high-flow experiment and previous high-flow experiments

Geographic Scope

Colorado River ecosystem (extending from the forebay of Glen Canyon Dam downstream to western boundary of Grand Canyon National Park, Ariz.)

Abstract

This study is aimed at providing a comprehensive synthesis of knowledge gained from multiple interdisciplinary research studies conducted under implementation of this science plan, assuming a high flow occurs. This integrated science-reporting activity will attempt to summarize and synthesize physical and nonphysical results from not only the 2008 high-flow experiment, but will also attempt, as possible and appropriate, to summarize information previously obtained from earlier high-flow experiments in 2004 and 1996.

Study Goals

The goals of this study are to (1) derive more highly integrated understanding about how high-flow experiments have influenced the sediment and related biological and cultural/recreational aspects of the Colorado River ecosystem, not only associated with the 2008 high flow, but also those associated with two prior tests in 2004 and 1996, and (2) use this synthesized science information to evaluate future management options for using high-flow experiments to achieve management objectives of the GCDAMP in a variety of resource areas linked with sandbar rebuilding and maintenance.

Need for Study

Despite two previous high-flow experiments that were conducted in 1996 and 2004, there is still need for more comprehensive reporting about how high-flow results related to a variety of resource management issues. The 1996 test was reported to have occurred under depleted sand-supply conditions and the 2004 test was conducted under minimally enriched sand-supply conditions. The

2008 high flow will occur under what might be considered highly enriched sand-supply conditions. Hence, a comprehensive synthesis of sediment responses under a full range of sand-supply conditions is needed. Additional biological and cultural/recreational information will be derived from the 2008 test that exceeds information previously derived from the 2004 and 1996 tests, and these results need to be more fully synthesized and integrated with the comprehensive synthesis that will occur for sediment in study 1. Following the third high flow in 2008, the opportunity to fully synthesize learning about the relationship between high-flow experiments and a range of downstream resource responses is vitally needed for managers to evaluate future flow options from Glen Canyon Dam. In addition, a more complete and synthetic reporting of financial costs associated with high-flow experiments is needed for resource managers to fully evaluate and consider options for achieving downstream resource management objectives through use of high-flow experiments.

Strategic Science Question

All strategic science questions included in the preceding sections of this science plan shall be considered as part of the synthesis of knowledge reporting study. Owing to the sediment-focused nature of the 2008 high flow (and those that preceded it); particular emphasis shall be placed on the overarching question:

> **SSQ 4.1—** Is there a "flow-only" operation that will rebuild and maintain sandbar habitats over decadal timescales?

Working Hypotheses

All hypotheses included in the preceding experimental study descriptions shall be revisited and evaluated as part of the synthesis of knowledge study. As an outgrowth of the interdisciplinary collaboration of the writing team members, new hypotheses may be generated as a natural outcome of integrated science writing workshops intended to support development of the draft report on high-flow experiments, especially where appropriate and when linkages between sediment, biological, and cultural/recreational elements are most obvious.

Methods

A critical component of this science plan will be the integrated synthesis of findings from the individual studies in the science plan. During FY 2008, scientists will focus mainly on collection of field data before, during, and following the high-flow release. Data processing and initial analyses will proceed during the remainder of calendar year 2008, along with preparation of preliminary reports to the GCDAMP on test results from each of the studies. Individual draft study reports will be peer reviewed as part of standard GCMRC protocols. Following review, these reports will be revised and finalized during FY 2009 by each of the studies' lead investigators. As the study reports are being reviewed and finalized, another reporting activity will start in FY 2009 to synthesize the results from all previous high-flow experiments into a comprehensive, integrated report. Lead authors from each of the previous high flow studies will develop this synthesis of knowledge report as members of a writing team in cooperation with the GCMRC staff and its Science Advisors. One or two writing workshops will be convened by the GCMRC during spring and fall of 2009 to guide and focus this integrated science reporting effort. The primary focus of the first workshop will be to review all of the detailed findings from the 2008 high flow, as well as results from the previous two high-flow experiments in 1996 and 2004.

After careful review of the results, the objective for the synthesis team authors will be development of a comprehensive approach to reporting the test results in an integrated format. Discussions among participating researchers are likely to be most effective within the context of a writing workshop approach convened in Flagstaff by the GCMRC. Initially, synthesis efforts will focus on linkages that are intended to be integrated within multipart studies, such as studies 1 and 4; for instance between studies 1.A, 1.B, 1.C, and 1.D. The results of sediment and related studies will then be integrated with terrestrial vegetation and aquatic food web research outcomes (studies 2–5). To the degree possible, linkages among the studies will also be related to native fishes; in particular, 1.D outcomes that relate the distribution, abundance, and fate of backwater habitats will be related to the presence/absence and distribution of humpback chub.

The draft synthesis report will be most effectively developed after the findings from individual study reports have been peer reviewed and finalized, but preliminary findings will likely provide the basis for the first writing workshop. The proposed format for this synthesis of knowledge document will likely be a U.S. Geological Survey report, but might also be a manuscript submitted for consideration to a major scientific journal of appropriate scope. After the first synthesis workshop, the GCMRC will report to the GCDAMP on the progress in developing the 2008 high flow synthesis report. Owing to the nature of the synthesis of knowledge activities, additional costs for completing this crucial element of reporting are most logically covered by the 2009 and 2010 experimental fund.

Links/Relationship to Existing Work and Other Studies

Synthesis of knowledge reporting for the 2008 high flow is specifically intended to provide a comprehensive summary and evaluation of physical and nonphysical influences of high-flow releases from Glen Canyon Dam, and as such, the task relates to all experimental studies. In addition, the synthesis effort will also summarize and evaluate lessons learned from two previous high-flow experiments conducted under differing and similar sand-supply and flow conditions in 1996 and 2004. Finally, the synthesis also allows for longer term monitoring data to be specifically incorporated into the evaluation of the results all three high-flow experiments, both in a physical (flow and sediment) and nonphysical (aquatic and terrestrial organisms) way.

Products/Reports

The current strategy for synthesis of knowledge reporting on the 2008 high flow is to develop a comprehensive report that includes all available physical and nonphysical results from the 2008 test, as well as previously reported results from the 1996 and 2004 high-flow experiments. This report might then be included as one of several chapters of a future USGS circular or SCORE report that would be published in FY 2010.

Budget Summary

FUNDING PROPOSAL		
Study 7. Synthesis of knowledge – Integrated interdisciplinary reporting on high-flow experiments.		
	FY 2009	**FY 2010**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high flow; 21% Burden)	0	0
GCMRC Study Related Travel/Training (21% burden)	5,000	5,150
GCMRC Operations/Supplies/Publishing (21% burden)	0	100,000
GCMRC Equipment Purchases/Maintenance/Replacement (21% burden)	0	0
AMP Logistical Support (21% burden)	0	0
Outside GCMRC & Contract Science Labor (21% burden)	160,000	50,000
Cooperative/Interagency Agreements (6.09% burden)	55,000	200,000
Study Subtotal	**$220,000**	**$355,150**
DOI Customer Burden (combined 6.09% and/or 21% burden)	38,000	44,762
Study Total (including burden)	**$258,000**	**$399,912**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	98%	70%

Note: Cost estimates for FY 2009 are based on a CPI increase of 3% from the current year's cost estimates along with personnel increases as determined by the USGS BASIS+ financial system estimates and an increase in burden to 21%. FY 2010 cost estimates include a CPI increase of 3% from FY 2009 costs and burden estimates are held at 21%.

Support Function 8. Logistics activities in support of experimental studies

Scheduling Considerations

Scheduling a future high flow during the spring period poses several considerations for the GCMRC Logistics Program. The primary logistical constraints for scheduling a high flow in the spring are (1) consideration of scheduling impacts to the existing monitoring program, (2) provision of adequate lead time for preparation for the additional demands required to support high-flow research, and (3) provision of adequate time to work with the National Park Service on permitting activities and public outreach to address safety concerns for backcountry and river users during periods of high flows.

Year one of this science plan requires launching 11 motorized trips and 1 nonmotorized research trip (plus an additional press/VIP trip) and support of research studies in the Glen Canyon reach and upstream of Diamond Creek (table 6). Trips are initiated 4 weeks prior to the scheduled high-flow peak and up to 12 weeks after the peak flow, encompassing a 4-month time period. During this period in the spring, there are typically three major studies scheduled to conduct field research: mainstem fish monitoring, aquatic food base, and sediment-mass balance. The combination of high-flow trips and regularly scheduled monitoring trips places a heavy demand on the resources available to the GCMRC Logistics Program. The increased demand exceeds the current capacity of the GCMRC Logistics Program, requiring additional equipment, upgrade of current capacities, and coordination of additional external resources.

Year two of the high-flow experiment includes continuation of the components of several studies. Logistical support will require nonmotorized launches and support of research activites in Glen Canyon.

Funding must be made available to the Logistics Program 8 weeks before the scheduled launch of the first high-flow trip so that resources are available to support the experimental high-flow trips while maintaining adequate support for regularly scheduled monitoring trips.

Permitting

The final science plan will be submitted to the Grand Canyon National Park Research Permits Office for review as a study requiring a Research and Collecting Permit. Following approval of a Research and Collecting Permit, individual trip permit applications will be submitted for each of the 11 (should this be 12 with nonmotorized trip, as above? The press trip is showed unnumbered in table 5) trips proposed in this science plan. Requests for permit approval should occur no less than 8 weeks before the first high-flow research trip launch date.

Public Outreach

The GCMRC will collaborate with the National Park Service to establish a public outreach plan to inform the public, specifically recreational river and backcountry users, about safety concerns because of high flows. In collaboration with the National Park Service, a handout will be prepared informing the public on the purpose and effects of a future high flow, including a hydrograph of the peak flows, which will be distributed to all river and backcountry users who may be affected. This plan also includes a budget for an unscheduled press river trip.

Logistics

A future high flow will require one nonmotorized and nine motorized trips (Not sure why this is a different number of trips) to support the proposed research activities outlined in this plan. One trip will launch in advance of the high flow. Five trips will be launched before the high flow to be stationed at river mile 30, 45, and 60, Phantom Ranch, and National Canyon to conduct sampling before, during, and after the high flow. One trip launches on the initiation of the peak flow and the final two trips are conducted after the high flow. Additionally, work will take place in the Glen Canyon reach between Lees Ferry and Glen Canyon Dam and upstream of Diamond Creek at river mile 225. A post-experiment briefing trip has been planned to provide the opportunity for agency officials and managers and members of the press to observe and discuss the effects of the experiment.

Table 6. Logistical support requirements for proposed experimental studies.

	Study	Boats	Location	Trip length	# Personnel
Trip 1	1.C	2-33’,1-22’ (Eyeball), 1-22’ (Hydro), 1-sport (Osprey)	RM 0–225	18 days	18–20
Trip 2	1.D	2-22’, 2-sport (Achilles)	RM 0-225	18 days	10-12
Trip 3	1.A,3	1-33’, 2-sport (Osprey)	RM 61	20	8–12
Trip 4	1.A	1-22’, 1-sport (Osprey)	RM 166	15	2-4
Trip 5	1B	1-33’, 1-22’ (Hydro)	RM 45	16	6–8
Trip 6	1a,KAS compliance	1-33’, 1-sport (Osprey), 1-sport (Achilles)	RM30	16	10-12
Trip 7	1.A,3	1-33’, 1-22’, 1-sport (Achilles)	RM 87/ Lower Lagrangian	14	6–8
Trip 8	1.A,3	1-33’, 1-22’	Upper Lagrangian	12	6–8
Trip 9	1.C,2,4.B	2-33’,1-22’ (Eyeball), 1-22’ (Hydro), 1-sport (Osprey), 1-18’ (row)	RM 0–225	18	20-22
Trip 10	1.D	2-22’, 2-sport (Achilles)	RM 0-225	18 days	10-12
Trip 11	1.C	2-33’	RM 0–225	18	12–14
Trip 12	1.D,2	6-18’(row)	RM 0–225	16	16-18
Press Trip	8	2-22’	RM 0–225	8	14-16

Recommended Timeline

- Final approval high flow and hydrograph (date and hour specific)
- Permitting and logistical planning initiated (8 weeks prior to trip 1 launch)
- First high-flow research trip launches (4 weeks prior to initiation of high flows)
- High flows initiated
- Press trip launches (1 week following high flows)
- Final post-experiment trip launches (8 weeks following high flows)

Estimated Logistics Costs (using FY 2007 costs)

Experimental studies and associated logistical support activities		Year 1 projected cost (included in study budgets)	Year 2 projected cost (included in study budgets)
1.A	Sand Budgeting	$99,213	
1.B	Sandbar Depositional Rates	$19,302	
1.C	Sandbar Fate	$127,081	
1.D	Shoreline Habitat Mapping	$122,104	$69,577
2	Riparian Vegetation Studies	$15,750	$7,875
3	Lower Trophic Levels	$46,483	
4.A	Rainbow Trout Studies – Early Stages	$33,934	$33,934
4.B	Rainbow Trout Studies – Adult Distribution	$30,085	
5	Lake Powell	$0	$0
6	KAS Compliance	$8,600	
TOTAL PROJECTED IN-STUDY LOGISTICS COSTS:			

Budget Summary

FUNDING PROPOSAL		
Support Function 8. Logistics activities in support of experimental studies—direct costs (not included in study estimates)		
	FY 2008	**FY 2009**
GCMRC Personnel Costs (includes overtime and additional hires necessary to complete high-flow; 19.1% Burden)	8,000	0
GCMRC Study Related Travel/Training (19.1% burden)	0	0
GCMRC Operations/Supplies/Publishing (19.1% burden)	20,000	0
GCMRC Equipment Purchases/Maintenance/Replacement (19.1% burden)	60,000	0
AMP Logistical Support (19.1% burden)	15,000	0
Outside GCMRC & Contract Science Labor (19.1% burden)	0	0
Cooperative/Interagency Agreements (6.09% burden)	0	0
Study Subtotal	**$103,000**	**$0**
DOI Customer Burden (combined 6.09% and/or 19.1% burden)	19,673	0
Study Total (including burden)	**$122,673**	**$0**
Percent outsourced (not including incorporated personnel costs; including 50% logistical support)	7%	0%

Note: Cost estimates for FY 2008 are from current year projections; FY 2009 are based on a CPI increase of 3% from the current year's costs along with personnel increases as determined by the USGS BASIS+ financial system estimates; and an increase in burden to 21%.

References

Andrews, E.D., Johnston, C.E., Schmidt, J.C., and Gonzales, M., 1999, Topographic evolution of sand bars, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 117–130.

Arizona Game and Fish Department, 1996, Ecology of Grand Canyon backwaters: Flagstaff, Ariz., report to Bureau of Reclamation, Glen Canyon Environmental Studies, Cooperative Agreement 9-FC-40-07940, 155 p.

Benke, A. C., and Wallace, J. B., 1980, Trophic basis of production among net-spinning caddisflies in a southern Appalachian stream: Ecology, v. 61, no.1, p. 108–118.

Blinn, D.W., Shannon, J.P., Wilson, K.P., O'Brien, C., and Benenati, P.L., 1999, Response of benthos and organic drift to a controlled flood, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 259–272.

Brock, J.T., Royer, T.V., Snyder, E.B., and Thomas, S.A, 1999, Periphyton metabolism: a chamber approach, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 217–223.

Brown, R.S., Cooke, S.J., Anderson, W.G., and McKinley, R.S., 1999, Evidence to challenge the “2% Rule” for biotelemetry, North American Journal of Fisheries Management, v. 19, p. 867–871.

Carpenter, M.C., 1996, Monitoring erosion and deposition using an array of load-cell scour sensors during the spring 1996 controlled flood experiment on the Colorado River in the Grand Canyon, Arizona [abs.]: American Geophysical Union Transactions, v. 77, no. 46, p. F271.

Case, T.J. 1990. Invasion resistance arises in strongly interacting species-rich model competition communities: Proceedings of the National Academy of Science 87:9610–9614.

Case, T.J. and Bolger, D.T., 1991, The role of introduced species in shaping the distribution and abundance of island reptiles: Evolutionary Ecology 5:272–290.

Chezar, H., and Rubin, D., 2004, Underwater microscope system: U.S. Patent and Trademark Office, patent number 6,680,795, January 20, 2004, 9 p.

Close, T.L, and Anderson, C.S., 1992, Dispersal, density-dependent growth, and survival of stocked steelhead fry in Lake Superior tributaries: North American Journal of Fisheries Management, v. 12, p. 728–735.

Coggins, L.G., Pine, W.E., III, Walters, C.J., Van Haverbeke, D.R., Ward, D., Johnstone, H.C., 2006, Abundance trends and status of the Little Colorado River population of humpback chub: North American Journal of Fisheries Management, v. 26, p. 233–245.

Converse, Y.K., Hawkins, C.P., and Valdez, R.A., 1998, Habitat relationships of subadult humpback chub in the Colorado River through Grand Canyon: spatial variability and implications of flow regulation: Regulated Rivers: Research and Management 14: 267-284.

Darwin, C. 1859, The origin of species: Reprinted by Penguin Books, London, U.K.

Draut, A.E., and Rubin, D.M., 2005, Measurements of wind, aeolian sand transport, and precipitation in the Colorado River corridor, Grand Canyon, Arizona—November 2003 to December 2004: U.S. Geological Survey Open-File Report 2005-1309, 70 p., http://pubs.usgs.gov/of/2005/1309/.

Draut, A.E., and Rubin, D.M., 2006, Measurements of wind, aeolian sand transport, and precipitation in the Colorado River corridor, Grand Canyon, Arizona—January 2005 to January 2006: U.S. Geological Survey Open-File Report 2006-1188, 88 p., http://pubs.usgs.gov/of/2006/1188/.

Draut, A.E., and Rubin, D.M., 2007, The role of aeolian sediment in the preservation of archaeological sites in the Colorado River corridor, Grand Canyon, Arizona—Final report on research activities, 2003–2006: U.S. Geological Survey Open-File Report 2007-1001 : http:pubs.usgs.gov/of/2007-1001.

Draut, A.E., Rubin, D.M., Dierker, J.L., Fairley, H.C., Griffiths, R.E., Hazel, J.E., Jr., Hunter, R.E., Kohl, K., Leap, L.M., Nials, F.L., Topping, D.J., and Yeatts, M., 2005, Sedimentology and stratigraphy of the Palisades, Lower Comanche, and Arroyo Grande areas of the Colorado River corridor, Grand Canyon, Arizona: U.S. Geological Survey Scientific Investigations Report 2005-5072, 68 p., http://pubs.usgs. gov/sir/2005/5072.

Elliott, J.M., 1986, Spatial distribution and behavioural movements of migratory trout Salmo trutta in a Lake District stream: Journal of Animal Ecology, v. 55, p. 907–922.

Elliott, J.M., 1994, Quantitative ecology and the brown trout: Oxford, England, Oxford University Press, 287 p.

Elser, J.J., Acharya, K., Kyle, M., Cotner, J.B., Makino, W., Markow, T.A., Watts, T., Hobbie, S.E., Fagan, W.F., Schade, J., Hood, J., and Sterner, R.W., 2003, Growth rate-stoichiometry couplings in diverse biota: Ecology Letters, v. 6, p. 936–943.

Elton, C.S., 1958, The ecology of invasions by animals and plants: Methuen, London, U.K.

Fisher, S. G., Gray, L. J., Grimm, N. B., and Busch, D. E., 1982, Temporal succession in a desert stream ecosystem following flash flooding: Ecological Monographs, v. 52, p. 93–110.

Gaudin, P., 2001, Habitat shifts in juvenile riverine fishes: Arch. Hydrobiol. Suppl., 135/2-4. 393 p.

Goeking, S.A., Schmidt, J.C., and Webb, M.K., 2003, Spatial and temporal trends in the size and number of backwaters between 1935 and 2000, Marble and Grand Canyons, Arizona: Utah State University, Logan, report 01WRAG0059 to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Graf, W.L., 1978, Fluvial adjustments to the spread of tamarisk (*Tamrix chinensis*) in the Colorado Plateau region: Bulletin of the Geological Society of America, v. 89, p. 1491–1501.

Grimm, N.B., and Fisher, S.G., 1989, Stability of periphyton and macroinvertebrates to disturbance by flash floods in a desert stream: Journal of the North American Benthological Society, v. 8, p. 293–307.

Hall, R.O., Rosi-Marshall, E.J., and Baxter, C., 2005, Linking whole-system carbon cycling to quantitative food webs in the Colorado River: Flagstaff, Ariz., research proposal submitted to Grand Canyon Monitoring and Research Center.

Hall, R.O., and Tank, J.L., 2003, Ecosystem metabolism controls nitrogen uptake in streams in Grand Teton National Park, Wyoming: Limnology and Oceanography, v. 48, p. 1120–1128.

Hall, R.O., Wallace, J.B., and Eggert, S.L., 2000, Organic matter flow in stream food webs with reduced detrital resource base: Ecology v. 81, p. 3445–3463.

Hazel, J.E., Jr., Kaplinski, M., Parnell, R., Kohl, K., and Breedlove, M., in review, Chapter 2. Control Network and Conventional Survey Techniques: Fine-Grained Sediment Monitoring in the Colorado River Ecosystem, 26 p.

Hazel, J.E., Jr., Kaplinski, M., Parnell, R., and Manone, M., 2000, Sand Deposition in the Colorado River ecosystem from flooding of the Paria River and the effects of the November 1997, Glen

Canyon Dam Test Flow: Final Report to the Grand Canyon Monitoring and Research Center, Northern Arizona University, Flagstaff, Arizona, 37p.

Hazel, J.E., Jr., Kaplinski, M., Parnell, R., Manone, M., and Dale, A., 1999, Topographic and bathymetric changes at thirty-three long-term study sites, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 161–184.

Hazel, J., Jr., Topping, D.J., Schmidt, J.C., and Kaplinski, M., 2006, Influence of a dam on fine-sediment storage in a canyon river: Journal of Geophysical Research, v. 111, F01025, 16 p.

Heggenes, J., and Traaen, T., 1988, Downstream migration and critical water velocities in stream channels for fry of four salmonid species: Journal of Fish Biology, v. 32, p. 717–727.

Hereford, R., Thompson, K. S., Burke, K. J., and Fairley, H. C., 1996, Tributary debris fans and the Late Holocene alluvial chronology of the Colorado River, Eastern Grand Canyon, Arizona: Geological Society of America Bulletin, v. 108, p. 3–19.

Houde, E.D., 1987, Fish early life dynamics and recruitment variability: American Fisheries Society Symposium 2, p. 7–29.

Hueftle, S.J., and Stevens, L.E., 2001, Experimental flood effects on the limnology of Lake Powell reservoir, southwestern USA: Ecological Applications, v. 11, p. 644–656.

Jensen, A.J., and Johnsen, B.O., 1999, The functional relationship between peak spring floods and survival and growth of juvenile Atlantic salmon (*Salmo salar*) and brown trout (*Salmo trutta*): Functional Ecology, v. 13, p. 778–785.

Kaplinski, M., Hazel, J.E., Jr., Parnell, R., Breedlove, M., and Gonzales, M., in review, The Fine Grained Integrated Sediment Team (FIST) Project: Methods II: Bathymetric surveys for monitoring change in sediment resources within the Colorado River ecosystem, Arizona, 40 p.

Kaplinski, M., Hazel, J.E., Jr., Parnell, R., Breedlove, M., and Schmidt, J.C., 2007, Integrating bathymetric, topographic, and LiDAR surveys of the Colorado River in Grand Canyon to assess the effect of a flow experiment From Glen Canyon Dam on the Colorado River ecosystem: Proceedings of the Hydrographic Society of America 2007 Annual Meeting, May 14–17, Norfolk, Virginia, 22 p.

Kaplinski, M., Hazel, J.E., Parnell, R., Manone, M., and Gonzales, M., 2000, Evaluation of hydrographic survey techniques used for channel mapping by the Grand Canyon Monitoring and Research Center in the Colorado River ecosystem, Grand Canyon, Arizona: Final Report to the Grand Canyon Monitoring and Research Center, Northern Arizona University, Flagstaff, AZ, 37 p.

Kearsley, M.J.C., 2006, Vegetation dynamics in Kearsley, M.J.C. ed., Inventory and monitoring of terrestrial riparian resources in the Colorado River corridor of the Grand Canyon: an integrative approach: Final report from Northern Arizona University submitted to the Grand Canyon Monitoring and Research Center, U.S. Geological Survey, Flagstaff, Ariz., 218 p.

Konieczki, A.D., Graf, J.B., and Carpenter, M.C., 1997, Streamflow and sediment data collected to determine the effects of a controlled flood in March and April 1996 on the Colorado River between Lees Ferry and Diamond Creek, Arizona: U.S. Geological Survey Open-File Report 97-224, 55 p.

Korman, J., Kaplinski, M., Hazel, J.E., and Melis, T.S., 2005, Effects of experimental fluctuating flows from Glen Canyon Dam in 2003 and 2004 on the early life history stages of rainbow trout in the Colorado River: Flagstaff, Ariz., report prepared for Grand Canyon Monitoring and Research Center, 183 p.

Korman, J., Wiele, S.M., and Torizzo, M., 2004, Modelling effects of discharge on habitat quality and dispersal of juvenile humpback chub (Gila cypha) in the Colorado River, Grand Canyon. River Research and Applications 20: 379-400.

Lighthill, M.J., and Whitman, G.B., 1955, On kinematics waves, I. Flood movement in long rivers: Proceedings of the Royal Society A, v. 229, p. 281–316.

Lynch, L.D., Muth, R.T., Thompson, P.D., Hoskins, B.G., and Crowl, T.A., 1996, Options for selective control of nonnative fishes in the upper Colorado River Basin: Utah Division of Wildlife Resources Publication 96-14, Salt Lake City.

MacArthur, R.H., and Wilson, E.O., 1967, The theory of island biogeography: Princeton University Press, Oxford, U.K.

McCune, B., and Grace, J.B., 2002, Analysis of Ecological Communities: Gleneden Beach, Oregon, MjM Software Design.

McKinney, T., Rogers, R.S., Ayers, A.D., and Persons, W.R., 1999, Lotic community responses in the Lees Ferry Reach, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The Controlled Flood in the Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110., p. 249–258.

Meffe, G.K. 1984. Effects of abiotic disturbance on coexistence of predator-prey fish species: Ecology, v. 65, no. 5, p. 1525–1534.

Melis, T.S., Topping, D.J., Rubin, D.M. and Wright, S.A., 2007, Research furthers conservation of Grand Canyon sandbars: U.S. Geological Survey Fact Sheet 2007-3020, 4 p.

Melis, T.S., Martell, S.J.D., Coggins, L.G., Pine, W.E., III, and Andersen, M.E., 2006a, Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: using science and modeling to resolve uncertainty in river management, in Specialty Summer Conference on Adaptive Management of Water Resources, Missoula, Mont., 2006, CD-ROM Proceedings (ISBN 1-882132-71-8): Middleburg, Va., American Water Resources Association.

Melis, T.S., Wright, S.A., Ralston, B.E., Fairley, H.C., Kennedy, T.A., Andersen, M.E., Coggins, L.G. Jr., and Korman, J., 2006b, 2005 knowledge assessment of the effects of Glen Canyon Dam on the Colorado River ecosystem: an experimental planning support document, U.S. Geological Survey, Flagstaff, Ariz., 82 p.

Minckley, W.L., and Deacon, J.E., eds., 1991, Battle Against Extinction: Tucson, University of Arizona Press, 517 p.

Mitro, M.G., Zale, A.V., and Rich, B.A., 2003, The relation between age-0 rainbow trout (*Oncorynchus mykiss*) abundance and winter discharge in a regulated river: Canadian Journal of Fisheries and Aquatic Sciences, v. 60, p. 135–139.

Moulton, M.P., and Pimm, S.L., 1983: The introduced Hawaiian avifauna: biographic evidence for competition: The American Naturalist, v. 121, no. 5, p. 669–690.

Mueller, G.A., 2006, Ecology of bonytail and razorback sucker and the role of off-channel habitats in their recovery: U.S. Geological Survey Scientific Investigations Report 2006-5065, 64 p.

Naiman, R.J., Decamps, H., and McClain, M.E., eds., 2005, Riparia: ecology, conservation, and management of streamside communities: Amsterdam, Elsevier Academic Press.

Parnell, R.A., Jr., Bennett, J., and Stevens, L., 1999, Mineralization of riparian vegetation buried by the 1996 controlled flood, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The Controlled Flood in the Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 225–240.

Patten, D.T., Harpman, D.A., Voita, M.I., and Randle, T.J., 2001, A managed flood on the Colorado River: background, objectives, design, and implementation: Ecological Applications, v. 11, no. 3, p. 635–643.

Paukert, C.P., and Petersen, J.H., 2007, Comparative growth and consumption potential of rainbow trout and humpback chub in the Colorado River, Grand Canyon, Arizona, under different temperature scenarios: The Southwestern Naturalist 52(2): 234-242.

Peterson, C. G., Weibel, A. C., Grimm, N. B., and Fisher, S. G., 1994, Mechanisms of benthic algal recovery following spates: comparison of simulated and natural events: Oecologia, v. 98, p. 280–290.

Petersen, J.H., and C.P. Paukert, 2005, Development of a bioenergetics model for humpback chub and evaluation of water temperature changes in the Grand Canyon, Colorado River, Transactions of the American Fisheries Society 134:960–974.

Pimm, S.L., 1991, The balance of nature?: Chicago, University of Chicago Press.

Rader, R.B., Voelz, N.J., and Ward, J.V., 2007, Post-flood recovery of a macroinvertebrate community in a regulated river: resilience of an anthropogenically altered ecosystem, Restoration Ecology, 2007: 1–10.

Rubin, D.M., 2004, A simple autocorrelation algorithm for determining grain size from digital images of sediment: Journal of Sedimentary Research, v. 74, p. 160–165.

Rubin, D.M., Chezar, H., Topping, D.J., Melis, D.J., and Harney, J., 2007, Two new approaches for measuring spatial and temporal changes in bed-sediment grain size: Sedimentary Geology, 7 p., doi: 10.1016/j.sedgeo.2007.03.020.

Rubin, D.M., Nelson, J.M., and Topping, D.J., 1998, Relation of inversely graded deposits to suspended-sediment grain-size evolution during the 1996 flood experiment in Grand Canyon: Geology, v. 26, p. 99–102.

Rubin, D.M., and Topping, D.J., 2001, Quantifying the relative importance of flow regulation and grain-size regulation of suspended-sediment transport (α), and tracking changes in bed-sediment grain size (β): Water Resources Research, v. 37, p. 133–146.

Rubin, D.M., Topping, D.J., Schmidt, J.C., Hazel, J., Kaplinski, K., and Melis, T.S., 2002, Recent sediment studies refute Glen Canyon Dam hypothesis: EOS, Transactions, American Geophysical Union, v. 83, n. 25, p. 273, 277–278.

Rubin, D., Topping, D., and Wright, S., 2006, Status of sand mass balance in the Colorado River ecosystem below Glen Canyon Dam: memo to J. Hamill, Chief, Grand Canyon Monitoring and Research Center (October 19, 2006), Flagstaff, Ariz.

Schmidt, J.C., Andrews, E.D., Wegner, D.L., Patten, D.T., Marzolf, G.R., and Moody, T.O., 1999a, Origins of the 1996 Controlled Flood in Grand Canyon, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 23–36.

Schmidt, J.C., and Brim-Box, J., 2004, Application of a dynamic model to assess controls on age-0 Colorado pikeminnow distribution in the middle Green River, Colorado and Utah. Annals of the Association of American Geographers. 94(3): 458–476.

Schmidt, J.C., Grams, P.E., and Leschin, M.F., 1999b, Variation and magnitude of deposition and erosion in three long-term (8-12 km) reaches as determined by photographic analyses, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 185–204.

Schmidt, J.C., Parnell, R.A., Grams, P.E., Hazel, J.E., Kaplinski, M.A., Stevens, L.E., and Hoffnagle, T.L., 2001, The 1996 controlled flood in Grand Canyon: flow, sediment transport, and geomorphic change: Ecological Applications, v. 11, no. 3, p. 657–671.

Schmidt, J.C., Topping, D.J., Grams, P.E., and Hazel, J.E., 2004, System-wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, Arizona: Final report submitted to the Grand Canyon Monitoring and Research Center, 107 p.

Shannon, J.P., Blinn, D.W., McKinney, T., Benenati, E.P., Wilson, K.P., and O'Brien, C., 2001, Aquatic food base response to the 1996 test flood below Glen Canyon Dam, Colorado River, Arizona: Ecological Applications, v. 11, p. 672–685.

Speas, D.W., Slaughter, J.E., Rogers, R.S., Makinster, A.S., Ward, D.L., and Persons, W.R., 2002, Status of the Lee's Ferry trout fishery below Glen Canyon Dam, Arizona: 2002 annual report submitted to Grand Canyon Monitoring and Research Center, Flagstaff, Ariz., by Arizona Game and Fish Department.

Stevens, L.E., Ayers, T.J., Bennett, J.B., Christensen, K., Kearsley, M.J.C., Meretsky, J.V., Phillips, A.M., III, Parnell, R.A., Spence, J., Sogge, M.K., Springer, A.E., and Wegner, D.L., 2001, Planned flooding and Colorado River riparian trade-offs downstream from Glen Canyon Dam, Arizona: Ecological Applications, v. 11, p. 701–710.

Stohlgren, T.J., Binkley, D., Chong G.W., Kalkhan, M.A. Schell, L.D., Bull, K.A., Otsuki, Y., Newman, G., Bashkin, M., and Son Yowhan, 1999, Exotic plant species invade hot spots of native plant diversity: Ecological Monographs, v. 69, no. 1, p. 25–46.

Stohlgren, T.J., Bull, K.A., Otsuki, Y., Villa, C.A. and Lee, M., 1998, Riparian zones as havens for exotic plant species in the central grasslands: Plant Ecology, v. 138, p. 113–125.

Thébaud, C., and Debussche, M., 1991, Rapid invasion of Fraxinus ornus L. along the Herault River system in southern France: the importance of seed dispersal by water: Journal of Biogeography, v. 18, p. 7–12.

Topping, D.J., Rubin, D.M., and Melis, T.S., 2007, Coupled changes in sand grain size and sand transport driven by changes in the upstream supply of sand in the Colorado River: Relative importance of changes in bed-sand grain size and bed-sand area: Sedimentary Geology, 24 p., doi: 10.1016/j.sedgeo.2007.03.016.

Topping, D.J., Rubin, D.M., Nelson, J.M., Kinzel, P.J., III, and Bennett, J.P., 1999, Linkage between grain-size evolution and sediment depletion during Colorado River floods, *in* Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, p. 71–98.

Topping, D.J., Rubin, D.M., Nelson, J.M., Kinzel, III, P.J., and Corson, I.C., 2000b, Colorado River sediment transport: pt 2: systematic bed-elevation and grain-size effects of sand supply limitation: Water Resources Research, v. 36, p. 543–570.

Topping, D.J., Rubin, D.M., and Schmidt, J.C., 2005, Regulation of sand transport in the Colorado River by changes in the surface grain size of eddy sandbars over multi-year timescales: Sedimentology, v.52, p. 1133–1153.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Jr., Melis, T.S., Wright, S.A., Kaplinski, M., Draut, A.E., and Breedlove, M.J., 2006a, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2–6, 2006, ISBN 0-9779007-1-1.

Topping, D.J., Rubin, D.M., and Vierra, L.E., Jr., 2000a, Colorado River sediment transport 1. Natural sediment supply limitation and the influence of Glen Canyon Dam: Water Resources Research, v. 36, p.515–542.

Topping, D.J., Schmidt, J.C., and Vierra, L.E., Jr., 2003, Computation and Analysis of the Instantaneous-Discharge Record for the Colorado River at Lees Ferry, Arizona -- May 8, 1921, through September 30, 2000: U.S. Geological Survey Professional Paper 1677, 118 p.

Topping, D.J., Rubin, D.M., Schmidt, J.C., Hazel, J.E., Jr., Melis, T.S., Wright, S.A., Kaplinski, M., Draut, A.E., and Breedlove, M.J., 2006, Comparison of sediment-transport and bar-response results from the 1996 and 2004 controlled-flood experiments on the Colorado River in Grand Canyon: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2–6, 2006, ISBN 0-9779007-1-1.

Topping, D.J., Wright, S.A., Melis, T.S., and Rubin, D.M., 2006b, High-resolution monitoring of suspended-sediment concentration and grain size in the Colorado River using laser-diffraction instruments and a three-frequency acoustic system: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2–6, 2006, ISBN 0-9779007-1-1.

Tyus, H.M, and Saunders, J.F., III, 2000, Nonnative fish control and endangered fish recovery: lessons from the Colorado River: Fisheries v. 9, p. 17–24.

U.S. Department of the Interior, 1995, Operation of Glen Canyon Dam Final Environmental Impact Statement: Salt Lake City, Utah, Bureau of Reclamation, Upper Colorado Region, 337 p.

U.S. Department of the Interior, 2002, Proposed experimental release from Glen Canyon Dam and removal of nonnative fish: environmental assessment: Salt Lake City, Utah, Bureau of Reclamation, Upper Colorado Region, 112 p., appendices.

U.S. Department of the Interior, 2004, Supplemental environmental assessment: proposed experimental actions for water years 2005–2006 Colorado River, Arizona, in Glen Canyon National Recreation Area and Grand Canyon National Park.

U.S. Geological Survey, 2006, Assessment of the estimated effects of four experimental options on resources below Glen Canyon Dam (draft): Flagstaff, Ariz., Southwest Biological Science Center, Grand Canyon Monitoring and Research Center.

Valdez, R.A. and Cowdell, B.R., 1996 (unpublished), Effect of Glen Canyon Dam beach/habitat-building flows on fish assemblages in Glen and Grand Canyons, Arizona: Project completion report.

Valdez, R.A., Hoffnagle, T.L., McIvor, C.C., McKinney, T., and Leibfried, W.C., 2001, Effects of a test flood on fishes of the Colorado River in Grand Canyon, Arizona: Ecological Applications, v. 11, no. 3, p. 686–700.

Valdez, R.A., and Ryel, R.J., 1995, Life history and ecology of the humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona: Final report to Bureau of Reclamation, Salt Lake City, Utah, Contract No. 0-CS-40-09110, BIO/WEST Report No. TR-250-08, 286 pages.

Webb, R.H., Schmidt, J.C., Marzolf, G.R., and Valdez, R.A., eds., 1999, The controlled flood in Grand Canyon: Washington, D.C., American Geophysical Union, Geophysical Monograph Series, v. 110, 367 p.

Wiele, S.M., 1998, Modeling of flood-deposited sand distributions in a reach of the Colorado River below the Little Colorado River, Grand Canyon, Arizona: U.S. Geological Survey Water-Resources Investigations Report 97-4168, 15 p.

Wiele, S.M., Graf, J.B., and Smith, J.D., 1996, Sand deposition in the Colorado River in the Grand Canyon from flooding of the Little Colorado River: Water Resources Research, v. 32, no. 12, p. 3579–3596.

Wohl, E., Bennett, J.P., Blum, M.D., Grant, G.E., Hanes, D.M., Howard, A.D., Mueller, D.S., Schoellhamer, D.H., and Simoes, F.J., 2006, Protocols Evaluation Program (PEP-SEDS III): Flagstaff, Ariz., final report of the Physical Resources Monitoring Peer Review Panel, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, 25p., [http://www.gcmrc.gov/library/reports/PEP/Wohl2006.pdf].

Wright, S.A., and Gartner, J.W., 2006, Measurements of velocity profiles and suspended sediment concentrations in a Colorado River eddy during high flow: CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, Nevada, April 2–6, 2006, ISBN 0-9779007-1-1.

Wright, S.A., Melis, T.S., Topping, D.J., and Rubin, D.M., 2005, Influence of Glen Canyon Dam operations on downstream sand resources of the Colorado River in Grand Canyon, *in* Gloss, S.P., Lovich, J.E., and Melis, T.S., eds., The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282, p. 17–31.

Yeatts, M., 1996, High elevation sand deposition and retention from the 1996 spike flow—an assessment for cultural resources stabilization, *in* Balsom, J.R., and Larralde, S. eds., Mitigation and monitoring of cultural resources in response to the experimental habitat building flow in Glen and Grand Canyons, Spring 1996: Report submitted the Bureau of Reclamation (Grand Canyon Monitoring and Research Center), Flagstaff, Ariz., December 1996, p. 124–158.

Appendix A. Responses to issues raised by members of the Glen Canyon Dam Adaptive Management Program about a future beach/habitat-building flows test

During their meeting on December 5–6, 2006, members of the Glen Canyon Dam Adaptive Management Program (GCDAMP) identified issues of concern for the Grand Canyon Monitoring and Research Center (GCMRC) to consider and address in planning for a future high flow experiment. These concerns are summarized below from the meeting minutes and are followed by short responses prepared by GCMRC staff and cooperating scientists.

Issue 1: What are the tradeoffs between the benefits of a future high flow and possible negative impacts?

This is a broad question and one that GCMRC staff worked to address with input from the entire science staff. Please see appendix A, table A.1 for a summary of the pros and cons associated with a future high flow in late winter or early spring.

Issue 2: If a proposed future experiment is a new experiment, then what are the new hypotheses?

The proposal for a future high flow is a hybrid of the two previous experiments that have been conducted, incorporating key learning from both the 1996 and 2004 high-flow experiments. The next proposed high flow intends to return more closely to the original timing of spring (if sufficient sand enrichment exists at that time) for such a flow operation as described in the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement (EIS), a timing that attempts to approximate the spring flood disturbance regime of the ecosystem that typically occurred before the construction of Glen Canyon Dam. As proposed, it would also be a second test of the concept of implementing the high flow within a period when new sand supplies are known to exist in the main channel following tributary sand inputs. The 2004 high flow revealed that fall sand inputs from the Paria River were retained in the upper reaches of Marble Canyon under constrained daily dam operations that varied between 5,000 and 10,000 cubic feet per second (cfs). As a result, sediment experts determined that the resulting sandbar building using the sand supply was restricted to the upper half of Marble Canyon and that the new sand did not have time under that 60-hour test to be transported to reaches downstream of about river mile 40 or so.

Analysis of the 2004 results produced a revised hypothesis regarding sand transport. This new hypothesis postulates that new sand inputs that enter the ecosystem from the Paria River should be allowed some limited time to be transported downstream into lower Marble Canyon under the 1996 Record of Decision operations. Hence, there is an evolving question about the appropriate timing for when a high flow should optimally be tested and implemented relative to (1) the seasonal timing of when tributary sand typically is introduced to the ecosystem from the Paria River (late summer to fall), (2) how the new sand gets distributed downstream through Marble and Grand Canyons under Record of Decision operations within the months following inputs, (3) whether redistributing the new sand in a more uniform longitudinal pattern downstream before a high flow results in more uniform and robust sandbar deposition, and (4) the season in which historical flood disturbance occurs (spring).

The exact timing of a future high flow will depend on the magnitude of the sand inputs from the tributaries and the magnitudes of releases from the dam. The timing of a high flow could likely occur in spring if sand inputs greatly surpass the proposed trigger for a high flow and dam releases are lower. This would have been the scenario if a high flow had occurred in spring 2007. However, the timing of a high flow would be much earlier (potentially late fall or winter) to still be above the trigger threshold, if sand inputs equal the minimum required by the proposed trigger and are accompanied by moderate to high dam releases.

The science plan for a future high flow proposes to have additional studies tied to food base, fisheries, and cultural sites. The science questions that will be addressed in a future high flow are identified in table A.1. Specific hypotheses associated with these studies are described in the experimental study descriptions included in this science plan.

Issue 3: What is the reason behind replicating the 2004 (high flow) hydrograph?

The concept of replicating the 2004 hydrograph (i.e., replicating that portion of the 2004 hydrograph consisting of the rising limb, peak, and recession of the November 2004 high flow) was discussed extensively among cooperating sediment scientists at the 2005 knowledge assessment workshop convened by the GCMRC with stakeholders. The 2004 test hydrograph was designed using sandbar simulations for a subset of eddies under a scenario of 45,000 cfs peak magnitude and assuming sand concentrations that were measured in the postdam era. This information and data collected from the 1996 high flow were the basis for choosing 60 hours as the duration for the peak flow of a future high flow, a much shorter duration than the 168 hours tested in 1996. The 2004 high flow peak magnitude was limited to 41,500 cfs because one of the eight turbine units at Glen Canyon Dam was undergoing maintenance. The concept of replication of the 2004 hydrograph in a future test is aimed at determining whether or not the robust sandbar-building responses that occurred under the 2004 high flow will occur consistently with sand-enriched conditions. Replication of the 2004 hydrograph during sand-enriched conditions also allows scientists to evaluate whether there are incremental, cumulative benefits to sandbar conservation in lower Marble Canyon and Grand Canyon reaches each time enriched high-flow experiments occur.

If the results from replicating the 2004 hydrograph under sand-enriched conditions in the spring (following several months of downstream transport under the 1996 Record of Decision operations) are as good or better (more uniformly distributed sandbar responses under conditions of more uniformly distributed sand supply downstream) than those measured during the 2004 high flow, then this approach may be interpreted as being a sustainable strategy for longer term habitat restoration and maintenance using only downstream sand supplies. Such a replicated, positive result would also indicate that the more natural timing for flood disturbance in spring can be accomplished while conserving new sand inputs before they are exported to the upper Lake Mead delta. On the other hand, if a different high-flow hydrograph is used for the next test and the results are not as good as 2004 high-flow results, then the lack of replication will make it very difficult to determine whether the response was the result of different timing and supply conditions or to the different hydrograph.

Because the 2004 hydrograph design was tied to sandbar and eddy simulations made using measured channel topography and sediment transport data, and because the 2004 high flow did result in robust sandbar building in the reach where the sand supply was locally enriched (upper Marble Canyon), it seems reasonable to return to this hydrograph design for a future high flow to confirm its effectiveness.

Issue 4: What would be the pros and cons of a shorter-duration high-flow peak at 41,500 cfs (for instance, 30 hours)?

Discussions among scientists and managers about alternative duration peak flows for future high flow (i.e., shorter than the 60-hour peak tested in 2004) have been ongoing during recent planning activities. There are many factors to consider related to peak-flow duration and peak magnitudes for high-flow experiments (see appendix A, table A.2).

Issue 5: Is there a risk of a potential take or impact (of a future high flow) on juvenile humpback chub? HBC recruitment?

Assuming a future high flow will occur in spring, there appears to be little risk to juvenile humpback chub associated with a future high flow, given the results of fisheries studies conducted in association with the 1996 high-flow experiment in Grand Canyon. The abundance of juvenile humpback chub in the mainstem Colorado River is driven, in part, by freshet events in the Little Colorado River. Because the proposed timing of a future high flow is generally tied to late winter or early spring, scientists at the GCMRC expect few freshet events and therefore few juvenile humpback chub to be present in the mainstem Colorado River. This alone will reduce the number of humpback chub vulnerable to potential displacement or mortality because of a future high flow. Following extensive sampling to measure abundance of fish before and after the spring 1996 experiment, catch-rate metrics showed insignificant differences before and after the experiment for most fish (Valdez and others, 2001). The exceptions were a significant decrease in the abundance of small-bodied nonnative fish and a significant increase in the abundance of speckled dace. Additionally, results from telemetry and diet work suggest minimal behavioral or feeding disruptions of adult humpback chub and flannelmouth sucker associated with the spring 1996 high flow. Relative abundance of juvenile native fish was also estimated before and after the 2004 high flow downstream of the Little Colorado River confluence (GCMRC unpub. data; Coggins and others, 2005). Unfortunately, the results of the fall 2004 study were highly inconclusive owing to elevated turbidity following the 2004 high flow caused by flooding activity in the Little Colorado River. These conditions rendered catch-rate observations taken before and after the experiment unreliable, which was likely the result of changes in sampling gear efficiency.

The finding that native fish are little affected by high-flow events, which emerged from research associated with the 1996 high flow, is consistent with theory and other published studies. Meffe (1984) found that adapted native fish species tolerated elevated discharge associated with freshets better than introduced species. Brouder (2001) found that age-1 native roundtail chub increased or remained high in years following a late winter/early spring flood. Indeed, this differential tolerance to flooding has been suggested as a nonnative control method (Minckley and Meffe, 1987). Although these studies view high-discharge events as potential displacement mechanisms rather than direct sources of mortality, there is no evidence that humpback chub recruitment would be directly hindered by a future high flow. On the contrary, one hypothesis is that potential humpback chub recruits might enjoy higher survival rates because of increased food resources (see experimental study 3 description, this plan) and decreased negative interaction with nonnative fishes (Valdez and others, 2001). There is presently insufficient data to arbitrate among these competing hypotheses, although it is certainly valid to hypothesize that a future high flow could hinder recruitment by imposing some direct or indirect mortality source.

Issue 6: Will there be sufficient funds to address the HBC issue (relative to a future high flow)?

The GCMRC believes that funding is not the major impediment to studying the effects of a future high flow on humpback chub. The major challenge is attempting to evaluate changes in the distribution and fate of humpback chub without the appropriate techniques and/or technology to field a viable study (see appendix B).

Issue 7: Will there be negative impacts (from future high-flow experiments) to the food base? Will it clean or refresh the system?

We are uncertain about these important questions. While we know that the biomass (a static measure) of food base components is temporarily reduced following a future high flow, little is known about the effect of a future high flow on productivity (a dynamic process measure). The GCMRC's working hypothesis included in this science plan is that after the initial reduction in food following a future high flow, daily production and turnover of algae, invertebrates, and possibly fish are higher than before the high flow. This positive response by the food base may offset the initial negative effects such that there is little net loss of material and productivity when viewed on slightly longer time scales (months to a year). This knowledge gap is precisely why at least one additional high flow is needed to pin down quantitative answers for the important questions raised above.

Issue 8: What are the impacts (of a future high flow) on hydropower and other economic interests (i.e., fishing guides and river guides)?

Comprehensive studies to assess the economic impacts of conducting a future high flow have not been conducted, and, therefore, the full range of economic impacts cannot be definitively determined with available information. Based on the recent economic assessment by the Western Area Power Administration (WAPA) for the experimental options study (conducted in 2006 by the Science Planning Group), there would be some short-term, but significant, economic impacts for hydropower in the form of lost revenue generation opportunities (loss of potential marketable power because of water bypassing the generators during a future high flow). There would also be some immediate short-term gains resulting from running the generators at full capacity during a future high flow, although the gains would not be sufficient to offset future lost opportunity costs. In terms of recreational economic interests, short-term impacts are likely to the local fishing guide economy during and probably immediately following a future high flow. Based on the proposed timing and duration of the event, however, and considering the hypothesized response of the aquatic food base over the long term (short-term decline followed by relatively rapid rebound and potentially increased productivity), the economic impact to recreational fishing is uncertain and yet to be studied. Projected economic impacts to commercial river runners, on the other hand, are likely to be very minimal to nonexistent because the proposed timing of a future high flow will occur before the start of the commercial boating season. The larger question that remains to be determined is whether the combined potential economic impacts of conducting a future high flow outweigh the potential resource benefits and societal value derived from conducting the experiment. The answer to this question is critical for assessing the overall economic implications of a high flow. The GCDAMP is currently lacking up-to-date, comprehensive valuation data to address this larger economic question. A more comprehensive study of the economic impacts of conducting a future high flow considered during development of the Long Term Experimental Plan.

Issue 9: High-flow experiments result in a lot of sediment below Diamond Creek, resulting in economic concerns for the Hualapai Nation. Additionally, there is an archaeological site below Glen Canyon Dam that going to be harmed unless there is a plan for that site.

In recent years, with the lowering of Lake Mead because of drought and ongoing water withdrawal, formerly submerged sand deposits at the head of Lake Mead have become increasingly shallow, creating serious challenges for navigation. Also, the exposure of formerly submerged sandbars has cut off access to a formerly popular takeout point at Pierce Ferry. The Hualapai Tribe is concerned that a high flow could exacerbate these current problems by displacing sand from the main channel into areas used as harbors and launch sites by their boat operators. At Diamond Creek and other eddies immediately downstream, sand is very likely to be transferred into the eddies (this is why the previous 2004 high flow built sandbars and benefited camping beaches in a reach where new sand inputs were located). Assuming the lake remains low, a future high flow released into Lake Mead is also likely to generate a strong current in the upper part of the lake, which would remobilize some of the channel-clogging sediment and help to redefine a clear channel through the sandbars in the upper part of the lake. It is unknown whether and to what degree sediment would be redeposited in specific shoreline locations used by the Hualapai Nation tour operators, and whether it would have negative consequences for these commercial operations. What is known with certainty is that a future short-term high flow will not solve, nor will it significantly exacerbate, the long-term issue of sediment buildup in upper Lake Mead with its concomitant implications for future navigability.

The second part of the comment expresses concern about possible negative impacts of a high flow on archaeological sites, particularly one site located in the Glen Canyon reach. In 1996, before the first high flow, the Bureau of Reclamation funded a series of studies to evaluate and mitigate potential effects of high-flow experiments on cultural sites in the river corridor. Following completion of these compliance-driven studies, the Arizona State Historic Preservation Office issued a formal determination of "no adverse effect" for experimental flows up to 60,000 cfs (Nancy Coulam, pers. com., December 7, 2006). Recently, a team of archaeologists and one geomorphologist from the Navajo Nation Archaeology Department (NNAD) completed a geomorphic evaluation of all archaeological sites in the Glen Canyon reach, and they concluded that one site (AZ C:2:32) has the potential to be eroded by a future high flow. During the 1996 mitigation work, there was considerable uncertainty as to whether this site was truly cultural, but the recent reevaluation by NNAD confirms that this is a potentially significant archaeological site containing deposits dating to the late Archaic period, approximately 3,000 years BP. The NNAD archaeologists recommend that a portion of this threatened site adjacent to the river be excavated before conducting a future high flow. Mitigation of potential high-flow impacts is planned to occur in fiscal year 2008, as one component of a larger treatment study being proposed by the Bureau of Reclamation to address impacts of dam operations on archaeological sites.

Issue 10: Time is constrained by the possibility of one dam unit being down for maintenance after March.

From our understanding of the proposed annual maintenance schedule at Glen Canyon Dam, we do not see a problem with having one of the eight turbine units at the dam nonoperational annually through March during a future high flow, although having eight units fully operational would be optimal for sediment studies. A future high flow is not currently proposed for later than March.

Table A.1. Summary of pros and cons associated with conducting a future high flow.

General concerns	Pros	Cons	Uncertainties
Glen Canyon Dam Adaptive Management Program (GCDAMP) Resources	• Probable sandbar restoration and conservation of related physical habitats • Probable improvement of recreational camping sites • Probable enhancement of sediment transport to and mitigation of erosion at some archeological sites through secondary wind deposition • Creation of backwater habitats used by native fishes • Mimics seasonal flood disturbance to river ecosystem	• Lost hydropower capacity and revenue owing to bypass and monthly volume re-scheduling • Possible impact to a cultural site in Glen Canyon (to be mitigated) • Impact to Kanab ambersnail habitat (endangered species) at Vaseys Paradise (to be mitigated) • Increased use of motorized watercraft during Colorado River Management Plan non-motor season in Grand Canyon National Park (to be mitigated through public outreach)	• Aquatic food abundance • Impacts and/or benefits to humpback chub remain uncertain • Impacts on rainbow trout fishery • Impacts on native and nonnative terrestrial vegetation
Science (Learning by Doing)	• Advances learning about options for achieving GCDAMP goals related to sediment, humpback chub, food base, cultural resources, camping beaches, and riparian habitat • Provides information about optimal high-flow hydrograph design to maximize benefit and minimize costs • Informs interested public • Information transfer to other scientists and managers working on river restoration	• None	• None
Experimental fund budget	• Credible subset of studies can be implemented to address high-priority needs	• Available experimental funding is currently insufficient to implement all proposed studies	• None
Economic impacts	• Infusion of local economic activity linked to science support, etc.	• Foregone hydropower capacity in later timeframe (to be quantified by BOR/WAPA) • Potential short-term disruption of Lees Ferry angling recreation	• Financial impact is not yet fully quantified • Non-use values derived from resource effects are not known?

Table A.1. Summary of pros and cons associated with conducting a future high flow.—Continued.

Influence on annual work plan	• Shifts emphasis from solely monitoring to EXP research learning activities in a given year • New information will better inform GCDAMP process	• Number of non-experimental planned activities will need to be delayed/deferred • Impacts timing of some normal monitoring activities	• Full impact on a given typical annual work plan schedule is not completely known?
No high-flow experiments alternative (science/resource perspective)	• Would not impact annual work plan tasks of monitoring • Monitoring data on downstream fate of new sand supplies under modified low fluctuating flow (MLFF) • No hydropower impacts	• No opportunity to benefit sand and related physical habitats (such as backwaters that may benefit juvenile humpback chub) • Already have abundant data on export of sand under MLFF, hence little new learning would occur • No opportunity to learn more about how high-flow experiments may limit sand export under fluctuating flows that follow • Missed opportunity to gather data on high-flow experiments as related to strategic, experimental questions about sand conservation and effectiveness of high-flow experiments to meet Goal #8 objectives • High-flow experiments are dependent on meeting the sediment input trigger	• There is great uncertainty about when conditions in the future will trigger an enriched high-flow experiment owing to the fact that sand inputs from the tributaries cannot be predicted

Table A.2. Comparison of a 60-hour to 30-hour peak duration high flow at 45,000 cubic feet per second (cfs).

High-flow peak duration at 41,500 cfs	~ Glen Canyon Dam bypass volume (Hours)	Pros	Cons
OPTION A 60 hours (as determined by model simulations and recommended by sediment scientists)	~ 93,000 acre feet (91 hours)	• Provides most rigorous direct comparison with 2004 high-flow data • Maximum sandbar restoration predicted from modeling to occur in this timeframe • Resulted in net positive sand balance in 2004 high flow • Allows field scientists time for replicate eddy and SS measurements • 108 hours shorter than 1996 high flow • Greatest influence on exporting low oxygen from hypolimnion of Lake Powell	• Bypass volume is larger than suggested alternatives (below) • Highest impact on hydropower • Highest impact on recreational users
OPTION B 30 hours (alternative high-flow hydrograph)	~ 56,000 acre feet (61 hours)	• Reduces bypass volume • Reduced impact on hydropower • Reduced impact on recreational users • Reduces potential export of new sand supply relative to option A	• Potentially limits benefits to downstream sandbar restoration • Limits data capture potential • Shorter high-flow experiments result in less influence on exporting low oxygen from hypolimnion of Lake Powell

References

Brouder, M.J., 2001, Effects of flooding on recruitment of roundtail chub, *Gila robusta*, in a southwestern river: The Southwestern Naturalist, v. 46, no. 3, p. 302–310.

Coggins, L., Yard, M., Persons, B., Van Haverbeke, R, and David, J., 2005, Results of hoopnet sampling to examine changes in juvenile humpback chub abundance and size before and after the 2004 experimental high flow: presentation to the Adaptive Management Workgroup, March 3, 2005, [http://www.usbr.gov/uc/rm/amp/amwg/mtgs/05mar02/documents/Attach_07h.pdf].

Meffe, G.K., 1984, Effects of abiotic disturbance on coexistence of predator-prey fish Species: Ecology, v. 65, no. 5, p. 1525–1534.

Minckley, W.L., and Meffe, G.K., 1987, Differential selection for native fishes by flooding in streams of the arid American Southwest, *in* Matthews, W.J., and Heines, D.C., eds., Ecology and evolution of North American stream fish communities: Norman, Oklahoma, University of Oklahoma Press, p. 93–104.

Valdez, R.A., Hoffnagle, T.L., McIvor, C.C., McKinney, T., and Leibfried, W.C., 2001, Effects of a test flood on fishes of the Colorado River in Grand Canyon, Arizona: Ecological Applications, v. 11, no. 3, p. 686–700.

Appendix B: Factors influencing the design of high flow experimental studies for fisheries and water quality

Fisheries Studies Associated with a Future High Flow

The use of beach/habitat-building flows (BHBF) was identified in the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement (EIS) as a strategy to rebuild sediment resources tied to physical nearshore habitats thought to be important to native fish in the mainstem Colorado River below Glen Canyon Dam. Short-term experimental releases have previously been reported to have limited immediate influence on long-lived fishes (Valdez and others, 2001). It is still unclear what role the abundance, size, and distribution of nearshore sandbar features such as backwaters play in the life history of humpback chub in the Colorado River ecosystem. Evaluating complex and multiyear fish responses that might be associated with infrequent, short-duration high-flow experiments (mostly designed with sediment studies in mind) is difficult. Simply put, the capture and enumeration of rare fishes in a large, turbid river are difficult tasks that, despite recent advances, continue to be associated with high uncertainty.

The GCMRC and its cooperators continue to work on this problem and are improving both capture and estimation techniques for the rare native fishes, especially humpback chub. Because of the high level of interest in these species, monitoring for humpback chub and other native fishes occurs throughout the year (illustrated by the 2007 work plan summarized in table B.1), providing a long-term perspective on the status and trends of these populations. Such a sampling regimen will bracket a future high flow whenever it is scheduled and provide a valuable long-term perspective on the fate of humpback chub and other native fishes.

Table B.1. Native fish monitoring below Glen Canyon Dam in 2007.

Study	Timing	Primary Objective
Downstream Native Fishes	March	Monitor native fishes from Lees Ferry to Diamond Creek (spring)
Little Colorado River (LCR) Humpback Chub	April	Population estimate of humpback chub in the LCR (concurrent sample)
Little Colorado River Lower 1,200 meters/PIT tag antennae	April–May	Intensive monitoring of humpback chub in lowest 1,200 meters of the LCR/test remote PIT tag antennae
Downstream Native Fishes	April	Population estimate of humpback chub in the mainstem Colorado River (concurrent sample)
Little Colorado River Humpback Chub	May	Population estimate of humpback chub in the LCR (concurrent sample)
Downstream Native Fishes	May	Population estimate of humpback chub in the mainstem Colorado River (concurrent sample)
Above Chute Falls	June	Monitor the translocated population of humpback chub upstream in the LCR
Warm Water Fishes/Sonic Tags	June	Monitor channel catfish in lower Colorado River/test application of sonic tags
Above Chute Falls	June-July	Monitor the translocated population of humpback chub upstream in the LCR
Downstream Native Fishes	March	Monitor native fishes from Lees Ferry to Diamond Creek (autumn)
Backwater Monitoring	September–October	Monitor small-bodied fishes in nearshore habitats, primarily backwater eddies
Little Colorado River Humpback Chub	September	Population estimate of humpback chub in the LCR
Little Colorado River Humpback Chub	October	Population estimate of humpback chub in the LCR

Fisheries scientists attempted to evaluate changes in distribution of native and nonnative fishes using catch-rate metrics from conventional sampling gear (e.g., hoopnets, electrofishing, etc.) used during the 1996 and 2004 high-flow experiments. This common strategy was based on the assumption that catch rate (number of fish captured per each unit of sampling effort) is directly proportional to fish abundance. However, this assumption will be violated if the efficiency of the sampling gear (catchability) is substantially affected by any uncontrollable variables (e.g., temperature, turbidity; reviewed by Arreguin-Sanchez, 1996). Therefore, comparisons of catch rate before and after an event like a future high flow are only valid to infer changes in abundance if it can be safely assumed that catchability was equal between the two samples. Violations of this assumption are particularly problematic when comparisons are made between only two events, as opposed to inferring trend in abundance from extensive time-series data, where variability in catchability can sometimes be taken into consideration. Additionally, catch-rate estimates for rare fishes are frequently estimated with low precision. This is clearly illustrated in the results of the 1996 high flow (Valdez and others, 2001). Careful inspection of these results suggests that the statistical power to detect changes in rare species using single-event sampling is very low.

A further problem with this type of study is that displacement does not necessarily imply mortality. For instance, even if the decline in catch rate associated with the 2004 high flow (U.S. Geological Survey, unpub. data; Coggins and others, 2005) was related to a change in abundance rather than a change in catchability, it is unknown whether the change in abundance was because of mortality. It is also possible that this change was simply a result of fish using different habitats following the 2004 high flow, or of temporary downstream displacement. Regardless of which of these hypotheses is correct, this type of study cannot ultimately provide information on the fate of fish associated with a future high flow. Therefore, we conclude that new techniques are required to answer the recurring question asked by managers: What is the fate of juvenile native fish during a future high flow?

We propose that direct measurement of individual fish movement, accomplished through telemetry studies, would be the most conclusive method for inferring the fate of fish associated with a future high flow. Telemetry techniques have advanced substantially in the last decade and we are considering their use to investigate a host of fisheries-related questions (see section 2, experimental study 4.B). However, using telemetry requires substantial training and trial applications. We are currently engaged in trials of this technology, and the initial results are encouraging.

Historically, the Lees Ferry reach has provided an ideal environment for the application of new technologies, suggesting a high probability of success. This is attributable in part to the ease of logistics, the small spatial scale, and the presence of large numbers of study animals (rainbow trout) in a relatively clear aquatic environment. Experimental study 4.B proposes to study the effects of a high flow on the distribution of juvenile and adult rainbow trout in the Lees Ferry reach using both indices of abundance and acoustic telemetry (this gear is being studied in 2007; see table B.1). A study of this nature has a high probability of success for multiple reasons. One benefit of launching this type of study in the Lees Ferry reach is that working with rainbow trout provides ample study organisms that can be collected with little effort. This not only promotes the ability to detect small experimental effects but also incurs modest logistical costs. Alternatively, attempting such a study for humpback chub would likely require a large effort and cost to attain enough organisms. This would be difficult given the proposed timing of a high flow because juvenile humpback chub are at their highest abundance in the mainstem Colorado River during and after the monsoon season (middle to late summer), but far fewer fish are expected to be available for study in November–March (the likely timing of future high-flow experiments).

The mortality risk associated with telemetry studies on juvenile rainbow trout is less than that for juvenile humpback chub because of the broad experience with surgical techniques for juvenile salmonids. The GCMRC and associated cooperators have experimented with sonic telemetry equipment in the Lees Ferry reach to determine its effectiveness under those specific conditions. Initial experimentation in December 2006 was very successful in that experimental sonic tags could be readily tracked in the Lees Ferry reach.

Sonic tags will be tested further in 2007 under more demanding conditions, especially in the presence of higher turbidities than occur in the Lees Ferry reach. The value of the sonic tag technology to the GCDAMP will increase if it can be shown to perform well under the more turbid conditions of the Little Colorado River inflow and below Diamond Creek. Investigators will also gain expertise with implanting these tags in 2007. If the tags are still detectable in turbid conditions, and if investigators achieve good survival rates for fish implanted with the tags during 2007 studies, the GCMRC will propose that this technology be used with individual humpback chub, subject to regulatory agency approval. The 2007 results, and results in future years, will help determine the minimum size of humpback chub that would be proposed for tagging and tracking; however, there is general agreement among the cooperators that younger, smaller fish are of greatest concern and, therefore, would be most important to track. Specific recommendations for use of sonic tag technology, including an associated budget, will be prepared, reviewed, and distributed at least 120 days in advance of a proposed future high flow.

The thoughtful review of the GCDAMP Science Advisors clearly articulates the opinion that additional work on humpback chub should be a priority associated with future high-flow experiments. We attempted to highlight the problems and shortcomings associated with fish sampling and monitoring connected with past experimental high flows and outline our approach to overcoming these issues using telemetry (see above). Subsequently, we have also identified a relatively new set of estimation techniques that could allow better inferences about the effects of high-flow experiments on humpback chub than the index-based methods used in the past.

Since 2000, much work has been done to characterize change in fish population size, distribution, and habitat use in situations where it is not practical to estimate or index abundance (Mackenzie and others, 2006). These newly developed techniques hold promise for quantifying change in fish density and habitat use before and after an experimental high flow. The basic idea is that rather than comparing abundance indices (such as catch per unit effort) before and after some event where the critical assumption of equal capture probability is typically not testable, occupancy models estimate not only the proportion of sampling units occupied, but also the detection probability. As such, probability of occupancy becomes a comparable state variable between, for instance, two time periods. If sampling units are further grouped by a covariate such as habitat type, occupancy rates become a measure of habitat use. Finally, since detection probability is likely influenced by abundance, methods have also been developed to extract abundance.

We are intrigued by this novel approach because of its potential for monitoring small-bodied fish. We plan to analyze several existing datasets, including the data collected in association with the 2004 high flow, and conduct simulation studies using this technique to evaluate its use in estimating fishes before and after any future high flow. Pending these evaluations, we may propose further sampling to estimate occupancy and associated parameters to better understand the effects of experimental high flows on humpback chub. If these methods are shown to be applicable for use in Grand Canyon, then we would propose adding a study for occupancy estimation for humpback chub in association with a high flow. This proposal and associated budget would be submitted for consideration at least 120 days before a proposed future high flow.

Summary of Challenges in Assessing the Effects of a Future High Flow on Native Fish Populations in the Colorado River in Grand Canyon

Trends in Fish Abundance in Glen and Grand Canyons

- Humpback chub abundance in Grand Canyon showed continuing decline through the 1990s, based on catch-per-effort (CPE) and tagging assessments. Trends in adult abundance observed during the 1990s suggest that recruitment of young humpback chub began declining by the mid-1980s. The more rare a species, the more difficult it is to monitor (Thompson, 2004).
- Reductions in daily fluctuations and increased minimum flows beginning in the early 1990s likely caused the large increases in rainbow trout in Glen Canyon and in Grand Canyon near the Little Colorado River confluence where humpback chub are most abundant.
- There is considerable uncertainty about the cause of the decline in humpback chub recruitment. The timing of the recruitment decline in the mid-1980s does not match the timing of the rainbow trout increase in the mid-1990s, although increasing numbers of rainbow trout may have continued to suppress the humpback chub population.

Glen Canyon Dam Treatments Targeted at Improving Humpback Chub Recruitment

The 1996 Biological Opinion for the EIS recommended modifications to Glen Canyon Dam operations designed to rebuild some elements of downstream physical habitat for humpback chub, including:

- Seasonally adjusted steady flows to increase shoreline habitat stability and increase water temperature to stimulate mainstem spawning and improve juvenile survival rates.
- Testing of thermal modification of releases from Glen Canyon Dam.

The most recent experimental flow treatment recommended by the Glen Canyon Dam Adaptive Management Work Group called for increased daily flow fluctuations (5,000–20,000 cfs) from January–March in 2003 and 2004. The increase in daily fluctuations was intended to limit rainbow trout abundance and associated negative interactions with humpback chub.

The use of high-flow experiments to rebuild nearshore sandbar habitats were also described as part of the 1996 Record of Decision, and additional sediment tests were recommended by the GCDAMP as part of integrated physical and biology experimentation in 2002. A second high flow was then conducted in fall 2004 when the Paria River delivered new sand to the ecosystem in Marble Canyon.

The potential for improving our understanding of the effects of dam operations, particularly high-flow experiments, is limited for the following reasons:

- Assessments of juvenile abundance based on catch rate metrics (CPE) are difficult to interpret because of uncontrollable changes in gear efficiency (catchability), particularly for fishes in low abundance and over short time intervals (e.g., difficulty in assessment during the short-term high flow).
- Tagging assessments are more reliable than CPE data, but there is a long lag (3+ years) between the time a change in recruitment occurs and when it can be observed using the tagging assessment data. The occupancy estimation models being investigated by GCMRC and others may be employed to help address earlier life stages.
- Imprecision in all available assessment methods makes it difficult to detect year-to-year differences in recruitment unless they are extremely large.
- Experimental flows need to be replicated over multiple years to account for environmental variability and the limitations in available assessment methodology.
- The short-term single-year approach to experimental management currently adopted by the AMWG greatly reduces the chance of measuring native fish responses and does not embrace recommendations from the broader scientific literature on adaptive management experimental design. Further, the natural variability of annual sand production from the tributaries and other considerations typically mean that a future high flow is likely to occur relatively infrequently under sand-enriched conditions and that annual replication is unlikely.

Evaluating the status and trends of native and nonnative fish populations in Grand Canyon is extremely difficult because of sampling logistics and the low abundance of native fishes, especially in the early months of the year. Application of stock assessment modeling procedures, originally developed for managing commercial fisheries, has been helpful for estimating population trends from the historical fisheries data (Coggins and others, 2006), but tagging-based assessments involve considerable lag time before reliable assessments of recruitment responses to management actions are available. However, the sonic tagging of fish being studied by GCMRC and cooperators has the potential to provide some short-term information on individual fish movements. Tagging will be especially valuable if it proves to be useful in evaluating whether native fishes displaced by temporary high flows retain the ability to return to an area following the flows. Tagging methods are generally not sufficient to resolve whether declines in native fish populations have been caused by the increasing abundance of nonnative fishes, dam operations (including high-flow experiments), or a combination of the two. Our ability to detect fish population responses to a future high flow is limited in spite of the lessons learned from stock assessment modeling and expanded monitoring efforts. Additional methods are needed and are currently under development by the GCMRC and cooperating agencies, especially Arizona Game and Fish Department.

Additional Study to Monitor Backwater Habitats

After reviewing earlier iterations of this plan, comments were received from the GCMRC Science Advisors and from GCDAMP stakeholders requesting additional monitoring of the fish community, especially humpback chub, and fish use of backwater habitats. Despite some of the limitations described above, the GCMRC is proposing expanding efforts to monitor backwater habitats each year whether a high flow is conducted or not. A spring backwater monitoring trip has been proposed to respond to the calls for additional monitoring. Funding for this study is included in this document in case a high flow is implemented before this study can be included in the annual work plan because of timing, funding, or other restrictions.

It is believed that in addition to future high flow tests, by developing and calibrating additional sediment transport and deposition models, scientists will be better able to interpolate between observed effects and help rule out scenarios that are unlikely to yield positive, sustainable results. Some of the data needed to develop a model could be obtained through laboratory studies or field studies conducted during normal flow conditions. Data from the anticipated 2008 high-flow test would also be very important for the development of additional predictive models. Such an approach would likely reduce the overall research costs and help minimize impacts to hydropower.

Water Quality

Any investigation of the dynamics of the Colorado River ecosystem in Grand Canyon must not only document and understand the water quality in Grand Canyon itself, but also the water quality in Lake Powell, the reservoir created by Glen Canyon Dam. The impoundment of a river system in a reservoir alters downstream water quality in many ways (Nilsson and others, 2005). The formation of Lake Powell in 1963 was accompanied by reductions in suspended sediment and nutrient transport and by changes in seasonal temperatures, discharge levels, and benthic community structure of the Colorado River (Paulson and Baker, 1981; Stevens and others, 1997; Topping and others, 2000a; 2000b). More recently, reservoir and downstream water quality has been affected by reservoir drawdown from a 5-year basinwide drought in the Western United States. Water released from Glen Canyon Dam in 2003 and 2004 was the warmest recorded since August 1971, when Lake Powell was in its initial filling period (initial filling of the reservoir began in 1963 with the closure of Glen Canyon Dam; the reservoir reached full pool of 3,700 ft for the first time in 1980).

Water temperature, nutrient concentrations, turbidity, and other water-quality parameters are of interest to managers and scientists because these parameters influence a range of ecosystem components, from support of aquatic microorganisms and invertebrates to the behavior of native and nonnative fishes. For example, water quality is an important determinant of food-web structure in aquatic habitats and the abundance of consumers like fish in those food webs (Carpenter and Kitchell, 1996; Wetzel, 2001).

Scientists hypothesize that operational changes associated with any future high-flow experiments could have significant effects on the quality of water released from Glen Canyon Dam. The experimental work proposed in this science plan will measure changes in water-quality characteristics for the water leaving the dam and the water in the tailwaters during and immediately following a future high flow.

References

Arreguin-Sanchez, F., 1996, Catchability: a key parameter for fish stock assessment: Reviews in Fish Biology and Fisheries, v. 6, p. 221–242.

Carpenter, S.R., and Kitchell, J.F., eds. 1996, The trophic cascade in lakes: Cambridge, England, Cambridge University Press, 385 p.

Coggins, L., Yard, M., Persons, B., Van Haverbeke, R., and David, J., 2005, Results of hoopnet sampling to examine changes in juvenile humpback chub abundance and size before and after the 2004 experimental high flow: Presentation to the Adaptive Management Workgroup, March 3, 2005, [http://www.usbr.gov/uc/rm/amp/amwg/mtgs/05mar02/documents/Attach_07h.pdf].

Coggins, L.G., Pine, W.E., III, Walters, C.J., Van Haverbeke, D.R., Ward, D., Johnstone, H.C., 2006, Abundance trends and status of the Little Colorado River population of humpback chub: North American Journal of Fisheries Management, v. 26, p. 233–245.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L., and Hines, J.E., 2006. Occupancy estimation and modeling. Elsevier, New York.

Nilsson, C., Reidy, C.A., Dynesius, M., Revenga, C., 2005, Fragmentation and flow regulation of the world's large river systems: Science, v. 308, p. 405–408.

Paulson, L.J., and Baker, J.R., 1981, Nutrient interactions among reservoirs on the Colorado River, *in* Stephan, H.G., ed., Proceedings of the Symposium on Surface Water Impoundments: New York, American Society of Civil Engineers, p. 1648–1656.

Stevens, L.E., Shannon, J.P., Blinn, D.W., 1997, Colorado River benthic ecology in Grand Canyon, Arizona, USA: dam, tributary, and geomorphological influences: Regulated Rivers: Research & Management, v. 13, p. 129–149.

Thompson, W.L., ed., 2004, Sampling rare or elusive species: concepts, designs, and techniques for estimating population parameters: Washington, D.C., Island Press.

Topping, D.J., Rubin, D.M., and Vierra, L.E., Jr., 2000a, Colorado River sediment transport: pt. 1: natural sediment supply limitation and the influence of Glen Canyon Dam: Water Resources Research, v. 36, p.515–542.

Topping, D.J., Rubin, D.M., Nelson, J.M., Kinzel, III, P.J., and Corson, I.C., 2000b, Colorado River sediment transport: pt 2: systematic bed-elevation and grain-size effects of sand supply limitation: Water Resources Research, v. 36, p. 543–570.

Valdez, R.A., Hoffnagle, T.L., McIvor, C.C., McKinney, T., and Leibfried, W.C., 2001, Effects of a test flood on fishes of the Colorado River in Grand Canyon, Arizona: Ecological Applications, v. 11, no. 3, p. 686–700.

Wetzel, R.G., 2001, Limnology, lake and river ecosystems (3d ed.): San Diego, Calif., Academic Press, 1006 p.

United States Department of the Interior
BUREAU OF RECLAMATION
Upper Colorado Regional Office
125 South State Street, Room 6107
Salt Lake City, Utah 84138-1147

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DEC 21 2007

MEMORANDUM

To: Steve Spangle
Field Supervisor
U.S. Fish and Wildlife Service
2321 West Royal Palm Road, Suite 103
Phoenix, AZ 85021

From: Larry Walkoviak
Regional Director

Subject: Transmittal of Bureau of Reclamation Biological Assessment Regarding the Operation of Glen Canyon Dam

Pursuant to Section 7(a)(2) of the Endangered Species Act, 16 U.S.C. § 1531 *et seq*. and the implementing regulations at 50 C.F.R. 402.16, Reclamation requested reinitiation of formal consultation with the U.S. Fish and Wildlife Service (Service) regarding operations of Glen Canyon Dam, Colorado River Storage Project, Coconino County, Arizona, by letter dated November 13, 2007.

The basis of this request is new information that may reveal effects of dam operations that may affect listed species including Kanab ambersnail (*Oxyloma haydeni kanabensis*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and southwestern willow flycatcher (*Empidonax traillii extimus*), or designated critical habitat in a manner or to an extent not previously considered. In addition to this new information, Reclamation is proposing experimental modifications of dam operations through water year 2012, as are described in detail in the attached Biological Assessment.

The attached Biological Assessment was prepared by Reclamation staff and contractors as described in 50 C.F.R 402.12. The biological assessment incorporates results of onsite inspections, updates information on listed species and designated habitats based on the views of recognized experts, reviews the literature, and reaches new findings about the status of listed species and critical habitat in the action area below the dam. The findings are that the proposed action, as described in the attached Biological Assessment:

- may affect, is likely to adversely affect the humpback chub and Kanab ambersnail due to potential take of individuals of both species resulting from the proposed high flow test of 41,500 cubic feet per second in March 2008;

- may affect, is not likely to adversely affect the razorback sucker, Southwestern willow flycatcher, and bald eagle because these species are not likely to be present in the action area during the proposed high flow test in March 2008 and because the steady flows proposed during the fall of 2008 through 2012 are not likely to have any measurable effect on the population numbers, distribution, or breeding, feeding, or shelter of these species.

In assessing effects on designated critical habitats below the dam, the proposed action:

- is not likely to result in destruction or adverse modification of designated critical habitat for the endangered humpback chub, listed birds, or invertebrates; and

- the critical habitat for the razorback sucker should now be considered unoccupied critical habitat because the species has not been documented in the action area recently.

In compliance with section 9 of the Endangered Species Act, Reclamation anticipates potential take of individual humpback chub and Kanab ambersnail from the proposed March 2008 high flow test. The form of take is expected to be displacing individual humpback chub and potential harm to Kanab ambersnail resulting from degradation of their habitat during the proposed high flow test. Reclamation is hoping to continue to consult with you regarding ways to minimize or mitigate this incidental take; however, it should be noted that Reclamation does not believe the level of take would result in jeopardy to the continued existence of any species identified in the Service's letter of December 5, 2007.

We appreciate your expedited consideration of this request for reinitiation of consultation in light of the proposal to undertake a high flow experimental release in early March 2008. We also understand that the U.S. Geological Service has nearly completed the science plan associated with the proposed high flow test. In the next few days, we will forward this science plan and wish it to be considered along with the information in this Biological Assessment.

If you have questions regarding the Biological Assessment, please contact Randall Peterson at 801-524-3758.

Attachment

cc: UC-413
UC-438
UC-600
UC-720
(each w/att)

RECLAMATION
Managing Water in the West

Biological Assessment on the Operation of Glen Canyon Dam and Proposed Experimental Flows for the Colorado River Below Glen Canyon Dam During the Years 2008-2012

U.S. Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

December 2007

Table of Contents

1 Introduction and Background

This document serves as the biological assessment for the Bureau of Reclamation's (Reclamation) re-initiation of consultation on the operation of Glen Canyon Dam and proposed experimental flows for the Colorado River below Glen Canyon Dam during the years 2008-2012. It is prepared by Reclamation as part of its compliance with the Endangered Species Act of 1973 (ESA), 87 Stat. 884, as amended, 16 U.S.C. §1531 *et seq*. This document is designed to facilitate compliance with Sections 7 and 9 of the ESA with respect to potential effects to listed species within the United States (US).

1.1 Proposed Federal Action

Reclamation, an agency within the Department of the Interior (Department), operates Glen Canyon Dam of the Colorado River Storage Project as a multipurpose storage facility in northern Arizona. Construction of the dam was authorized by the 1956 Colorado River Storage Project Act and operation of the dam is governed by a complex set of compacts, federal statutes and regulations, court decrees, and an international treaty commonly referred to as the Law of the River and as further described in Section 1.2.1. In the 1980s, Reclamation studied the relationship between the condition of downstream river resources and operations of Glen Canyon Dam, culminating in an environmental impact statement (EIS) finalized in 1995 (Reclamation 1995). Based on analyses in the EIS, the Secretary of the Interior determined in a 1996 record of decision (ROD) that the dam should be operated using the Modified Low Fluctuating Flow (MLFF) Alternative. Region 2 of the U.S. Fish and Wildlife Service (FWS) issued a biological opinion on implementation of the MLFF in 1995 (FWS 1995). The fundamental direction contained in the 1995 Biological Opinion was that future modifications to Glen Canyon Dam operations be analyzed in the context of adaptive management. The 1996 ROD established the Glen Canyon Dam Adaptive Management Program (AMP). Reclamation has undertaken a number of experimental actions consistent with these elements of the ROD and the Biological Opinion; these experimental actions have involved section 7 consultation with the FWS regarding benefits and impacts to listed species, and are fully identified and described in Section 2.1.

In a letter to the FWS dated November 13, 2007, Reclamation requested re-initiation of formal ESA Section 7 consultation on the operation of Glen Canyon Dam. This request is based on the acquisition of new scientific information about the status and trends of federally listed species and effects of dam operations on the species and critical habitat. In a letter dated December 5, 2007, the FWS provided Reclamation with a species list that included humpback chub, razorback sucker, Kanab ambersnail, and Southwestern willow flycatcher.

The request is also based on the fact that Reclamation proposes to conduct experimental releases from Glen Canyon Dam, including one experimental high flow test during 2008 and five years of experimentation implementing steady dam releases during the months of September and October for the period 2008 - 2012. This action is intended to assist in the conservation of endangered species as well as providing benefits to sediment conservation, increase scientific understanding, and to collect data for use in determining future dam operations. Scientific information leading to re-initiation of ESA consultation and the identification of the Proposed Action and preparation of this BA have been developed based on nearly 30 years of experimentation, research, and monitoring of resources of the Colorado River below Glen Canyon Dam, with emphasis on information gained through experimentation and monitoring under the auspices of the AMP, pursuant to the framework required by the 1995 biological opinion. This information includes results of studies gained through implementation of the 2002 Experimental Plan that was the subject of previous Section 7 consultation, and undertaken as part of the AMP, as provided in the 1996 ROD. This research and monitoring information was collected as part of the AMP through a cooperative effort with the US Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC). Participants within the AMP that have contributed the new research and monitoring information include the Adaptive Management Work Group, the Technical Work Group, Science Advisors, and scientists. It is important to note that the Proposed Action is expected to produce an overall additional positive benefit to endangered species (over and above the recent improving status of the endangered humpback chub), as well as critical habitat downstream of Glen Canyon Dam. Reclamation's conclusion is that this overall additional positive benefit will exceed anticipated short-term minor impacts to some resources, including anticipated temporary downstream displacement of humpback chub during experimental high-flow releases designed to enhance areas of backwater habitat.

1.2 Relevant Statutory Authority

In compliance with ESA §7(a)(2) and its implementing regulations, Reclamation is responsible for defining the extent of its discretionary authority with respect to this action. Reclamation's authority stems from the following laws.

1.3 The Law of the River

The 1922 Colorado River Compact divided the mainstream Colorado River and tributaries above Lee Ferry (approximately one mile below the confluence of the Paria and Colorado rivers) into the Upper Basin, and the river and tributaries below that into the Lower Basin. The Secretary of the Interior is vested with the responsibility to manage the mainstream waters of the Lower Basin pursuant to applicable federal law. The responsibility is carried out consistent with a body of documents commonly referred to as the Law of the River. While there is no universally accepted definition of this term, the Law of the River comprises numerous operating criteria, regulations, and administrative decisions included in federal and state statutes, interstate compacts, court decisions and decrees, an international treaty, and contracts with the Secretary.

Notable among these documents are:

1) The Colorado River Compact of 1922 (Compact), which apportioned beneficial consumptive use of water, in perpetuity, between the Upper Basin and Lower Basin;

2) The 1944 Treaty (and subsequent minutes of the International Boundary and Water Commission) related to the quantity and quality of Colorado River water delivered to Mexico;

3) The Upper Colorado River Basin Compact of 1948, which apportioned the Upper Basin water supply among the Upper Basin states;

4) The Colorado River Storage Project Act of 1956 (CRSPA), which authorized a comprehensive water development plan for the Upper Basin, including the construction of Glen Canyon Dam and other facilities;

5) The 1963 United States Supreme Court Decision in *Arizona v. California* which confirmed that the apportionment of the Lower Basin tributaries was reserved for the exclusive use of the states in which the tributaries are located; confirmed the Lower Basin mainstream apportionments of 4.4 million acre-feet (maf) for use in California, 2.8 maf for use in Arizona and 0.3 maf for use in Nevada; provided water for Indian reservations and other federal reservations in California, Arizona and Nevada; and confirmed the significant role of the Secretary in contracting for, and managing the mainstream Colorado River within the Lower Basin;

6) The 1964 US Supreme Court Decree in *Arizona v. California* which implemented the Court's 1963 decision; the Decree was supplemented over time after its adoption and the Supreme Court entered a Consolidated Decree in 2006 which incorporates all applicable provisions of the earlier-issued Decrees;

7) The Colorado River Basin Project Act of 1968 (CRBPA) which authorized construction of a number of water development projects including the Central Arizona Project and required the Secretary to develop Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs (LROC), and issue an annual operating plan (AOP) that, among other information, identifies the anticipated annual operation for mainstream Colorado River reservoirs. The AOP is a single, integrated reference document required by section 602(b) of the CRBPA regarding past and anticipated operations;

8) The Colorado River Basin Salinity Control Act of 1974, which authorized a number of salinity control projects and provided a framework to improve and meet salinity standards for the Colorado River in the United States and Mexico; and

9) The Grand Canyon Protection Act of 1992, which addressed the protection of resources in Grand Canyon National Park and in Glen Canyon National Recreation Area, consistent with applicable federal law.

1.4 Detailed Description of the Proposed Action

1.4.1 Proposed Operation of Glen Canyon Dam

The Proposed Action is to continue Modified Low Fluctuating Flow releases as described in the 1995 EIS. Nothing in this Proposed Action would modify the annual volume of water released from Glen Canyon Dam; this determination is made pursuant to the 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Guidelines or Shortage ROD). These Guidelines were adopted pursuant to a ROD, signed by the Secretary of the Interior on December 13, 2007.

As Reclamation implements the Shortage ROD, MLFF flows will be released as provided in the 1996 ROD, which places significant constraints on allowable fluctuations of powerplant releases. Section 2.2 describes these constraints in greater detail (Table 5). Exception criteria as outlined in the 1997 Glen Canyon Dam Operating Criteria would also continue.

As part of this experimental action, Reclamation proposes to incorporate experimental flows that have been designed to benefit endangered humpback chub and conservation of sediment resources in Grand Canyon. The experimental Proposed Action is: (1) an experimental high flow test of approximately 41,500 cubic feet per second (cfs) for a maximum duration of 60 hours in March 2008, and (2) fall (September and October) steady flows over the next five years (2008 - 2012). The high flow test hydrograph will duplicate the November 2004 high flow test hydrograph and consists of the following elements:

- on the evening of March 2, 2008 (or other approximate date in early March 2008) the MLFF release pattern will increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;
- once powerplant capacity has been reached each of the four bypass tubes will be opened beginning on the morning of March 3, 2007, where once every three hours bypass releases will be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;
- an essentially constant flow of 41,500[1] cfs will be maintained for 60 hours, with flow changes less than 1,000 cfs/day;
- discharge will then be decreased at a down-ramping rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached[2];

The steady releases during September and October of 2008 through 2012 will include the following constraints:

- the typical monthly dam release volumes will be maintained in all water years except water year (WY) 2008, where reallocation of water would occur for the high flow test in March;
- the dam releases for September and October will be steady[3], with a release rate determined to yield the appropriate monthly release volume;

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[1] Maximum capacity value calculated from the November 24-Month Study projected March 2008 Lake Powell reservoir elevation of 3586 feet and interpolated from the maximum full gate turbine capacity for seven units. One of the powerplant units will be off-line for repairs and unavailable for use in the experiment.

[2] If this element of the Proposed Action is undertaken, implementation of the high flow experiment will not affect the annual volume of water released from Glen Canyon Dam during WY 2008.

[3] Regulation release capacity of +/- 1,200 cfs will be available if needed for hydropower system regulation within each hour during the steady flow periods. Also, spinning reserves will be available if needed for emergency response purposes.

- If possible, the monthly dam release volumes should be managed and determined to produce similar volumes in the months of September and October (Table 1).

Monthly dam release volumes during the period of the Proposed Action could vary depending on the annual water release volume, as determined by the Shortage ROD. After 2012, releases would be made according to the 1996 ROD unless the AMP proposes and Reclamation implements experimental alternative release patterns.

Water year 2008 monthly water release volumes would be adjusted to provide water for a March high flow test (Table 1), but this would not cause the annual release from Glen Canyon Dam in WY 2008 to change. Maximum releases during March 2008 under the Proposed Action would be approximately 41,500 cfs during the peak high experimental flows. Tables 2 and 3 provide monthly release volumes and mean, minimum, and maximum daily releases for 10^{th}, 50^{th}, and 90^{th} percentiles determined for the Shortage EIS and ROD (Reclamation 2007). The 7.48 maf release pattern corresponds to the 10^{th} percentile category (dry hydrology), the 50^{th} percentile corresponds to the 8.23 maf pattern, and the 12.3 maf monthly release pattern (wet hydrology) corresponds to the 90th percentile volume for the period of the Proposed Action (2008-2012). All monthly volumes are modeled volumes and subject to change based on actual hydrology and operations.

Releases greater than 9.5 maf generally occur during periods of equalization of reservoir storage contents between Lake Powell and Lake Mead. Implementation of equalization and balancing will follow the Shortage ROD. When operating in the equalization tier, the upper elevation balancing tier, or the lower elevation balancing tier, scheduled water year releases from Lake Powell will be adjusted each month based on forecasted inflow and projected September 30 active storage at Lake Powell and Lake Mead, as discussed in the Shortage ROD.

The high flow test is intended to create and improve eddy complexes, including backwater habitats and beaches. With respect to potential benefits for native fish, the hypothesis to be tested is that widespread beach building and sediment retention will result from controlled releases from the dam under sediment-enriched conditions in Grand Canyon. It is also hypothesized that high releases from the dam will increase sandbar crest height, while increasing return channel depth through scouring. If these geomorphic changes occur as a result of the high flow test, greater and more persistent backwaters could be created, which may benefit conservation of the humpback chub and other native fish species.

Second, by steadying flows during September and October, backwater and other near shore habitat used by young native and endangered fish will become more hydraulically stable, with potentially warmer water temperatures than would exist under regular MLFF operations. These changes could create conditions for improved young-of-year humpback chub survival and growth rates, more persistent suitable habitat (depth and velocity over preferred substrates), and increased productivity of algal and invertebrate prey items for use by humpback chub.

Reclamation considers the high flow test and the steady fall releases experimental actions to better understand benefits to humpback chub and native fish. Hence, the evaluation of the high flow test should focus on benefits to shaping humpback chub habitat, especially nursery backwaters, and the possible downstream transport of young humpback chub. Evaluation of the steady fall flow is important to better understand the contrast between fluctuating flows and steady flows with respect to the extent of longitudinal warming, warming of shoreline habitats and nursery backwaters, stability of shoreline habitats, and the effect on humpback chub survival, growth, and bioenergetic expenditure. Full evaluation of this aspect of the Proposed Action is important to better understand how such test flows affect humpback chub and long-term species conservation. There is a high likelihood that dam releases during this proposed five-year experiment will be cool or cold. If so, this experiment also could provide the opportunity to contrast recent years of cool to warm release temperatures (2003 - 2005) with cool to cold release temperatures during the test period.

Table 1. Projected Glen Canyon Dam releases for Water Year 2008

	Without Proposal (No Action)				Proposed Action			
Month	Monthly Volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)	Monthly Volume (maf)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	600	9,758	6,800	12,800	601	9,774	6,800	12,800
Nov	600	10,083	7,100	13,100	604	10,134	7,200	13,200
Dec	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Jan	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Feb	600	10,804	7,800	13,800	600	10,804	7,400	13,400
Mar	600	9,758	6,800	12,800	830	13,499	7,200	13,200
Apr	600	10,083	7,100	13,100	550	9,243	6,200	12,200
May	600	9,758	6,800	12,800	555	9,042	6,000	12,000
Jun	650	10,924	7,900	13,900	650	10,924	7,900	13,900
Jul	850	13,824	9,800	17,800	820	13,336	9,300	17,300
Aug	900	14,637	10,600	18,600	820	13,336	9,300	17,300
Sep	630	10,588	7,600	13,600	600	10,083	10,083	10,083

Table 2. Projected releases from Glen Canyon Dam without the Proposed Action under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	5,300	10,300	9,758	6,800	12,800	9,378	6,800	12,800
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	7,100	13,100	10,588	7,600	13,600	21,056	19,400	25,000

Table 3. Projected releases from Glen Canyon Dam with the Proposed Action under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012

	7.48 maf			8.23 maf			12.3 maf		
Month	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
Oct	7,502	7,002	8,002	9,758	9,258	10,258	9,378	8,878	9,878
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	8,575	9,575	10,588	10,088	11,088	21,056	20,556	21,556

1.4.2 Basis and Approach to Proposed Action

The purpose of the special experimental high flow test is to take advantage of large amounts of sediment available in the Grand Canyon that currently exist in order to further analyze, through a high flow test, the effectiveness of such an approach to protect and improve downstream resources in the Grand Canyon.

Following the proposed experimental high flow test, the Department will analyze the data collected during the test, as well as information collected during the previous 1996 and 2004 high flow experiments, and other information, in order to develop predictive models and other analytical tools to better inform future decision making regarding dam operations and other related management actions. The Department does not propose through this Proposed Action to undertake any further experimental high flow testing until the information from this element of the Proposed Action is fully analyzed, presented to the Adaptive Management Work Group and the general public and can be integrated into an appropriate analytical framework based on predictive models and other analytical tools.

In proposing this element, the Department intends to undertake a unique experiment based on the extremely favorable sediment conditions afforded by recent high-volume 2006-2007 sediment inputs into the Grand Canyon below Glen Canyon Dam. In proposing this high flow experiment, the Department is not modifying, in any manner, the current long-term management approach to implementation of "beach-habitat building flows" as described in section 3 of the Operating Criteria for Glen Canyon Dam, published at 62 Fed. Reg. 9447 (Mar. 3, 1997). As provided in section 3 of the Operating Criteria, in adopting the management approach for "beach-habitat building flows" the Secretary found that releases pursuant to such an approach "are consistent with the 1956 Colorado River Storage Project Act, the 1968 Colorado River Basin Project Act, and the 1992 Grand Canyon Protection Act." Id. While no modification is proposed or anticipated at this time, any future potential modification of the 1996 ROD or 1997 Glen Canyon

Dam Operating Criteria would only occur after public review, comment and consultation, as well as any required environmental compliance efforts.

The Department recognizes that differences exist with respect to interpretations of certain provisions contained in the "law of the river" related to the implementation of “beach-habitat building flows (BHBFs)” and the proper application and interpretation of those provisions of law. In proposing a single experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours in March 2008, the Department does not intend at this time to revisit or modify, in any manner, the determinations or considerations that led to the adoption of the management approach for BHBFs contained in Section 3 of the 1997 Glen Canyon Dam Operating Criteria or the 1996 ROD. Nor does the Department intend that the implementation of this experimental high flow test constitute a formal determination regarding the multiple and complex issues that would need to be considered in the event that a decision were made to revisit the BHBF management strategy contained in Section 3 of the Glen Canyon Operating Criteria. Accordingly, the Department recognizes that positions and rights concerning the issues related to BHBF management strategies and releases of water from Lake Powell are reserved, and shall not prejudice the position or interests of any stakeholder. The Secretary, through this Proposed Action, makes no determination with respect to the correctness of any interpretation or position of the individual Colorado River Basin states or any other stakeholder. Implementation of this element of the Proposed Action shall not represent a formal interpretation of existing law by the Secretary, nor predetermine in any manner, the means of operation of Glen Canyon Dam that the Secretary may adopt in the future following implementation of the Proposed Action, nor the design and implementation of future experimental actions.

1.4.3 Geographic Scope and Extent of Action Area

The area directly affected by this Proposed Action is Glen Canyon Dam in Coconino County, Arizona downstream to Separation Canyon, Mohave County, Arizona below the 41,500 cfs stage level of the Colorado River, as shown in Figure 1. Below Separation Canyon, ESA compliance is not addressed within the AMP but within the Lower Colorado River Multi-species Conservation Program (MSCP). The MSCP addresses areas up to and including the full-pool elevation of Lake Mead, and downstream areas along the Colorado River within the U.S.

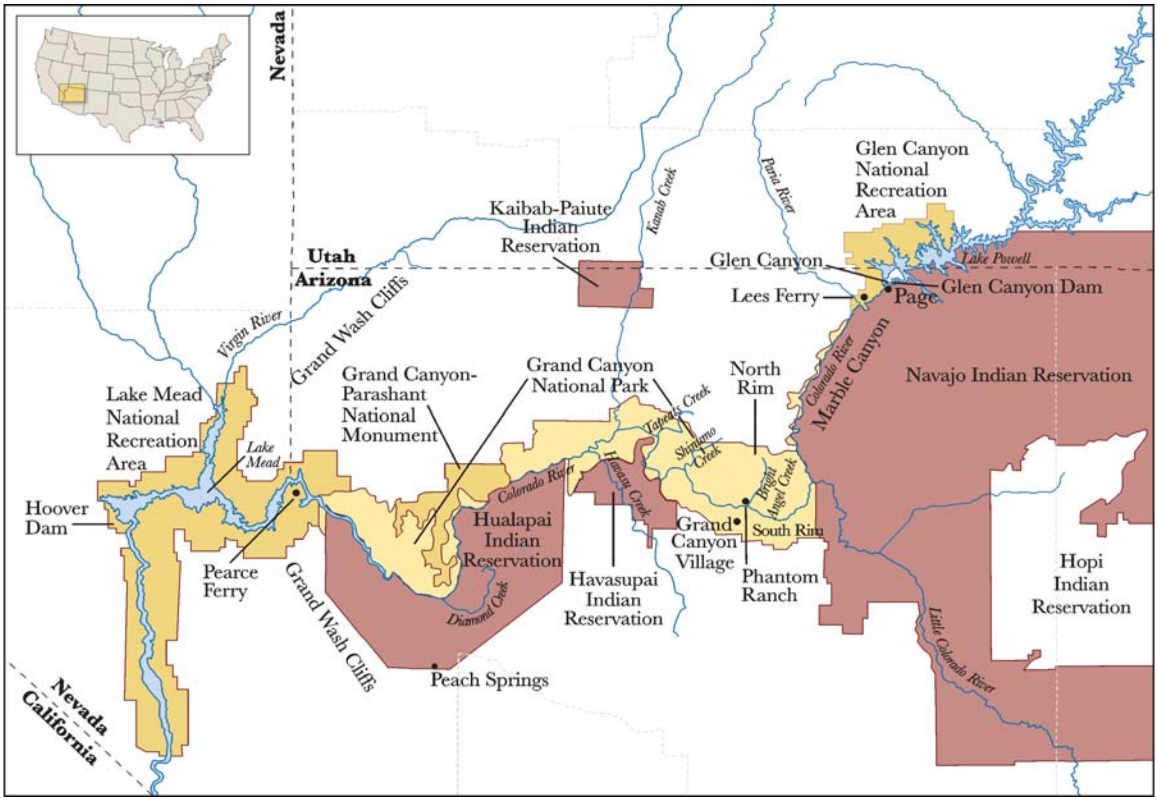


Figure 1. Action area from below Glen Canyon Dam to Separation Canyon.

1.5 Species Identified for Analysis

Four species identified as threatened or endangered are addressed in this biological assessment: Kanab ambersnail (*Oxyloma haydeni kanabensis*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and southwestern willow flycatcher (*Empidonax traillii extimus*). Critical habitat also is considered for humpback chub, razorback sucker, and southwestern willow flycatcher. The list of species is based on a December 5, 2007, letter from the FWS. This biological assessment summarizes Reclamation's consultation history, actions taken in response to the 1995 biological opinion, and distribution and abundance, life requisites, new information resulting from onsite inspections, views of recognized experts, review of the current literature, and potential impacts of the test flows on these species and their habitats. Summary effect determinations are provided in Table 4.

Table 4. Summary of effects determinations for the four listed species

Species	Determination	Basis for Determination
Humpback chub	May affect, is likely to adversely affect	Take could occur from downstream transport during high flow test; long-term benefit to critical habitat from high flow test and potential benefit to juvenile fish from steady fall flows

Razorback sucker	May affect, not likely to adversely affect	Critical habitat in action area is unoccupied
Kanab ambersnail	May affect, is likely to adversely affect	A percentage of snails and habitat will be translocated during high flow test; while moving snails, some take may occur resulting in an adverse effect; no effect on snails or habitat would result from steady fall flows
Southwestern willow flycatcher	May affect, not likely to adversely affect	Birds will not be present during high flow test, resulting in no effect; birds will be off nests by Sept-Oct, but they will be foraging and there could be some indirect effect to their food

1.6 Summary of New Information

The following bullets identify the key elements of new information referenced in Section 3.2 with respect to these species.

1.6.1 Fluvial Geomorphology and High Flow Tests

- The EIS assumption about main channel accumulation of sediment during years of below average sediment and constant sediment rating curves has been shown to be an incorrect assumption based on more recent monitoring and experimentation (Topping et al. 2000a, b).
- Sediment rates vary significantly with grain size (Topping et al. 2000a, b).
- Tributary inputs are typically transported downstream within months under ROD operations (Rubin et al. 2002).
- Current sediment in the upper reaches of the Grand Canyon are the highest since 1998, and are three times the amount available at the time of the 2004 high flow test.
- Above average sediment inputs were unexpectedly retained during 2006-2007 (USGS 2006b).

1.6.2 Backwaters

- Persistence of backwaters created during 1996 appeared to be strongly influenced by post-high flow dam operations (Brouder et al. 1999).
- Biological effects of fluctuating flows include reduced availability of invertebrate prey, water exchange with main channel, and reduced temperature (Grand et al. 2005).
- There is a strong need for additional research on relationship between backwaters and fish habitat suitability and humpback chub survival and recruitment.

1.6.3 Water Temperature and Flow Regime

- Reduced Lake Powell elevations can produce significant increases in dam release temperatures.
- Downstream warming of water is directly affected by seasonal climatology and water release volumes (Vernieu et al. 2005).
- Nearshore river areas warm substantially for brief periods each day (Korman 2006).
- Modeling predicts dam releases likely will be cold (<11 °C) during the five years of the Proposed Action.

1.6.4 Humpback Chub

- Recruitment failure through the mid-1990's resulted in a decline of the Little Colorado River (LCR) population of humpback chub to 2,400 to 4,400 adult fish (Coggins et al. 2006).
- Increase in recruitment of humpback chub under MLFF began 4 to 9 years prior to implementation of non-native fish control, warmer dam release temperatures, the 2000 steady flow experiment, and the 2004 high flow test (Coggins 2007).
- Significantly greater numbers of young humpback chub have been found in the mainstem during 2002 to 2006, including upstream of the LCR (Ackerman 2007).
- Current adult population estimates for humpback chub have increased to an estimated 5,300 to 6,800 adult fish in 2006 (Coggins 2007).
- Humpback chub translocated above Chute Falls have experienced high survival and growth rates, and are a source of recruitment to the lower LCR and the mainstem (Stone 2007).
- Douglas and Douglas (2007) recommended further study of the 30-mile aggregation of humpback chub to evaluate their potential distinctiveness.
- Mainstem parasite infestation rates in humpback chub are much lower than fish in the LCR, and may be temperature-limited (Arizona Game and Fish Department [AGFD] 1996).
- Hoffnagle (2000) reported greater condition and abdominal fat of humpback chub in the mainstem than the LCR, possibly due to increased prevalence of parasites in the LCR fish.

1.6.5 Non-Listed Native and Non-native Fish

- The Grand Canyon fish community has shifted in the last five years from one dominated by non-native salmonids to one dominated by native species (Ackerman 2007).
- Trout abundance in the Lees Ferry reach has declined but trout condition has increased, reflecting a strongly density dependent fish population (McKinney and Speas 2001).
- A wide range of non-native fish have been captured in the LCR (Stone 2007), indicating that the LCR is a viable conduit for introduction of non-native fish into the mainstem.

1.6.6 Non-native Fish Control

- Electrofishing has reduced the rainbow trout population in the vicinity of the LCR confluence by about 90 percent during 2003-2006 (GCMRC unpublished data).

- Backpack electroshocking in Bright Angel and Shinumo Creeks [has reduced rainbow trout populations] by about 50 percent (Leibfried 2006).

2 Environmental Baseline

2.1 Regulatory Context

The focus of this biological assessment is on the threatened and endangered species that live in the Colorado River and floodplain between Glen Canyon Dam and Separation Canyon, near the inflow area of Lake Mead, Coconino and Mohave counties, northern Arizona (Figure 1). The river flows through the lowermost portion of Glen Canyon National Recreation Area and Grand Canyon National Park.

Observed flows recorded at Lees Ferry, Arizona surface water discharge station for the period 1922 through 2006 are shown in Figure 2. Flow in the Colorado River has varied significantly during the 20th century due to a combination of El Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) processes and due to consumptive use upstream (Webb et al. 2005). For example the highest annual flow volume occurred in 1984 (22.2 maf), and the highest three-year average flow was 20.3 maf for the period 1983-1985. Prior to the current drought, the lowest previous three-year average flows were 7.3 maf from 1954-1956 and 8.0 maf from 1933-1935 (Webb 2004). This variability in annual flow, as well as the water temperature of discharges from Lake Powell as a result of the construction of Glen Canyon Dam, were previously considered by the FWS in their 1995 biological opinion, and thus are part of the baseline.

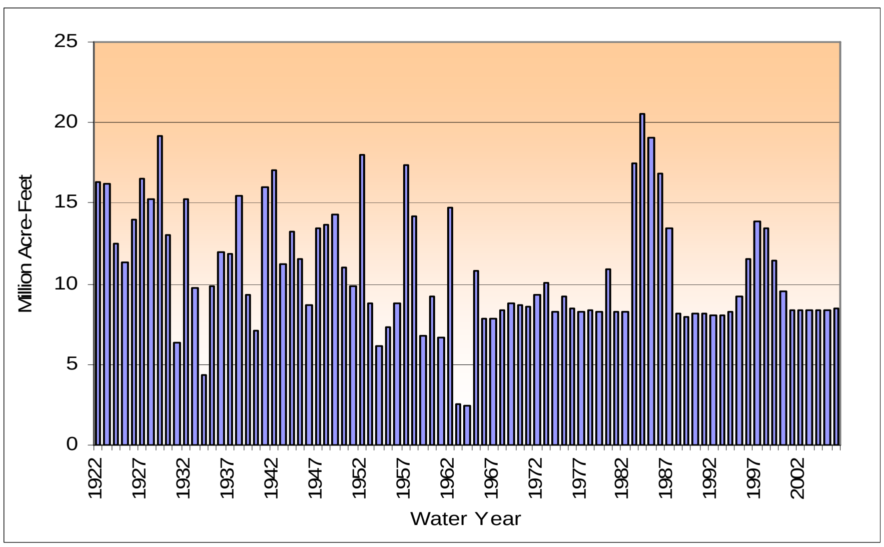


Figure 2. Observed annual stream flow volume (million acre feet) for the Colorado River at Lee's Ferry, AZ, 1922 to 2006.

The eight-year period from 2000 through 2007 was the driest eight-year period in the 100-year historical record of the Colorado River. This drought in the Colorado River Basin has reduced Colorado River system storage, while demands for Colorado River water supplies have continued to increase. From October 1, 1999 through September 30, 2007, storage in Colorado River reservoirs decreased from 55.8 maf (approximately 94 percent of capacity) to 32.1 maf approximately 54 percent of capacity), and was as low as 29.7 maf (approximately 52 percent of capacity) in 2004. Annual releases from Glen Canyon Dam since 2000 have not exceeded 8.23 maf.

Following adoption of the 1996 ROD, Glen Canyon Dam has been operated in accordance with release constraints in Table 5, aside from specific experimental releases in 1996, 1997, 2000 and 2004. These requirements, coupled with those from the Department's Shortage ROD (2007) and its associated biological opinion (FWS 2007), serve as the regulatory baseline for this biological assessment.

Table 5. Glen Canyon Dam release constraints under the 1996 ROD and 1997 Glen Canyon Operating Critera

Parameter	Release Volume (cfs)	Conditions
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

1 May be exceeded for emergency and during extreme hydrological conditions. Emergency exception criteria also exist during normal operations.

2 Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Since 1970, the annual volume of water released from Glen Canyon Dam has been made according to the provisions of the LROC that include a minimum objective release of 8.23 maf. The Shortage ROD (Reclamation 2007b), which implements relevant provisions of the LROC for an interim period through 2026, allows Reclamation to modify these operations by allowing for potential annual releases both greater than and less than the minimum objective release under certain conditions. However, even in years with an annual release less than 8.23 maf, daily and hourly releases would continue to be made according to the parameters of the 1996 Glen Canyon Dam ROD (Reclamation 1996b), which would not be affected in any manner by the Proposed Action. See discussion at Shortage 2007 biological opinion (FWS 2007) and Section 2.2.6 (infra). By comparison, the No Action alternative as described in the Shortage FEIS (Reclamation 2007a) depicts how Reclamation would likely have operated Glen Canyon Dam under shortage conditions without adoption of the Guidelines.

Cold water discharges that have adversely affected native warm water fish and their habitat are part of the baseline. Variations in water year annual releases are in the baseline due to consultations resulting in the 1995 and 2007 biological opinions. Monthly releases that were the subject of prior consultations, as well as the daily fluctuation patterns in Table 5, are also in the baseline.

2.2 Related Consultation History and Experimental Actions Pursuant to the AMP

Reclamation has consulted with the FWS under section 7 of the ESA for various projects that could have had effects on ESA listed species and designated critical habitat within the action area, leading to the definition of the current baseline. Since 1995, Reclamation has consulted with FWS on a total of 5 important experimental actions, and undertaken a sixth experimental action that did not required separate ESA consultation. This history is listed and described below. The FWS issued a "jeopardy" biological opinion in the 1995 biological opinion, but non-jeopardy opinions on all other actions.

2.2.1 1996 Record of Decision on the Operation of Glen Canyon Dam

Reclamation received a final biological opinion from the FWS on the proposed preferred alternative for the Operation of Glen Canyon Dam EIS in January 1995. The FWS concluded that without the included reasonable and prudent alternative, implementation of the MLFF alternative was likely to jeopardize the continued existence of the humpback chub and razorback sucker and was likely to destroy or adversely modify their critical habitat, but was not likely to jeopardize the bald eagle, Kanab ambersnail and peregrine falcon. The 1995 biological opinion on the Operation of Glen Canyon Dam identified one reasonable and prudent alternative (RPA) containing four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker. These elements are described in more detail in Section 3.1. Reclamation has implemented these elements through the principles of adaptive management since 1996 within the Glen Canyon Adaptive Management Program. The FWS has agreed with Reclamation that sufficient progress has been made on some elements of the 1995 biological opinion, which are discussed in detail below in Section 3. Among other considerations, Reclamation has formulated this Proposed Action to address areas that have been identified as not fully achieving sufficient progress.

2.2.2 Spring 1996 High Flow Test from Glen Canyon Dam

Consultation was initiated in November of 1995 for a proposed high flow test from Glen Canyon Dam in the spring of 1996 in the Colorado River. Consultation with the FWS was re-initiated on the preferred alternative from the 1995 FEIS because a new species was listed since the original consultation (southwestern willow flycatcher with proposed critical habitat), and new information revealed that incidental take for the Kanab ambersnail determined in the January 1995 biological opinion preferred alternative would be exceeded. Reclamation concluded in its biological assessment that the test would have no effect on the endangered peregrine falcon, threatened bald eagle and the endangered razorback sucker. The FWS concluded it its biological opinion that the proposed test was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail and southwestern willow flycatcher, and was not likely to destroy or adversely modify humpback chub critical habitat. The FWS also provided a conference opinion that the test was not likely to destroy or adversely modify proposed southwestern willow flycatcher critical habitat.

2.2.3 November 1997 Fall Test Flow from Glen Canyon Dam

The 1997 action was proposed as a test of a powerplant capacity release of 31,000 cfs for 48 hours. While powerplant capacity releases were described in the 1995 EIS as habitat maintenance flows, such a test in the fall was not addressed in the 1995 FEIS, which necessitated additional consultation. The FWS in its biological opinion concluded that the test flow was not likely to jeopardize the continued existence of the humpback chub or Kanab ambersnail and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. The FWS concluded the action would have no effect on the bald eagle or the American peregrine falcon.

2.2.4 2000 Steady Flow Test from Glen Canyon Dam

During the period March 25, 2000 through September 30, 2000, Reclamation conducted a 6-month test of steady flows, high in the spring and low during the summer and fall. Included were two high flow releases at powerplant capacity (31,000 cfs) during early-May and early September. Releases from late-March to late-May were generally steady at about 17,000 cfs, except for a week of high releases of about 19,000 cfs during late-May. Releases during the remainder of the period were steady at 8,000 cfs. This test was performed in accordance with the 1995 biological opinion element, so no additional consultation with FWS was conducted.

2.2.5 2002-2004 Experimental Releases from Glen Canyon Dam and Removal of Non-Native Fish

In 2002, Reclamation, the National Park Service (NPS), and the United States Geological Survey (USGS) consulted with the FWS on: (1) experimental releases from Glen Canyon Dam, (2) mechanical removal of non-native fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish, and (3) release of non-native fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31. Implicit in the experimental flows and mechanical removal Proposed Action was the recognition that modification of dam operations alone likely would be insufficient to achieve objectives of the AMP, which include removal of jeopardy from humpback chub and razorback sucker.

In their biological opinion, the FWS concluded the Proposed Action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher. The December 2002 biological opinion included incidental take of up to 20 humpback chub during the non-native fish removal efforts and the loss of up to $117m^2$ of Kanab ambersnail habitat.

Two conservation measures were included in the FWS biological opinion. The first measure included relocation of 300 humpback chub above Chute Falls in the LCR to increase the likelihood of humpback chub surviving in the lower LCR, reduce predation, and other inclement environmental conditions. The second conservation measure consisted of temporary removal and safeguard of approximately $29m^2$ – $47m^2$ (25 to 40 percent) of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat and ambersnails would be replaced once the high flow was complete to facilitate re-establishment of vegetation.

FWS translocated young humpback chub above Chute Falls in the Little Colorado River (ca. 16 km from the confluence). Under contract with GCMRC, FWS translocated nearly 300 young humpback chub above a natural barrier in the Little Colorado River located 16 km above the confluence in August 2003. This translocation was followed by another 300 fish in July 2004, and finally by another 567 fish in July 2005 (Sponholtz et al. 2005; Stone 2006). Preliminary results indicate that translocated fish survival and growth rates are high; limited reproduction and downstream movement below Chute Falls has also been documented (Sponholtz et al. 2005; Stone 2007).

The sediment input-triggered high experimental flow was analyzed for an indefinite period of time because of the uncertainty of knowing when the sediment trigger would be reached. The other two actions were analyzed for water years 2003 and 2004. Consultation was initiated in 2004 to make several changes to the timing and duration of the proposed experiments described in the 2002 consultation. The 2004 high flow experiment was intended to occur immediately following significant tributary sediment inputs, while the 2002 high flow experiment was proposed to occur in winter or spring. In a biological opinion dated November 2004, the FWS concurred with Reclamation that the action was not likely to adversely affect razorback sucker or its critical habitat, California condor or southwestern willow flycatcher. The FWS concluded that the modified action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, or bald eagle. The FWS also concluded that designated humpback chub critical habitat would not be destroyed or adversely modified. The biological opinion included the 2002 conservation measures related to humpback chub including the continuation of translocating humpback chub in the Little Colorado River, and further study and monitoring of the results and study of effects on chub from various flow conditions.

Reclamation reinitiated Section 7 consultation in March 2003 (Peterson 2003) to propose a change in the size of humpback chub translocated as part of the management activities detailed in the Environmental Assessment of 2002 (USDI 2002). The FWS (2003a) responded with a finding of no jeopardy to the proposed changes. A Finding of No Significant Impact was made in July 2003 by Reclamation and others (2003) on a proposed modification to remove non-native fish from the Colorado River in an expanded area downstream of the confluence with the LCR. The FWS (2003b) concurred with a finding of no jeopardy on the expanded non-native fish action in August 2003. Activities to remove non-native fish from the expanded area (river mile 56.2 to 72.7) were thus incorporated into future non-native removal efforts (Coggins and others 2002).

Kanab ambersnail conservation measures included removal and safeguard of Kanab ambersnail habitat that would be inundated by the experimental release. Reclamation implemented conservation measures for Kanab ambersnail and humpback chub in conjunction with the proposed activities (Peterson 2002).

2.2.6 2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Final EIS

The December 2007 biological opinion on the Shortage ROD included the geographic scope of this biological assessment, Glen Canyon Dam to Lake Mead. The Shortage ROD specified reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. The Shortage ROD, as adopted on December 13, 2007 establish annual release volumes from Glen Canyon Dam, but do not, in any manner, alter the constraints imposed by the 1996 ROD or as adopted in the 1997 Glen Canyon Dam Operating Criteria (discussed in Section 1.4.2). Since many of the potential resource impacts identified in that final EIS were being investigated in the AMP, the biological opinion made use of this institutional arrangement as a key mechanism for addressing these impacts. With respect to the listed species in Grand Canyon the FWS determined that implementation of the Guidelines is not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher.

The following conservation measures were included in the biological opinion: non-native fish control, humpback chub refuge, genetic biocontrol symposium, sediment research, parasite monitoring, and other monitoring and research. These measures are summarized here.

Non-native Fish Control

In coordination with other Interior AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water non-native fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of non-native fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Refuge

Reclamation will assist FWS in development and funding of a broodstock management plan and creation and maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing expedited advancement of $200,000 in funding to the FWS during CY 2008; this amount shall be funded from, and within, the amount identified in the MSCP biological opinion (FWS 2005a; page 26). Creation of a humpback chub refuge will reduce or eliminate the potential for a catastrophic loss of the Grand Canyon population of humpback chub by providing a permanent source of genetically representative stock for repatriating the species.

Genetic Biocontrol Symposium

Reclamation will transfer up to $20,000 in fiscal year 2008 to FWS to help fund an international symposium on the use and development of genetic biocontrol of non-native invasive aquatic species which is tentatively scheduled for October 2009. Although only in its infancy, genetic biocontrol of non-native species is attracting worldwide attention as a potential method of controlling aquatic invasive species. Helping fund an effort to bring researchers together will further awareness of this potential method of control and help mobilize efforts for its research and development.

Sediment Research
In coordination with other Interior AMP participants and through the AMP, Reclamation will monitor the effect of sediment transport on humpback chub habitat and will work with the GCMRC to develop and implement a scientific monitoring plan acceptable to FWS. Although the effects of dam operation-related changes in sediment transport on humpback chub habitat are not well understood, humpback chub are known to utilize backwaters and other habitat features that require fine sediment for their formation and maintenance. Additional research will help clarify this relationship.

Parasite Monitoring
In coordination with other Interior AMP participants and through the AMP, Reclamation will continue to support research on the effects of Asian tapeworm (Bothriocephalus acheilognathi) on humpback chub and potential methods to control this parasite. Continuing research will help better understand the degree of this threat and the potential for management actions to minimize it.

Monitoring and Research
Through the AMP, Reclamation will continue to monitor Kanab ambersnail and its habitat in Grand Canyon and the effect of dam releases on the species, and Reclamation will also continue to assist FWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies.

Monitoring and Research
Through the AMP, Reclamation will continue to monitor southwestern willow flycatcher and its habitat and the effect of dam releases on the species throughout Grand Canyon and report findings to FWS, and will work with the NPS and other AMP participants to identify actions to conserve the flycatcher.

2.3 Description of Glen Canyon Dam Adaptive Management Program

The 1996 ROD directed the formation and implementation of an adaptive management program to assist in monitoring and future recommendations regarding the impacts of Glen Canyon Dam operations. The AMP was formally established in 1997 to implement the Grand Canyon Protection Act (GCPA), the 1995 Operation of Glen Canyon Dam Final Environmental Impact Statement, and the 1996 ROD. The AMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management actions. This is accomplished through the Adaptive Management Work Group (AMWG), a federal advisory committee to the Secretary of the Interior. The AMWG consists of stakeholders that are federal and state resource management agencies, representatives of the seven Basin States, Indian Tribes, hydroelectric power marketers, environmental and conservation organizations and recreational and other interest groups. The duties of the AMWG are in an advisory capacity only. Coupled with this advisory role are long-term monitoring and research activities that provide a continual record of resource conditions and new information to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions.

The AMP consists of the following major components:

- The AMWG which is a federal advisory committee which makes recommendations on how to adjust the operation of Glen Canyon Dam and other management actions to fulfill the obligations of the GCPA.

- The Secretary of the Interior's Designee which serves as the chair of the AMWG and provides a direct link between the AMWG and the Secretary of the Interior.

- The Technical Work Group (TWG) which translates AMWG policy into information needs, provides questions that serve as the basis for long-term monitoring and research activities, and conveys research results to AMWG members.

- The USGS Grand Canyon Monitoring and Research Center (GCMRC) which provides scientific information on the effects of the operation of Glen Canyon Dam and related factors on natural, cultural, and recreational resources along the Colorado River between Glen Canyon Dam and Lake Mead.

- The independent review panels (IRPs) which provide independent assessments of the AMP to assure scientific validity. Academic experts in pertinent areas make up a group of Science Advisors (SAs).

2.4 Description of Species Identified for Analysis

2.4.1 Humpback Chub

Legal Status
The humpback chub (*Gila cypha*) is currently listed as "endangered" under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.). It was first included in the List of Endangered Species issued by the Office of Endangered Species on March 11, 1967 (32 FR 4001) and was considered endangered under provisions of the Endangered Species Conservation Act of 1969 (16 U.S.C. 668aa). The humpback chub was included in the United States List of Endangered Native Fish and Wildlife issued on June 4, 1973 (38 FR No. 106) and received protection as endangered under Section 4(c)(3) of the original ESA of 1973. The latest revised humpback chub recovery plan was approved on September 19, 1990 (FWS 1990a) and Recovery Goals were approved on August 1, 2002 (FWS 2002a). The Recovery Goals were declared "of no force and effect" by a federal judge on January 23, 2006, and were withdrawn by the FWS. Revised Recovery Goals are expected to be issued in 2008. The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374) and final designation became effective on April 20, 1994. Critical habitat includes 280 km of the Colorado River through Marble and Grand canyons from Nautiloid Canyon (RM 34) to Granite Park (RM 208) and the lower 13 km of the LCR. Primary threats to the species include streamflow regulation and habitat modification (including cold-water dam releases and habitat loss), competition with and predation by non-native fish species, parasitism, hybridization with other native Gila, and pesticides and pollutants (Colorado River Fishes Recovery Team 1990; FWS 2002a).

Historical and Current Range

The humpback chub is a moderately large cyprinid fish endemic to the Colorado River system (Miller 1946) that was first described from Grand Canyon specimens in 1946 (Miller 1946). The species was rare in early collections and historical distribution is not known with certainty (Valdez and Clemmer 1982; Tyus 1998). It probably existed in extant populations, each centered in relatively inaccessible canyons at middle elevations of the Colorado River system. It is surmised from various reports and collections that the species presently occupies about 68 percent of its historic habitat of about 756 km of river (FWS 2002a). Range reduction is thought to have been caused primarily by habitat inundation from reservoirs, cold-water dam releases, and non-native fish predation.

Six humpback chub populations are currently known—all from canyon-bound reaches (FWS 2002). Five are in the upper Colorado River Basin and the sixth is located in Marble and Grand canyons of the lower basin. Upper basin populations range in size from a few hundred individuals to about 5,000 adults. These populations are located in reaches that vary from 4 to 74 km within Black Rocks, Westwater Canyon, and Cataract Canyon of the Colorado River; Desolation and Gray canyons of the Green River; and Yampa Canyon of the Yampa River. The lower basin population is found in the Little Colorado River and the Colorado River in Marble and Grand canyons.

Population within the Action Area

The humpback chub presently occurs as nine aggregations within the action area in Marble and Grand canyons (Valdez and Ryel 1995). These aggregations are found within about 295 km of the Colorado River in Marble and Grand canyons and are known as 30-Mile (RM 29.8-31.3), LCR Inflow (RM 57.0-65.4), Lava to Hance (RM 65.7-76.3), Bright Angel Inflow (RM 83.8-92.2), Shinumo Inflow (RM 108.1-108.6), Stephens Aisle (RM 114.9-120.1), Middle Granite Gorge (126.1-129.0), Havasu Inflow (RM 155.8-156.7), and Pumpkin Spring (RM 212.5-213.2). Subsequent monitoring of fish in Marble and Grand canyons has confirmed the persistence of these aggregations (Trammell et al. 2000), although few or no humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Humpback chub have been caught infrequently downstream of Pumpkin Spring. One adult was captured downstream of Maxson Canyon (RM 244) in 1994 (Valdez 1994), and four humpback chub were caught at Separation Canyon (RM 239.5) in 2006 (AGFD 2006).

The largest aggregation is a self-sustaining population located in the lower 13 km of the Little Colorado River and the adjoining 15 km of the Colorado River (RM 57.0-65.4). This population has been expanded upstream of Chute Falls through mechanical translocation of fish (Stone and Sponholtz 2003, 2004) as described in Section 2.1.4.

The population of humpback chub associated with the LCR inflow aggregation is believed to be stable with about 6,000 adults in 2006 (age 4+, ≥200 mm total length (TL); Figure 3; Coggins 2007). Catch rates using hoop nets for subadults and adults show a similar pattern to adult population numbers with earlier decreases followed by more recent increases (Figure 4). Apparent recruitment failure through the mid 1990s resulted in a population decline to a low in 2001 of between 2,400 and 4,400 age 4+ fish (Gloss and Coggins 2005; Coggins et al. 2006). While the recent increase in population size and stability has previously been attributed to increased recruitment resulting from warmer water temperatures, mechanical removal of nonnative piscivorous fish and/or experimental flows (high flow tests, steady flows in 2000), recent modeling suggests that increased recruitment predates each of these factors by at least four years (Coggins et al. 2007). No explanations for this recruitment increase have been proposed to date, particularly whether the increase was due to factors associated with the Little Colorado River, the mainchannel Colorado River, or both parts of the system.

The first population estimate for humpback chub in Grand Canyon was based on a mark-recapture estimator with Carlin-tagged fish (Kaeding and Zimmerman 1982) and yielded a “ball park” estimate of 7,000-8,000 individuals in 1982 larger than 200 mm TL in the Little Colorado River. The estimates shown in Figure 3 are based on the mark and recapture histories of humpback chub with PIT tags, a marking program that began in May of 1989. Valdez and Ryel (1995) used PIT-tagged fish and estimated 3,482 adult (>200 mm TL) humpback chub in a 14-km reach of the mainstream Colorado River near the Little Colorado River inflow for 1990-1993. Douglas and Marsh (1996) estimated the LCR population in 1992 for PIT-tagged humpback chub greater than 150 mm total length at about 4,346 individuals. Since a portion of the humpback chub population moves back and forth between the Little Colorado River and mainstream, some of the same individuals were likely included in both estimates and the total population was less than the sum of these estimates. Valdez and Ryel (1995) also provided mark-recapture estimates for PIT-tagged humpback chub adults (≥200 mm TL) in five of the remaining eight aggregations, including 30-Mile (estimate, n-hat = 52), Shinumo Inflow (n-hat = 57), Middle Granite Gorge (n-hat = 98), Havasu Inflow (n-hat = 13), and Pumpkin Spring (n-hat = 5).

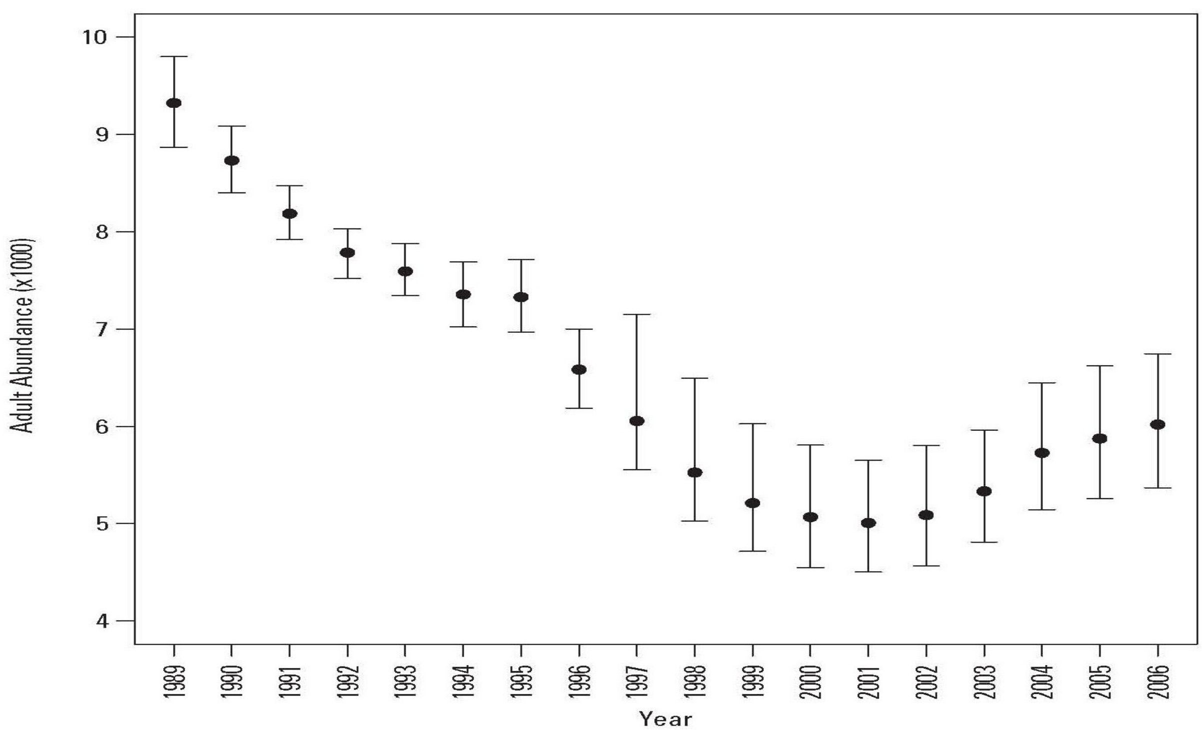


Figure 3. Adult (age 4+) humpback chub population estimates (1989-2005) for the Little Colorado River. Error bars are 95 percent Baysian credibility intervals and reflect uncertainties in assignment of age (USGS 2007).

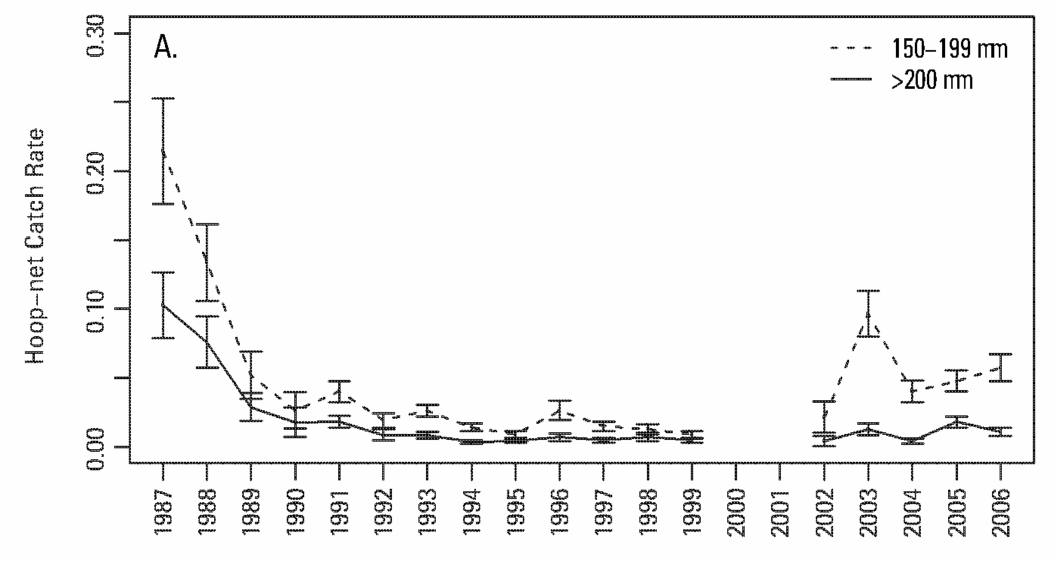


Figure 4. Relative abundance indices of sub-adult (150–199 mm total length (TL)) and adult (>200 mm TL) humpback chub based on hoop-net catch rate (fish/hour) in the lower 1,200-m section of the Little Colorado River.

Young and juvenile humpback chub are found primarily in the Little Colorado River and the Colorado River near the Little Colorado River inflow. Reproduction by humpback chub occurs annually in spring in the Little Colorado River, and the young fish either remain in the Little Colorado River or disperse into the Colorado River. Dispersal of these young fish has been documented as nighttime larval drift during May through July (Robinson et al. 1998), as density-dependence movement during strong year classes (Gorman 1994), and as movement with summer floods caused by monsoonal rain storms during July through September (Valdez and Ryel 1995). Survival of these young fish in the mainstem is thought to be low because of cold mainstem temperatures, but fish that survive and return to the Little Colorado River contribute to recruitment in this population. Fish distribution patterns in the Colorado River downstream of the Little Colorado River and size composition of humpback chub aggregations suggest that young dispersing from the Little Colorado River also recruit into downstream aggregations (Valdez and Ryel 1995). However, the young fish in these aggregations may not all be from the Little Colorado River and some may originate from local reproduction.

Young-of-year and juvenile humpback chub were commonly found from RM 110-130 (Middle Granite Gorge) and RM 160-200 (Ackerman 2007; AGFD 1996; Johnstone and Lauretta 2004, 2007; Trammell et al. 2002). The Middle Granite Gorge aggregation (which includes adults) has been stable or increasing in size since 1993 (Trammell et al. 2002) and may be sustained via immigration from the LCR aggregation, as well as local reproduction. Valdez et al. (2000) identified this aggregation as the most likely candidate for a second spawning population in the mainchannel given favorable conditions (mainly temperature). Population estimates have not been made for other mainstream aggregations since 1993 (Trammell et al. 2002).

Reproduction

The humpback chub is an obligate warm-water species that requires relatively warm temperatures of about 16-22 °C for spawning, egg incubation, and survival of young. Spawning is usually initiated at about 16 °C (Hamman 1982). Highest hatching success is at 19–20 °C with incubation time of 3 days, and highest larval survival is slightly warmer at 21–22 °C (Marsh 1985). Hatching success under laboratory conditions was 12 percent, 62 percent, 84 percent, and 79 percent in 12–13 °C, 16–17 °C, 19–20 °C, and 21–22 °C, respectively, whereas survival of larvae was 15 percent, 91 percent, 95 percent, and 99 percent, at the same respective temperatures (Hamman 1982). Time from fertilization to hatching ranged from 465 hours at 10.0 °C to 72 hours at 26.0 °C, and time from hatching to swim-up varied from 372 hours at 15.0 °C to 72 hours at 21.0–22.0 °C. The proportion of abnormal fry varied with temperature and was highest at 15.0 °C (33 percent) and was 17 percent at 25.0 °C. Marsh and Pisano (1985) also found total mortality of embryos at 5, 10, and 30 °C. Bulkley et al. (1981) estimated a final thermal preference of 24ºC for humpback chub during their first year of life (80–120 mm).

Humpback chub are broadcast spawners with a relatively low fecundity rate compared to cyprinids of similar size (Carlander 1969). Eight humpback chub (355–406 mm TL), injected with carp pituitary and stripped in a hatchery, produced an average of 2,523 eggs/female, or about 5,262 eggs/kg of body weight (Hamman 1982). Egg diameter ranged from 2.6 to 2.8 mm (mean, 2.7 mm). Eleven humpback chub from the LCR yielded 4,831 eggs/female following variable injections of carp pituitary and field stripping (Clarkson 1993).

Humpback chub in Grand Canyon spawn primarily during March–May in the lower 13 km of the Little Colorado River (Kaeding and Zimmerman 1983; Minckley 1996; Gorman and Stone 1999; Stone 1999) and during April–June in the upper basin (Kaeding et al. 1990; Valdez 1990; Karp and Tyus 1990). Most fish mature at about 4 years of age. Gonadal development is rapid between December and February to April, at which time somatic indices reached highest levels (Kaeding and Zimmerman (1983). Adults stage for spawning runs in large eddies near the confluence of the Little Colorado River in February and March and move into the tributary from March through May, depending on temperature, flow, and turbidity (Valdez and Ryel 1995). Spawning has not been observed, but ripe males have been seen aggregating in areas of complex habitat structure (boulders, travertine masses, and other sources of angular variation), and it is thought that ripe females move to these aggregations to spawn (Gorman and Stone 1999). Abrasions on anal and lower caudal fins of males and females in the LCR and in Cataract Canyon (Valdez 1990) suggest that spawning involves rigorous contact with gravel substrates.

Unlike larvae of other Colorado River fishes (e.g., Colorado pikeminnow and razorback sucker), larval humpback chub show little evidence of long-distance drift (Robinson et al. 1998). At hatching, larvae have nonfunctional mouths and small yolk sacs (Muth 1990). The larvae swim up about 3 days after hatching but tend to remain close to spawning sites. Robinson et al. (1998) found small numbers of larvae drifting in the LCR from May through July, primarily at night. Hence, it is believed that the majority of newly-hatched humpback chub remain close to their natal sites.

The presence of young humpback chub in various locations of the Colorado River in Marble and Grand canyons indicates that recruitment is occurring from the Little Colorado River, but there is also a strong evidence of mainstem reproduction. Young humpback chub have been collected in or near Bright Angel Creek, Shinumo Creek, Kanab Creek, and Havasu Creek (Arizona Game and Fish Department 1996, Brouder et al. 1997; Maddux et al. 1987; Kubly 1990). Aside from mainstem reaches immediately below the LCR, young-of-year and juvenile humpback chub have been found in the mainchannel Colorado River most commonly from RM 110-130 (Middle Granite Gorge) and RM 160-200 (AGFD 1996; Trammell et al. 2000; Johnstone and Lauretta 2004, 2007; Ackerman 2006). During 2002-2006, a total of 1,191 humpback chub <100 mm TL were caught in the Colorado River through Marble and Grand canyons (Ackmerman 2007; Figure 5); 442 (mean = 38 mm TL) were upstream of the Little Colorado River and 749 (mean = 67 mm TL) were downstream. Of the 749 fish downstream of the Little Colorado River, 135 were downstream of RM 108 (Shinumo Creek inflow). The fish downstream of Shinumo Creek occurred as three distinct groups, at Stephen Aisle and Middle Granite Gorge (n=40, RM115-135), Havasu Creek to Lava (n=58, RM 155-190), and Pumpkin Spring (n=23, RM 195-220). Four juveniles (64-67 mm TL) were also caught at Separation Canyon (RM 239.5). The combination of larval to postlarval sizes and the low probability of these fish surviving the extreme rapids of the inner gorge in Grand Canyon strongly suggest that their origin is natural reproduction outside of the Little Colorado River.

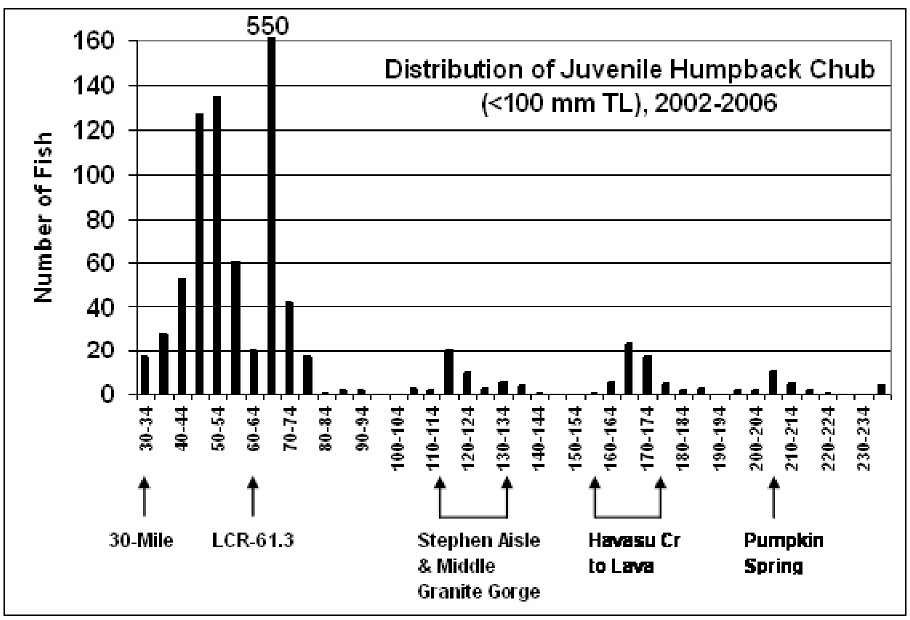


Figure 5. Distribution of juvenile humpback chub <100 mm TL during 2002-2006 by 5-mile increments from RM 30 to RM 230 (data from Ackerman 2007).

Young humpback chub have also been caught upstream of the Little Colorado River. An unknown number of juveniles were caught at RM 44 between 1970 and 1976 (Carothers and Minckley 1981; Suttkus et al. 1976). In 1993, the Arizona Game and Fish Department (1994) captured 20 young-of-year (20-50 mm TL) in a backwater at RM 44.3. The only documented evidence of reproduction was the capture of post-larvae in July, 1994, in a thermal riverside spring located at RM 30.9, about 72 km downstream of Glen Canyon Dam (Valdez and Masslich 1999). The 30-Mile aggregation of humpback chub is associated with this complex of eight warm springs, but the large size structure of the aggregation indicates little recruitment (Valdez and Ryel 1995). During 2002-2006, a total of 442 humpback chub <100 mm TL were captured upstream of the Little Colorado River inflow (RM 61.3) as far upstream as RM 30.7 (Ackmerman 2007). Of the 442 fish, 225 (13-66 mm TL) were caught between RM 30 and RM 50. The 30-Mile aggregation is located 31 miles upstream of the Little Colorado River inflow and it is unlikely that the young humpback chub swam upstream for that distance, especially in the cold mainstem temperatures. Bulkley et al. (1982) found that juvenile humpback chub 73-134 mm TL forced to swim at a velocity of 0.51 m/sec fatigued after an average of 85 minutes at 20 °C, but fatigued after only 2 minutes at 14 °C; a decrease of 6 °C reduced fatigue time by 98 percent. Furthermore, the distribution of these fish (Figure 5), as well as averages size above (mean = 38 mm TL) and below the LCR (mean = 67 mm TL), indicate that the natal source is upstream of RM 50 and not from the Little Colorado River.

From the time that Lake Powell first filled in about 1980 until about 2000, cold hypolimnetic releases of 8-10 °C were characteristic of Glen Canyon Dam operations. These cold temperatures largely prevented mainstem reproduction by humpback chub, except perhaps in localized warm springs (Valdez and Masslich 1999). Throughout this post-dam period, low survival of larval and post-larval fish led to low recruitment to the adult population. This trend was attributed to effects of cold water temperatures (thermal shock, poor swimming performance and predator avoidance) and non-native fish predators and competitors (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Clarkson and Childs 2000, Robinson and Childs 2001; Ward et al. 2002). Low reservoir elevations in recent years have resulted in withdrawal of warmer epilimnetic water from Lake Powell and warmer water temperatures through Marble and Grand canyons, such that in 2005, dam release temperatures reached 18 °C. Dramatic increases in numbers of young flannelmouth suckers and bluehead suckers indicate that these species are spawning in the mainstem with increased growth and survival as a result of warmer temperatures or are experiencing enhanced survival of young fish moving from tributaries to the mainstem. These warm releases may be similarly affecting humpback chub.

Habitat and Movement

At the macrohabitat scale, humpback chub occupy swift, deep, canyon reaches of river (Archer et al. 1985; Valdez and Clemmer 1982; Valdez and Ryel 1995), but microhabitat use varies considerably among age groups (Valdez et al. 1990). Within Grand Canyon, adults demonstrate high microsite fidelity and occupy main channel eddies, while subadults use nearshore habitats (Valdez and Ryel 1995). Young-of-year humpback chub use shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (AGFD 1996). These habitats are usually warmer than the main channel especially if they persist for a long time and are not inundated or desiccated by fluctuating flows (Stevens and Hoffnagle 1999). During the summer months, backwaters offer low velocity, relatively warm, protected, food-rich environments when compared to nearby mainstream habitats (Maddux et al. 1987; Kennedy 1979; Grabowski and Hiebert 1989; Arizona Game and Fish Department 1996; Hoffnagle 1996). Subadults also use shallow, sheltered shoreline habitats but with greater depth and velocity (Valdez and Ryel 1995; Childs et al. 1998). In Grand Canyon, nearly all fish smaller than 100 mm TL were captured near shore, whereas most fish larger than 100 mm TL were captured in offshore habitats (Valdez and Ryel 1995). Highest densities of subadults were found along shorelines with vegetation, talus, and debris fans (Converse et al. 1998). Korman et al. (2004) predicted that downstream displacement rates of small-bodied fish in the Colorado River immediately below the Little Colorado River will increase with increased discharge, but that this pattern would vary considerably with reach geomorphology and assumptions on swimming behavior of the fish.

Valdez and Ryel (1995, 1997) reported that adult humpback chub in the Colorado River in Grand Canyon used primarily large recirculating eddies, occupying areas of low velocity adjacent to high-velocity currents that deliver food items. They also reported that adults congregated at tributary mouths and flooded side canyons during high flows. Adults were captured (88 percent) and radio-contacted (74 percent) primarily in large recirculating eddies disproportionate to their availability (21 percent). Smaller percentages of adults were captured or radio contacted in runs (7 percent and 16 percent, respectively) that comprised 56 percent of surface area, pools (1 percent and 3 percent, respectively) that comprised 16 percent of surface area, and backwaters (4 percent and 7 percent, respectively) that comprised 0.1 percent of surface area. Hoffnagle et al. (1999) reported that juveniles in Grand Canyon used talus shorelines at all discharges and apparently were not displaced by controlled flood of 45,000 cfs in late March and early April, 1996. Valdez et al. (1999) also reported no displacement of radiotagged adults, with local shifts in habitat use to remain in low-velocity polygons within large recirculating eddies.

As young humpback chub grow, they exhibit an ontogenic shift toward deeper and swifter offshore habitats that usually begins at age 1 (about 100 mm TL) and ends with maturity at age 4 (≥200 mm TL; Valdez and Ryel 1995, 1997). In the Colorado River in Grand Canyon, minimum, average, and maximum velocities selected by young-of-year (21–74 mm TL) were 0.0, 0.06, and 0.30 m/s, respectively, all at depths less than 1 m. Minimum, average, and maximum velocities selected by humpback chub (75–259 mm TL) were 0.0, 0.18, and 0.79 m/s, respectively, all at depths less than 1.5 m. Hence, young humpback chub remained along shallow shoreline habitats throughout their first summer, but shifted to more offshore habitats by fall and winter.

Ontogenic shifts in habitat use were also seen in the Little Colorado River. Larval and early juvenile humpback chub used shallow, low-velocity habitats, different than those used by young of other native species, indicating resource partitioning (Childs et al. 1998). Gorman (1994) found that juveniles or early stages less than 50 mm TL occupied near-benthic to mid-pelagic positions in shallow, nearshore areas that were less than 10 cm deep and had low-velocity flow, small substrate particle sizes, moderate cover, and vertical structure. Juveniles 50–100 mm TL used similar habitats of moderate depth (less than 20 cm) that had small to large substrate, moderate to high cover, and vertical structure. Juveniles 100–150 mm TL used shoreline and offshore areas of moderate to deep water (less than 30 cm during the day; less than 20 cm at night) that had slow currents, small and large substrate particle size, moderate to high levels of cover, and vertical structure.

Humpback chub spawn in spring but little is known about specific habitat used for spawning. Gorman and Stone (1999) reported ripe male humpback chub in the Little Colorado River in areas of complex habitat structure (i.e., matrix of large boulders and travertine masses combined with chutes, runs, and eddies, 0.5–2.0 m deep) and associated with deposits of clean gravel. In the Upper Colorado River Basin during spring runoff, spawning adult humpback chub appear to utilize cobble bars and shoals adjacent to relatively low-velocity shorelines that are typically described as runs and eddies (Valdez et al. 1982; Karp and Tyus 1990; Valdez et al. 1990; Valdez and Ryel 1995, 1997). Tyus and Karp (1989) reported that humpback chub in the Yampa

River occupy and spawn in or near shoreline eddy habitats. They hypothesized that spring peak flows were important for reproductive success and that loss or reduction of spring peak flows could potentially reduce availability of spawning habitat.

Movement of adult humpback chub is substantially limited compared to other native Colorado River fishes (Valdez and Ryel 1995). Adults have a high fidelity for site-specific habitats in the Colorado River and generally remain within a 1-km area, except during spawning ascents of the Little Colorado River in spring. Adult radio-tagged humpback chub demonstrated a consistent pattern of greater near-surface activity during the spawning season and at night, and day-night differences decreased during moderate to high turbid.

Growth

Humpback chub attain a maximum size of about 480 mm TL and 1.2 kg in weight (Valdez and Ryel 1997) and can live to be 20-30 years old (Hendrickson 1993). Humpback chub grow relatively quickly at warm temperatures until maturity at about 3 years of age, then grow rate slows substantially. Humpback chub larvae are approximately 7 mm long at hatching (Muth 1990). In a laboratory, post-larvae grew at a rate of 10.63 mm/30 days at 20 °C, but only 2.30 mm/30 days at 10 °C (Lupher and Clarkson 1994). Similar growth rates were reported from back-calculations of scale growth rings in wild juveniles at similar water temperatures from the Little Colorado River (10.30 mm/30 days at 18–25 °C) and the mainstem Colorado River in Grand Canyon (3.50–4.00 mm/30 days at 10–12 °C; Valdez and Ryel 1995). Clarkson and Childs (2000) found that lengths, weights, and specific growth rates of humpback chub were significantly lower at 10 °C and 14 °C (similar to hypolimnetic dam releases) than at 20 °C (i.e., more characteristic of Little Colorado River temperatures during summer months).

Growth rates of humpback chub differ between the Little Colorado River and the mainstem Colorado River. Based on scale back-calculations, humpback chub from the Little Colorado River were 100 mm TL at 1 year of age and 250–300 mm TL at 3–4 years of age (Kaeding and Zimmerman 1983); whereas, fish 1, 2, and 3 years old from the mainstem Colorado River in Grand Canyon were 95, 155, and 206 mm TL, respectively (Valdez and Ryel 1995). Using 30-day growth rates of humpback chub from the Little Colorado River (Minckley 1992), lengths at ages 3 and 4 were estimated at 170 and 200 mm TL, respectively. Mark-recapture data from the Little Colorado River (Minckley 1992) and the Colorado River in Grand Canyon (Valdez and Ryel 1995) show that young humpback chub grow faster in the Little Colorado River (about 10 mm/30 days) than in the mainstem (2–4 mm/30 days), but fish older than about 3 years of age grow faster in the mainstem (0.79–2.79 mm/30 days) than in the Little Colorado River (<1–1.4 mm/30 days). Apparently food resources, habitat, and water temperatures are more suitable for young fish in the Little Colorado River, but habitat, food, and space may be limiting for adults. Abundant habitat, suitable food, and a relatively stable, regulated flow may favor adult growth in the mainstem, despite cold water temperatures.

Hendrickson (1993) aged humpback chub from the Little Colorado River and the mainstem Colorado River in Grand Canyon and showed a maximum of 23 annular rings. Based on polynomial regression of average number of annuli from otoliths (lapillus and asteriscus) and opercles, age-3 fish were 157 mm TL and age-4 fish were 196 mm TL. Valdez and Ryel (1995) recorded size at first observed maturity (based on expression of gametes, presence of spawning tubercles) of humpback chub in Grand Canyon at 202 mm TL for males and 200 mm TL for females; computed length of age-4 fish with a logarithmic growth curve was 201 mm TL.

Meretsky et al. (2000) reported a decline in condition factor of adult humpback chub not in immediate spawning condition from the Little Colorado River confluence from 1978 to 1996, hypothesizing that the decline could be caused by one or more factors; e.g., a recent invasion of the Asian tapeworm (*Bothriocephalus acheilognathi*), researcher variation in weighing fish, or natural population variation. Hoffnagle (2000) reported that condition and abdominal fat were greater in the mainstem Colorado River than in the Little Colorado River during 1996, 1998, and 1999 possibly because of an increased prevalence and abundance of parasites (especially *Lernaea cyprinacea* and *Bothriocephalus acheilognathi*) in the Little Colorado River fish and/or greater food availability in the Colorado River.

Diet

Humpback chub are typically omnivores with a diet consisting of insects, crustaceans, plants, algae, seeds, and occasionally small fish and reptiles (Kaeding and Zimmerman 1982, Kubly 1990, Valdez and Ryel 1995). They appear to be opportunistic feeders, capable of switching diet according to available food sources, and ingesting food items from the water's surface, mid-water, and river bottom. Specimens caught below Glen Canyon Dam in the early 1970's had been feeding on zooplankton flushed from Lake Powell (Minckley 1973). Juvenile humpback chub forage near the substrate, feeding on benthic insect larvae, crustaceans, and organic detritus (Carothers and Minckley 1981). Guts of 158 adults from the mainstem Colorado River, flushed with a nonlethal stomach pump, had 14 invertebrate taxa and nine terrestrial taxa (Valdez and Ryel 1995), including simuliids (blackflies, in 77.8 percent of fish), chironomids (midges, 57.6 percent), *Gammarus* (freshwater shrimp, 50.6 percent), *Cladophora* (green alga, 23.4 percent), Hymenoptera (wasps, 20.9 percent), and cladocerans (water fleas, 19.6 percent). Seeds and human food remains were found in eight (5.1 percent) and seven (4.4 percent) fish respectively. Longitudinal differences in diet were evident reflecting relative abundance of available food sources; i.e., simuliids were available and consumed throughout the canyon, but terrestrial invertebrates replaced *Gammarus* in lower reaches where the latter were absent. Seasonal differences were also evident with *Gammarus* as the primary food item in spring (40.1 percent by volume), and simuliids in summer (46.4 percent) and fall (44.7 percent). Diets of adult humpback chub during an experimental high dam release in 1996 showed a preference for terrestrial insects and aquatic invertebrates dislodged by the flood and entrained in large recirculating eddies (Valdez and Hoffnagle 1999).

Diets of humpback chub from the Little Colorado River and mainstem differ markedly, reflecting available food sources. Although larvae of simuliids and chironomids were present in both groups, *Gammarus* comprised only 1 percent volume of the diet of Little Colorado River fish (Kaeding and Zimmerman 1983), but approximately 64 percent of the diet of mainstem fish (Valdez and Ryel 1995); *Gammarus* are abundant in the mainstem but rare in the Little Colorado River. Adult humpback chub from the Little Colorado River have also been reported to be cannibalistic on their young during periods of high reproductive success (Gorman 1994). Arizona Game and Fish Department (1996a) reported that juvenile humpback chub in Grand Canyon consumed 19 different prey items, eight more than any other species examined. Chironomid larvae, terrestrial insects, simuliid larvae, and copepods were all found in at least 5 percent of the stomachs examined.

A number of investigators have reported large volumes of the green alga *Cladophora* mixed with a variety of invertebrates and detritus in diets of humpback chub from Grand Canyon (Minckley et al. 1980; Carothers and Minckley 1981; Kubly 1990; Valdez and Ryel 1995), suggesting that the fish feed on invertebrates entrained in the algae or the epiphytic diatoms may be an important source of lipids as was found for rainbow trout (Leibfried 1988). Humpback chub diet changes over the course of the year in response to food availability, dam releases and turbidity-related decreases in benthic standing biomass over distance downstream from Glen Canyon Dam (Blinn et al. 1995). However, composition and amount of humpback chub stomach contents were not altered significantly as a result of the 1996 high flow test (Valdez and Hoffnagle 1999).

Valdez and Ryel (1995) documented increasing densities of chironomids and simuliids on the descending limb of the diurnal hydrograph, and McKinney et al. 1999 documented a similar response for *G. lacustris*. In contrast, Grand et al. (2006) predicted that increased daily fluctuations can impede benthic productivity in backwater environments due to dewatered substrate, export of invertebrates through frequent water exhange, and lower temperatures. Thus availability of principle humpback chub forage items may actually be enhanced by daily fluctuations in flow in the mainchannel environment (most frequently occupied by subadult- and adult chub), but not backwaters, which are utilized heavily by young-of-year humpback chub during the months of June through October.

Parasites

The majority of parasites of humpback chub are alien to the Colorado River system, introduced through non-native fishes. Most notable are the external parasitic copepod, *Lernaea cyprinacea*, and the intestinal Asian tapeworm, *Bothriocephalus acheilognathi*. During 1990–1993, *L. cyprinacea* was found on 8 of 6,294 fish from the Colorado River in Grand Canyon for an infection rate of only 0.13 percent and an average of 1.25 copepods (range, 1–2) per infected fish (Valdez and Ryel 1997). None of the infected fish showed signs of stress or illness, although open lesions had formed at some anchor points. This parasite infected 5.3 percent of humpback chub from the Little Colorado River (Hoffnagle et al. 2000). *Lernaea cyprinacea* was first reported from Grand Canyon in 1979 (Carothers et al. 1981) but has not become problematic because the mainstem fails to reach optimum maturation temperatures of 23–30 °C (Bulow et al. 1979). *Lernaea* matures at temperatures as low as 18 °C (Grabda 1963).

The internal Asian tapeworm was first reported from Grand Canyon in 1990 (Brouder and Hoffnagle 1997; Clarkson et al. 1997). During 1990–1993, this parasite was found in gut contents of 6 of 168 (3.6 percent) mainstem adult humpback chub treated with a nonlethal stomach pump, for an average of 6.7 tapeworms per infected fish (range, 1–28; Valdez and Ryel 1997). Clarkson et al. (1997) found Asian tapeworms in 28 percent of sacrificed humpback chub examined from the Little Colorado River in 1990–94. They also reported the parasite in intestines of common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), speckled dace (*Rhinichthys osculus*), and plains killifish (*Fundulus zebrinus*). Brouder and Hoffnagle (1997) also found Asian tapeworms in humpback chub (22.5 percent) from the LCR in 1994, as well as in plains killifish (10.3 percent), speckled dace (3.8 percent), and fathead minnow (2.2 percent). They reported that nearly all (66.7–100 percent) of infected fish were captured near the Little Colorado River, although the parasite was found as far downstream as Kanab Creek, 132 km downstream of the LCR. During 1996–1997, the internal Asian tapeworm occurred in 31.6-84.2 percent of humpback chub examined in the LCR and 8.8–26.7 percent in the Colorado

River (Hoffnagle et al. 2000); *Lernaea cyprinacea* was found on 5.3–47.6 percent of chubs in the Little Colorado River and 0–6.7 percent in the Colorado River; the trematode (*Ornithodiplostomum* sp.) in 50 percent; and the nematode (*Rhabodochona* sp.) in 5.3 percent. Markedly lower infestation rates of most parasites in the Colorado River in Grand Canyon demonstrate the detrimental effect of cold temperatures on most fish parasites of the Colorado River System.

Infection of humpback chub by the Asian tapeworm is a concern because of possible stress and death to the host and widespread infestation during periods of stress. This parasite is able to complete its life cycle in the LCR where the temperature requirement of >20 °C is met (Granath and Esch 1983), and although unable to complete its life cycle in the mainstem, it is apparently able to survive in a fish host in the cold temperatures. Meretsky et al. (2000) hypothesized that an observed decline in condition of adult humpback chub in Grand Canyon was a result of recent infestation by the internal Asian tapeworm.

2.4.2 Razorback Sucker

Legal Status

The razorback sucker (X*yrauchen texanus*) was listed as "endangered" under the Endangered Species Act of 1973, as amended, on October 23, 1991 (56 FR 54957). A recovery plan was approved on December 23, 1998 (FWS 1998) and Recovery Goals were approved on August 1, 2002 (FWS 2002b). The final rule for determination of critical habitat was published on March 21, 1994 (59 FR 13374), and the final designation became effective on April 20, 1994. Designated critical habitat includes the Colorado River and its 100-year floodplain from the Paria River downstream through Marble and Grand canyons to Hoover Dam, including the full pool elevation of Lake Mead. Primary threats to razorback sucker populations are streamflow regulation and habitat modification and fragmentation (including cold-water dam releases, habitat loss, and blockage of migration corridors); competition with and predation by non-native fish species; and pesticides and pollutants (Bestgen 1990, Minckley 1991; FWS 2002b).

Historical and Current Range

The razorback sucker is endemic to the Colorado River system. Historically, it occupied the mainstem Colorado River and many of its tributaries from northern Mexico through Arizona and Utah into Wyoming, Colorado, and New Mexico. In the late 19th and early 20th centuries, it was reported as abundant in the Lower Colorado River Basin and common in parts of the Upper Colorado River Basin, with numbers apparently declining with distance upstream (Jordan and Evermann 1896; Minckley et al. 1991; Mueller 2006). Distribution and abundance of razorback sucker declined throughout the 20th century over all of its historic range, and the species now exists naturally only in a few small, discontiguous populations or as dispersed individuals. The razorback sucker has exhibited little natural recruitment in the last 40–50 years and wild populations are comprised primarily of aging adults, with steep declines in numbers. Reproduction occurs, but few juveniles are found. Razorback sucker in the lower Colorado River basin persist primarily in reservoirs, including Lakes Mohave and Mead (Minckley 1983). Few and decreasing numbers of wild fish have also been caught in Lake Havasu, at several other locations along the river, and in water diversion facilities (Bozek et al. 1991; Minckley et al. 1991).

Currently, the group of razorback sucker in Lake Mohave is the largest remaining in the entire Colorado River system. Observers reported these fish as being common to abundant when the reservoir was filling in the 1950s, with the number of adults appearing to remain fairly stable through the 1970's and 1980's (Minckley et al. 1991). No verified natural recruitment has been found in Lake Mohave despite documented spawning and the presence of larval fish (Minckley 1983; Marsh 1994). This failure to recruit has been attributed primarily to predation by non-native fishes (Minckley et al. 1991; Burke 1994; Horn 1996; Pacey and Marsh 1998b). Estimates of the wild stock in Lake Mohave, now old and senescent, have dropped precipitously in recent years from 60,000 in 1989 (Marsh and Minckley 1989) to 25,000 in 1993 (Marsh 1993; Holden 1994) and to about 9,000 in 2000 (personal communication, T. Burke, U.S. Bureau of Reclamation).

A major repatriation effort to conserve the gene pool of razorback sucker in Lake Mohave was initiated by the Native Fish Work Group in 1991, in which naturally hatched larvae are captured and raised to juveniles under protection from predators in isolated coves (Minckley et al. 1991; Clarkson et al. 1993; Burke 1994; Pacey and Marsh 1998b; Jahrke and Clark 2000). More than 23,000 repatriated juveniles were released into Lake Mohave between 1992 and 1998. A total of 212 repatriated fish had been recaptured from 1992 through 1999, representing about 1 percent of the total number of juveniles released. Using the wild adult population estimate of 9,087 and catch summaries from 1998 and 1999, Pacey and Marsh (1999) determined that the percentage of repatriated juveniles among total recaptures is about 34 percent. An estimate of the repatriated juvenile population size is thus 3,104 with a 13 percent survival. They estimate that there are currently 12,000 razorback sucker in Lake Mohave, 75 percent are wild adults and 25 percent are repatriated juveniles. Intensive management in some locations has helped to offset the decline of the razorback sucker, such as the capture and protective rearing of larvae in Lake Mohave for release at larger sizes, and raising of young in predator-free environments in Cibola High Levee Pond; a 2-ha pond containing approximately 3,000 razorback suckers with reproduction and recruitment (Marsh 2000). It is also estimated that there are more than 1,000 razorback sucker in the 60-mile reach of the lower Colorado River between Davis Dam (impounds Lake Mohave) and Lake Havasu, with evidence of reproduction (Mueller 2001). These individuals do not include small numbers of fish in Lake Havasu.

A second razorback sucker population of approximately 500 individuals occurs in Lake Mead. The species was reported as common in Lake Mead into the 1960's, but numbers were noticeably reduced by the 1970's, and the species was considered rare (Minckley 1973; Bozek et al. 1991). The Lake Mead population is the only known recruiting population of razorback sucker in the Lower Colorado River Basin (Holden et al. 2000; Abate et al. 2002; Albrecht and Holden 2005). Recent age-growth data showed fish at about 20–25 years of age, indicating recent recruitment (Ruppert et al. 1999). The majority of the fish are found in Las Vegas Bay and Echo Bay, where spawning has been documented over alluvial deposits and rock outcrops. The population in Lake Mead has been studied since 1996 (Holden et al. 2000). During the first four years, 115 individuals were collected, not counting larvae. In August 1999, an adult was found in upper Lake Mead at the western side of the mouth of Grand Wash. This discovery was followed in 2000 by collection of larval razorback sucker in the far eastern part of Lake Mead. Holden et al. (2000) concluded that “spawning occurred in the lake, either near the Colorado River inflow area or in the actual Colorado River before it enters the lake.” Limited and sporadic captures of naturally occurring fish occur throughout the remainder of the lower Colorado River basin

(Abate et al. 2002; Holden et al. 1997, 1999, 2000a, 2000b, 2001; Marsh and Minckley 1989; Welker and Holden 2003, 2004).

Between 1981 and 1990, more than 13 million hatchery-produced razorback sucker were released at 57 sites into historic habitat in Arizona, primarily in the Verde, Gila, and Salt rivers and their tributaries, where the natural population had been extirpated (Hendrickson 1994). Low short-term survival and no long-term survival was reported from these releases, primarily because of predation by non-native fishes, although 14 adults were recently reported from Fossil Creek. Since 1994, 17,371 razorback sucker have been stocked into the Verde River. Numerous fish have been recaptured and survival up to 2 years has been documented. In addition, ripe males have been encountered in the Verde River, but no evidence of reproduction or recruitment has been found (personal communication, D. Shroufe, Arizona Game and Fish Department).

The razorback sucker appear to be a highly diverse species, displaying many mitochondrial DNA (mtDNA) genotypes. Based on restriction endonuclease analysis of mtDNA, it was determined that fish from Lake Mohave displayed the highest degree of genetic variability of all remaining populations of razorback sucker. Moving from south to north, populations appear to be progressively less diverse and possess fewer unique genotypes. Most fish sampled exhibited genotypes identical to those in the Lake Mohave fish; unique genotypes were similar and rarely found (Dowling and Minckley 1993). Hybridization between razorback sucker and flannelmouth sucker was identified as early as 1889 (Hubbs and Miller 1953) and has been reported for many years (Hubbs and Miller 1953; Suttkus et al 1976; Kidd 1977; McAda and Wydoski 1980; Maddux et al. 1987; Valdez and Ryel 1995; Douglas and Marsh 1998).

Populations within the Action Area

The razorback sucker has not been reported from Grand Canyon since 1990, and only 10 adults were reported between 1944 and 1995 (Valdez 1996; Gloss et al. 2005). Carothers and Minckley (1981) reported four adults from the Paria River in 1978-1979. Maddux et al. (1987) reported one blind female razorback sucker at Upper Bass Camp (Colorado River Mile 107.5) in 1984, and Minckley (1991) reported five adults in the lower Little Colorado River from 1989-1990. Putative hybrids with flannelmouth sucker (*Catostomus latipinnis*) have been reported from the Little Colorado River (Suttkus and Clemmer 1979, Carothers and Minckley 1981; Valdez and Ryel 1995). Douglas and Marsh (1998) confirmed the presence of such hybrids and estimated their numbers between 8 and 136. Although hybridization between these species has been reported for many years (Hubbs and Miller 1953; McAda and Wydoski 1980), the incidence in Grand Canyon appears high relative to the number of razorback suckers, especially in the Little Colorado River where these fish concentrate during spawning.

Douglas and Douglas (2000) reported a larval razorback sucker identified by the Colorado State University Larval Fish Laboratory from collections made at the mouth of Havasu Creek in Grand Canyon. They admitted the possibility that this could have been of a hybrid between razorback sucker and flannelmouth sucker, but noted that all known hybrids occur considerably higher in the system, in Marble Canyon and the Little Colorado River. Douglas and Marsh (1996a) contend that razorback suckers were never abundant in Grand Canyon, noting that remains were not found at Stanton's Cave, where non-fossilized bones of five other native species were discovered. They suggest that razorback suckers were not residents of Grand Canyon, but transients, moving between more desirable habitats upstream and downstream.

A small number of hatchery adult razorback sucker equipped with radio transmitters were released in the Lake Mead inflow (Zimmerman and Leibfried 1997). After nearly two months of tracking, these tagged razorback sucker apparently left the area and were not relocated either up-river in the lower 40 miles of the Grand Canyon or down-lake in Gregg Basin or Virgin Basin (Abate et al. 2002; Holden et al. 1999). The migration of these fish out of the Colorado River inflow area, combined with the fact that no razorback sucker larvae were found in the area in 2002, suggests that decreasing lake levels altered habitat in this area and may have caused wild razorback sucker to move out of this vicinity.

Reproduction

Razorback suckers are warm-water species that spawn over a broad time span in late winter and spring, depending on latitude. In upper basin riverine environments, razorback sucker in reproductive condition and newly hatched larvae generally have been captured from mid-April through June on the ascending limb of the hydrograph (Modde and Wick 1997; Muth et al. 1998; McAda and Wydoski 1980; Osmundson and Kaeding 1989; Tyus and Karp 1989, 1990; Snyder and Muth 1990; Osmundson and Kaeding 1991; Tyus 1987; Valdez et al. 1982;). Further downstream, in Lake Mead, spawning takes place earlier, from mid-February to early June, peaking in March–April (Jonez and Sumner 1954; Holden et al. 1999a). Spawning occurs even earlier further downstream in Lake Mohave, beginning as early as November and continuing as late as May (Bozek et al. 1990, 1991; Burke and Mueller 1993; Minckley et al.1991; Schrader 1991). Activity appears to peak in January–March, with only scattered individuals in spawning condition found in May (Bozek et al. 1991).

Razorback suckers also have a wide temperature range for spawning, incubation, and rearing. The generally require about 12-22ºC for spawning with an optimum of 18ºC; and 14-25ºC with an optimum of 19ºC for egg incubation (Valdez 2006). The optimal thermal range for the razorback sucker is 22-25 °C (Bulkley and Pimentel 1983); however, the species occurs in widely varying temperatures. In the Upper Colorado River Basin, habitats are ice-covered during winter, while temperatures of mainstream habitats in the Lower Colorado River exceed 32^{o}C in summer (Dill 1944). Evidence of spawning in the Green River has been observed at water temperatures of 6–19 °C (McAda and Wydoski 1980; Tyus and Karp 1990; Snyder and Muth 1990; Muth et al. 1998), with an average of about 15 °C reported by Tyus and Karp (1990). Spawning in Lake Mohave has occurred at water temperatures between 9.5 °C and 22 °C (Minckley et al. 1991; Schrader 1991; Bozek et al. 1991; Burke and Mueller 1993). Gorman et al. (1999) observed spawning in the tailwaters of Hoover Dam at water temperatures of 11–12 °C. The population was characterized by a preponderance of spent/non-ripe males and gravid females, an unusual condition for suckers so late in the spawning season and possible evidence of retarded ovulation due to the cold dam tailwaters. Optimal water temperature for hatching success is around 20 °C; extreme limits of hatching are 10 °C and 30 °C (Marsh and Minckley 1985). Snyder and Muth (1990) found that eggs incubated at 18–20 °C hatch in 6–7 days, swim up in 12–13 days, and swim down in 27 days; eggs incubated at 15 °C hatch in 11 days, swim up in 17–21 days, and swim down in 38 days. Bozek et al. (1984) reported that eggs incubated at 10 °C hatched in 17.5–22.1 days, whereas Toney (1974) reported high mortality for eggs incubated at 11.7 °C. Marsh (1985) demonstrated in the laboratory that the highest successful hatching percentage for razorback suckers occurs at 20 °C, and that the hatch declines considerably at 15 °C with complete mortality at 10 °C.

Razorback sucker have high reproductive potential. McAda and Wydoski (1980) reported an average fecundity (N=10) of 46,740 eggs/fish (27,614–76,576), or about 39,600 eggs/kg. Inslee (1981) reported an average of 103,000 eggs/fish. Razorback sucker are broadcast spawners that scatter adhesive eggs over cobble substrate. Eggs incubate in interstitial spaces, and larvae must hatch and emerge from cobble substrates before being suffocated by deposited silt/sand (Minckley 1983; Minckley et al. 1991; Wick 1997). Adults make no effort to guard the nest sites (Jonez and Sumner 1954).

Survival of newly hatched larvae appears to be the limiting factor for razorback suckers in the Upper Colorado River Basin and may be dependent on availability of nursery areas in riverside floodplains (Bestgen 1990; Tyus 1998; Tyus and Karp 1990). Riverine spawning typically occurs in shallow water over gravelly substrates, often in areas of inflowing streams or on large cobble bars where gravel sorting has occurred (Minckley 1983; Mueller 1989). In riverine situations in the Upper Basin, spawning begins on the rising limb of the spring hydrograph (April-May) and continues for an extended period through the spring runoff when riverside nursery floodplains are available. Larval razorback suckers drift downstream from spawning sites and become entrained in these nursery floodplains where they may remain for several years. The timing of floodplain inundation, food availability, and arrival of larvae are critical to the survival of these young fish (Modde et al. 1996).

Habitat and Movement
The razorback sucker evolved in warm-water reaches of larger rivers of the Colorado River system from Mexico to Wyoming. Adults in rivers use deep runs, eddies, backwaters, and flooded off-channel environments in spring; runs and pools often in shallow water associated with submerged sandbars in summer; and low-velocity runs, pools, and eddies in winter. Spring migrations of adult razorback sucker were associated with spawning in historic accounts and a variety of local and long-distance movements and habitat-use patterns have been documented. Spawning in rivers occurs over bars of cobble, gravel, and sand substrates during spring runoff at widely ranging flows and water temperatures and spawning in reservoirs takes place over rocky shoals and shorelines. Young require nursery environments with quiet, warm, shallow water such as tributary mouths, backwaters, or inundated floodplains in rivers, and coves or shorelines in reservoirs.

Adult razorback sucker tend to occupy different habitats seasonally (Osmundson et al. 1995), and can do well in both lotic and lentic environments (Minckley et al. 1991). In rivers, they usually are captured in lower velocity currents, more rarely in turbulent canyon reaches (Minckley et al. 1991; Bestgen 1990; Tyus and Karp 1990; Lanigan and Tyus 1989; Tyus 1987). An exception may be in the San Juan River, where hatchery-reared, radio-tagged adults preferred swifter mid-channel currents during summer–autumn base-flow periods (Ryden 2000). In the upper basin, bottomlands, low-lying wetlands, and oxbow channels flooded and ephemerally connected to the main channel by high spring flows appear to be important habitats for all life stages of razorback sucker (Modde et al. 1996; Muth et al. 2000). These areas provide warmwater temperatures, low-velocity flows, and increased food availability (Tyus and Karp 1990; Modde 1997; Wydoski and Wick 1998). For example, in Old Charlie Wash, a managed wetland on the middle Green River, spring–summer water temperatures were 2–8 °C higher than in the adjacent river (Modde 1996, 1997), density of benthos was 41 times greater than in other sampled habitats, and densities of zooplankton were 29 times greater than in backwaters and 157 times greater than in the main channel (Mabey and Shiozawa 1993). Many floodplain habitats comparable to Old Charlie Wash were available in the Green and Colorado River systems before dams, channelization, and levees altered large segments of the ecosystem (Tyus and Karp 1990; Osmundson and Kaeding 1991; Wydoski and Wick 1998). The loss of such habitats has been implicated in the decline of the species, but to some degree gravel pits and other artificial, relatively warm off-channel ponds are used as a substitute (Valdez and Wick 1983; Wick 1997; Maddux et al. 1993; Minckley et al. 1991).

During non-reproductive times of the year (summer–winter), adult razorback sucker in lotic environments have been found in deeper eddies, slow runs, backwaters, and other types of pool habitats with silt or sand substrate, depths ranging from 0.6 to 3.4 m, and velocities ranging from 0.3 to 0.4 m/s (Osmundson et al. 1995; Minckley et al. 1991; Tyus and Karp 1990; Valdez et al. 1982; Tyus 1987; Tyus et al. 1987). In summer, Osmundson and Kaeding (1989) captured adults in pools and runs 1.62 to 1.65 m deep. Tyus and Karp (1990) also found them in the vicinity of midchannel sandbars. In winter, Osmundson and Kaeding (1989) captured adults in pools and slow eddies 1.83 to 2.16 m deep, and Valdez and Masslich (1989) found them in slow runs, slack water, and eddies 0.6 to 1.4 m deep.

Hatchery-reared adults in the San Juan River generally moved out of the main channel and into edge pools during low winter base flows, using these habitats exclusively in January, the coldest month of the study (Ryden 2000). During the other winter months, fish ventured into the main channel during the warmest part of the day, presumably to feed. In the Verde River, adult razorback sucker were found in deeper pools and glides, at depths generally less than those reported in the upper basin (Clarkson et al. 1993; Creef et al. 1992). This difference was attributed to generally shallower conditions and possibly to hatchery conditioning (Clarkson et al. 1993). In the Gila River, Marsh and Minckley (1991) captured razorback sucker in flatwater, pools, and eddies.

In reservoirs in the lower basin, adult razorback sucker are pelagic at varying depths, except in breeding season, when they congregate in shallower, nearshore areas (Pacey and Marsh 1998b). Spawning takes place near shore in shallow water at temperatures of 10–21 °C, over flat, gravel and gravel mix substrate (Bozek et al. 1991; Minckley 1983; Schrader 1991; Burke and Mueller 1993). These areas tend to be located on outwash fans, along shorelines or on shoals that are swept free of silt by currents, wave action, and spawning activity. Larvae remain near shore for a few weeks before disappearing (Burke and Mueller 1993; Bozek et al. 1990, 1991; Minckley et al. 1991; Schrader 1991; Marsh and Minckley 1989). What happens to them is unknown; they may be dispersing to deeper water, but the near absence of juveniles suggests mortality at the larval stage, probably as a result of predation (Marsh and Langhorst 1988; Minckley et al. 1991; Horn 1996). Five tagged juveniles in Lake Mohave moved throughout the pelagic zones for the first week after release but then tended to occupy vegetated areas near the shore (Mueller et al. 1998). In the mixed channelized, lacustrine, and backwater environment of the Imperial Division of the Lower Colorado River, Bradford et al. (1999) tracked 58 fish with ultra-sonic tags and found that the main channel was used less frequently in proportion to availability; side channels were used in proportion to availability; backwaters were used slightly more relative to availability; and the reservoir was used more frequently in proportion to availability.

Growth

Adult razorback suckers attain a maximum size of about 1 m and can live to be 44 years old (McCarthy and Minckley 1987; Minckley 1973). Growth among individuals in the same cohort is highly variable (Minckley et al. 1991), and this variation may represent divergent strategies in this long-lived fish for dealing with the highly unpredictable environment of desert rivers in southwestern U.S. Growth is rapid for approximately the first six years, but then it slows dramatically (McCarthy and Minckley 1987). Based on analysis of bony structures, including otoliths from 70 razorback sucker from Lake Mohave, McCarthy and Minckley (1987) estimated ages ranging from 24 to 44 years. The relatively large size of wild adults in both the upper and lower basins, coupled with high incidences of blindness, external parasitism, tumors, and infections suggests that most populations are composed primarily of old fish (Valdez et al. 1982; Minckley 1983; Bozek et al. 1984; McCarthy and Minckley 1987). Razorback sucker in Lake Mead appear to be an exception. Ruppert et al. (1999) measured an annual average growth rate of 17.28 mm for wild (unstocked) razorback sucker in Lake Mead. This rapid growth is typical of young catostomids. Holden et al. (1999b) reported a lower annual growth rate (10 mm) from Lake Mead, but this is still three times the reported rate for both Lake Mohave and upper basin populations. Based on 10 years of data from Lake Mohave, Pacey and Marsh (1999) calculated an average monthly growth near zero (0.2–1.5 mm for females and 0.1–2.2 mm for males). In the upper basin, Modde et al. (1996) analyzed data from 1975–1992 and found the average growth rate to be only 1.66 mm/year.

Razorback sucker in the upper basin tend to be smaller than those in the lower basin, and grow more slowly (Minckley et al. 1991; Modde et al. 1996; Holden et al. 1999b). First-year growth of up to 400 mm was measured in the lower basin (Mueller et al. 1993), whereas average first-year growth of wild fish in the middle Green River was closer to 100 mm (Modde and Wydoski 1995). McAda and Wydoski (1980) reported that fish in upper basin riverine habitats mature after three to six growing seasons. In the lower basin, males usually reach maturity in their second year; females in their third year (U.S. Bureau of Reclamation 1996). Within the Green River, larvae in the upper river grew 6–21 percent faster than those in the lower river (Muth et al. 1998). Among stocked razorback sucker in the San Juan River, no difference was seen in growth between female and male fish, but, as expected, smaller fish grew faster than larger fish (Ryden 2000).

Rapid growth to adult size is correlated with food-rich, warm environments (Osmundson and Kaeding 1989; Minckley et al. 1991; Mueller 1995). Age-0 razorback sucker collected from Old Charlie Wash, a food-rich managed wetland adjacent to the middle Green River, grew 67 percent faster than larvae in hatchery ponds, and 29 percent faster than larvae in off-channel habitats (Muth et al. 1998). Enhanced growth is thought to increase survivorship, in part by reducing vulnerability to predation (Modde et al. 1999b). In laboratory experiments, slower larval growth of another native fish, Colorado pikeminnow, correlated to increased mortality due to predation (Bestgen et al. 1997).

Diet

All life stages of razorback sucker consume insects, zooplankton, phytoplankton, algae, and detritus; however, diet varies by age and habitat (Bestgen 1990, Muth et al. 2000). Within days of hatching, razorback sucker larvae (10–11 mm TL) begin to feed on plankton (Muth et al. 2000). As their terminal mouth migrates to a sub-terminal position, larvae begin feeding on benthos as well (Marsh and Minckley 1985). Razorback sucker diet composition is highly dependant upon life stage, habitat, and food availability. Upon hatching, razorback sucker larvae have terminal mouths and shortened gut lengths (less than 1 body length) which in combination, appears to facilitate and necessitate selection of a wide variety of food types. Exogenous feeding occurs at approximately 10 mm TL (approximately 8-19 days old), after which larvae from lentic systems feed mainly on phytoplankton and small zooplankton, while riverine inhabiting larvae are assumed to feed largely on chironomids and other benthic insects (Minckley and Gustafson 1982, Marsh and Langhorst 1988, Bestgen 1990, Papoulias and Minckley 1990, FWS 1998b). Papoulias and Minckley (1992) reared larval razorback sucker in three different ponds containing different densities of food resources to demonstrate that increased growth was positively related to invertebrate densities, suggesting the importance of larval food switching from algal and detrital food items to a diet enriched with invertebrates. Papoulias and Minckley (1990) showed that larval mortality is minimized when food levels are within the range of 50-1,000 organisms/L. In riverine environments in the upper basin, Muth et al. (1998) reported that cladocerans, rotifers, and algae decreased in importance as larvae grew larger, but chironomids remained the dominant food item at all lengths. Chironomids are among most common benthic invertebrates in riverine nursery habitats of the upper basin.

In Lake Mohave, Marsh and Langhorst (1988) reported a somewhat different diet for larvae < 21 mm TL. Larvae along a shoreline consumed primarily cladocerans, rotifers, or copepods; those in an adjacent backwater had a similar diet, but ate larval chironomids and trichopterans as well. When compared to hatchery larvae, wild specimens had a significantly greater frequency of empty guts, and guts with food contained significantly fewer organisms. Zooplankton densities are relatively low and variable in Lake Mohave, but primary productivity is high. Minckley et al. (1991) reported that nutritional levels appear to be high enough in most years to support the new year class, but Horn (1996) concluded that nutritional limitations in the reservoir may contribute to mortality of larvae directly through starvation or indirectly through reduced growth, which prolongs their susceptibility to predation. In a study of razorback sucker diet in Lake Mohave, Marsh (1987) found that the combination of planktonic crustaceans, rotifers, diatoms, detritus, and filamentous algae occurred in 44 percent of digestive tracts. *Bosmina* sp. was the most abundant item (100 percent of fish); followed by diatoms, primarily Fragillaria crotenensis (nearly 90 percent); and *Daphnia* sp. (72 percent). Rotifers, benthic ostracods, copepods, and chironomid dipteran larvae were found in 53 percent, 53 percent, 34 percent, and 3 percent of fish, respectively, but numbers were low, except for rotifers. Detrital organic matter and inorganic matter was found in 56 percent and 16 percent of digestive tracts, respectively.

Parasites

There is no evidence that disease is a significant factor in the decline and status of the razorback sucker. In a survey of pathogens recovered from endangered fishes in the Upper Colorado River Basin, Flagg (1982) reported the bacteria *Erysipelothrix rhysiopathiae*, the protozoan *Myxobolus* sp., and the parasitic copepod *Lernaea cyprinacea* in razorback sucker. The protozoan parasite *Myxobolus* can invade the eye tissue and eventually cause blindness, an ailment commonly reported in older specimens (Minckley 1983). Based on incidence of infection and condition of fish, Flagg (1982) concluded that parasitic infestation was not likely to be a contributing factor to mortality of native fish in the upper basin.

In the lower basin, *Lernaea* spp., the pathogenic protozoans *Myxobolus* and *Ichtyophthirius*, an internal monogenetic trematode of the suborder Polyopistocotyles, the cestode *Isoglaridacris bulbocirrus*, and nematodes of the genus *Dacnitoides* have all been reported from razorback sucker from Lake Mohave (Minckley 1983; Bozek et al. 1984). Mpoame (1981) reported a low rate of parasitism for the Lake Mohave razorback sucker. This contrasts with hatchery-reared razorback sucker recaptured after introduction into the Verde and Salt rivers, which exhibited extremely heavy infestations by *Lernaea*, particularly in summer and fall (Clarkson et al. 1993; Creef and Clarkson 1993; Hendrickson 1994). The heavily infected fish (several dozen parasites per individual) were pale and emaciated, and two of them exhibited partial loss of equilibrium (Hendrickson 1994). Hendrickson (1994) concluded that razorback sucker may be more susceptible to *Lernaea* infection than other species in the stocked areas, and that *Lernaea* and other exotic parasites may have been a factor in the decline of native fish in the lower basin. *Lernaea* was not present or was very rare in Arizona before the 1930's, but had increased significantly by the 1960's (James 1968). Researchers monitoring reintroduced razorback sucker in the Verde and Salt rivers continued to observe *Lernaea* infestation on this species in 1999; however, the incidence appears to have decreased from previously reported levels (personal communication, E. Jahrke, Arizona Game and Fish Department).

2.4.3 Kanab Ambersnail

Legal Status

The Kanab ambersnail, *Oxyloma haydeni kanabensis*, was listed as endangered in 1992 (FWS 1992) with a recovery plan completed in 1995 (FWS 1995). Fully mature snails are brown with an elongated first whorl and measure about 23 mm in shell size (Sorensen 2007). Kanab ambersnail are pulmonate or air-breathing mollusks, but are able to survive underwater for up to 32 hours in cold, highly oxygenated water (Pilsbry 1948). This adaptation may have allowed for dispersal of the species to new sites. Kanab ambersnail feeds on plant tissue, bacteria, fungi and algae. It scrapes this food off of plants by means of a radula or rasp tongue.

Historical and Current Range

Kanab ambersnail populations in the Southwest are believed to be relict populations from the late Pleistocene, when springs, seeps, and wetland habitat were more abundant (Spamer 1993; Szabo 1990). Historically, the region may have harbored many populations of ambersnails, but today the Kanab ambersnail occurs at only three springs: one at Three Lakes near Kanab, Utah; two in Grand Canyon National Park: one at Vaseys Paradise, a spring and hanging garden at the right bank at RM 31.8 and a translocated population at Upper Elves Chasm, at the left bank at RM 116.6 (Gloss et al. 2005). At Three Lakes near Kanab, two populations once existed, but one was extirpated by desiccation of its habitat. The remaining population at Three Lakes is located on private lands at several small spring-fed ponds dominated by cattail (Clarke 1991).

Through analysis of historic photographs, an increase in the vegetative cover along the river in Grand Canyon has occurred since the completion of Glen Canyon Dam in 1963 (Turner and Karpiscak 1980). The increase in cover, reduction in beach-scouring flows, and introduction of non-native water-cress, *Nasturtium officinale*, has lead to a >40 percent increase in suitable Kanab ambersnail habitat area at Vaseys Paradise from pre-dam conditions (Stevens et al 1997a).

Populations in the Action Area

Intensive searches at more than 150 springs and seeps in tributaries to the Colorado River between 1991 through 2000 found no additional Kanab ambersnail (Meretsky 2000; Meretsky and Wegner 1999; Sorensen and Kubly 1997, 1998; Webb and Fridell 2000). In September 1998, three springs along the Colorado River were stocked with young snails (AGFD 1998). Release sites were selected above the historic flood elevation (~100,000 cfs) and where populations would be unaffected by dam operations. One translocation site, Upper Elves Chasm, has established as a new population. Continued monitoring has detected numerous Kanab ambersnail persisting and reproducing at the initial release area, including migration into suitable adjacent habitat (Gloss et al. 2005).

Reproduction

Kanab ambersnail live approximately 12-15 months and are hermaphroditic and capable of self-fertilization (Clarke 1991; Pilsbry 1948). Mature Kanab ambersnail mate and reproduce May-August and deposit clear, gelatinous egg masses on undersides of moist to wet live stems, on the roots of watercress, and on dead stems of crimson monkey-flower (Nelson and Sorensen 2001; Stevens et al. 1997a). In warm winters, more than one reproductive period can occur. Adult mortality increases in late summer and autumn leaving the overwintering population dominated by subadults. Young snails enter dormancy in October-November and typically become active again in March-April. Over-winter mortality of Kanab ambersnail can range between 25 and 80 percent (KAIMG 1997; Stevens et al. 1997a). Populations fluctuate widely throughout the year due to variation in reproduction, survival, and recruitment (Stevens et al. 1997a). The number of ambersnails at Vaseys Paradise has remained stable since 1998 (Ralston 2005), although flows greater than 45,026 cfs (1275 cms) are thought to decrease the population by up to 17 percent in the short-term (Stevens et al. 1997a, 1998b).

Habitat

Vaseys Paradise is a small, spring-fed riparian area adjacent to the Colorado River at RM 31.8 (Stevens 1990). Ambersnails are found in the vegetation associated with this spring, which includes native crimson monkey-flower, *Mimulus cardinalis* Dougl. ex Benth., native water sedge, *Carex aquatilis* Wahlenb., and non-native water-cress, *Nasturtium officinale* L. Stevens et al. (1997a,b) found Kanab ambersnail at Vaseys Paradise predominantly use crimson monkeyflower and water-cress for food and shelter. They identified these two species as key habitat components for Kanab ambersnail. The other Grand Canyon habitat at Upper Elves Chasm is predominated by crimson monkeyflower and maidenhair fern, *Adiantum capillus-veneris*, with lesser amounts of sedges, *Carex aquatilis*, rushes, *Juncus* spp., cattails, water-cress, helleborine orchids, *Epipactis gigantean*, and grasses (Nelson 2001; Nelson and Sorensen 2002). From evidence collected under controlled laboratory conditions, microclimatic conditions such as higher humidity and lower air temperatures relative to the surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002).

Threats

Current threats to Kanab ambersnail include loss and adverse modification of wetland habitats, which are scarce in this semi-arid region (FWS 1995). The Three Lakes population is at risk due to commercial development by the private landowner. Historically, the Grand Canyon often experienced annual floods of 90,000 cfs (2,550 cms) or greater and Kanab ambersnail were likely swept downstream and drowned (Stevens et a. 1997a). Today, Glen Canyon Dam limits such floods, although numerous high flows (>45,000 cfs; 1,275 cms) have occurred in the last 30 years. For example, during the March 1996 high flow in the Grand Canyon, up to 16 percent of Kanab ambersnail habitat at Vaseys Paradise was lost or degraded and hundreds of snails were lost. Recovery of this habitat to pre-flood conditions required over two years (IKAMT 1998; Stevens et al. 1997b).

On a lesser scale, vegetation trampling and flash floods from the talus slope above Vaseys Paradise also contribute to habitat loss and direct Kanab ambersnail mortality. Due to steep slopes and a dense cover of poison ivy at this location, the impacts from river runners and hikers are reduced. Additionally, plateau-origin flash floods are rare in the region (Stevens et al. 1997a).

Parasites

Evidence exists that a small number of Kanab ambersnails at Vaseys Paradise were parasitized by a trematode, tentatively identified as *Leucochloridium* sp. (Stevens et al. 1997b). Potential vertebrate predators include rainbow trout in the stream mouth, Say's and black phoebe, *Savornis savi* and *S. niaricans*, canyon wren, *Catherpes mexicanus*, American dipper, *Cinclus mexicanus*, and canyon mice, *Peromyscus crinitus* (Stevens et al. 1997b; FWS 1995). Direct evidence of Kanab ambersnail consumption and predation rates by birds and mice are not available, but analysis of mice feces suggests that snails are not regularly eaten by rodents (Meretsky and Wegner 1999). Another natural threat is bighorn sheep, *Ovis canadensis*, which can consume water sedge, a source of forage for bighorn sheep, especially during droughts. With increased growth of water sedge, the springs at Vaseys Paradise are now habitually visited by bighorn sheep, resulting in vegetation used by the snails being regularly trampled and consumed (Gloss et al. 2005).

2.4.4 Southwestern Willow Flycatcher

Legal Status

The Southwestern willow flycatcher, *Empidonax traillii extimus,* (SWFL) was designated by the FWS (1995a) as endangered on February 27, 1995. A final recovery plan was completed in August 2002 (FWS 2002c). Critical habitat was initially designated in 1997 (62 FR 39129), but was rescinded by court order in 2001. Designation of critical habitat was finalized in October 2005 (FWS 2005b). The affected environment for this action does not include any critical habitat.

The SWFL is about 15 cm long, and weighs approximately 11 grams. It has a grayish-green back and wings, whitish throat, light grey-olive breast, and pale yellow belly. Two distinct wing bars are visible on the greater coverts, and an eye-ring is either absent or very faint. The upper mandible is dark, while the lower mandible is pale to yellowish (Phillips et al. 1964; FWS 2002c). Recognition of the different subspecies in the field is nearly impossible and is mainly based on differences in color and morphology using museum specimens (Paxton 2000; Unitt 1987). The SWFL may be distinguished from other *Empidonax* species by its primary song and its location on its breeding grounds only after spring migration is over (Sogge et al. 1997a,b).

Historic and Current Range

The historic breeding range of the SWFL included southern California, southern Nevada, southern Utah, Arizona, New Mexico, western Texas, southwestern Colorado, and extreme northwestern Mexico (Browning 1993; Paxton 2000; FWS 2002c; Unitt 1987). When the SWFL was listed as endangered in 1995, populations were estimated at 350 territories (FWS 2002c). Through increased surveys that number has increased to over 1,000 territories (Durst et al. 2005). Arizona Game and Fish documented 883 resident flycatchers at 483 territories in 47 sites in 2005 (English et al. 2006). Approximately 73 territories were documented in 2005 along the lower Colorado River and at sites in Nevada and the lower Grand Canyon (Koronkiewicz et al. 2006).

Another important component in the distribution of SWFL is its migration routes and migration stopover habitats. This neotropical migrant travels between breeding areas in the US to wintering grounds in Central and South America (FWS 2005b). Migration flyways include major rivers such as the Colorado (English et al. 2006; Koronkiewicz et al. 2006; Moore 2005; FWS 2005b; Yong and Finch 1997). Over 600 individual birds have been located during migration along the lower Colorado River near Yuma, Arizona (McLeod et al. 2005).

Wintering grounds for the SWFL are believed to include central America and northern South America. Surveys have been conducted in Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, and Panama (Koronkiewicz and Sogge 2000; Koronkiewicz and Whitfield 1999; Lynn and Whitfield 2002, Lynn et al. 2003; Nishida and Whitfield 2004). It is suspected that all subspecies may winter in similar locations, but because it is difficult to identify subspecies, specific areas where they winter are not well-known at this time.

In the Southwestern US, some 100 sites have been surveyed for SWFL including the Virgin River, Pahranagat National Wildlife Refuge, Grand Canyon, and the lower Colorado River from Lake Mead to Mexico. These surveys indicate the main breeding populations occur along the Virgin River from north of Mesquite, Nevada to the Virgin River delta with Lake Mead, at Pahranagat National Wildlife Refuge, at Topock Marsh near Needles, California, and on the Bill Williams National Wildlife Refuge, Arizona. Presence-absence surveys and life history studies of the SWFL have been conducted along the Colorado River since 1996 (Koronkiewicz et al. 2004, 2006a; McKernan and Braden 1997, 1998, 1999, 2001a, 2002, 2006a,b; McLeod 2005). These studies show the bird has consistently nested along the river in Grand Canyon from Separation Canyon to the delta of Lake Mead, as new riparian habitat, primarily tamarisk, has developed in response to regulated river flows (Gloss et al. 2005). The expansion of riparian vegetation in Grand Canyon may have provided additional habitat for the SWFL, but birds in the upper river corridor persist at a very low level at only one or two sites.

Populations in the Action Area

Southwestern willow flycatchers are not present around Lake Powell, but they have been documented along the Colorado River between RM 47 and RM 54, at RM 71, and at RM 259 (Sogge et. al. 1995; Tibbets and Johnson 1999, 2000; Unitt 1987). Population numbers have fluctuated between five breeding pairs and three territorial, but non-breeding pairs in 1995, to one single breeding pair more recently. The year 2004 marked the sixth consecutive year in which surveys located a single breeding pair at the upper sites, the lowest population level since surveys began in 1982. Given these low numbers, the continued presence of the SWWF in Grand Canyon appears tenuous.

The SWWF has been detected within lower Grand Canyon-upper Lake Mead since surveys began in 1997 with breeding flycatchers detected in 1999–2001, but not in 2002 or 2003. A single breeding pair was detected in 2004 and an unpaired male occupied this same area in 2005 (Koronkiewicz et al. 2006a). Two nests were detected during the 2006 breeding season (Koronkiewicz et al. 2006a). Due to extreme drops in water levels that started in 2000, much of the occupied habitat of the 1990s is now dead or dying. More recently, new stands of vegetation have been developing in areas exposed by receding water and this vegetation is now developing into suitable flycatcher habitat.

Reproduction

The SWFL breeds across the lower Southwest from May through August. SWFL typically arrive on breeding grounds between early May and early June. Males generally arrive first to set up territories, with females arriving a week or two later. Males are highly territorial and will defend their territory through counter singing and aggressive interaction. Flycatchers often clump together in one area of the habitat patch, which leads to an indication that this species is semi-colonial. Males are usually monogamous, but polygyny occurs at approximately 10-20 percent (Pearson 2002; FWS 2002c). Genetic evidence suggests extra-pair copulation exists by either mated or unmated males with females in neighboring territories (FWS 2002).

Dense riparian vegetation near surface water or saturated soil, across a large elevational and geographic area is the dominant habitat for breeding SWFLs (FWS 2002c; Sogge et al. 1997a). Dominant plant species consist of large riparian trees such as Coyote willow (*Salix exigua*), Goodding willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii)*, boxelder (*Acer negundo)*, tamarisk, and Russian olive (*Elaeagnus angustifolia)* (FWS 2002c).

Occupied sites vary in size and shape but all have dense vegetation with some open areas, and are usually associated with open or standing water. Occupied patches can be as small as two acres and as large as several hundred acres, but are typically greater than 10 m wide. Although most of the sites are associated with open water, marshy seeps, or saturated soil where the nest tree can be in standing water, hydrologic conditions can change drastically during the breeding season and between years (Koronkiewicz et al. 2006a; FWS 2002c; Sogge et al. 1997a; Sogge and Marshall 2000). Because birds are exposed to extreme environmental conditions throughout the desert southwest, dense vegetation and moist soils at the nest may be needed to provide a more suitable microclimate for raising young by increasing humidity within the site (Allison et al. 2003; Koronkiewicz et al. 2006a; Sogge and Marshall 2000).

Vegetation analysis for occupied SWFL sites suggests that flycatchers breed in a wide variety of habitats throughout the region (Koronkiewicz et al. 2006a; McKernan and Braden 2002). These areas contain relatively homogenous, contiguous stands of riparian vegetation that differ from each other both structurally and compositionally. Preliminary nest productivity, as related to vegetation type (e.g., non-native versus native), shows no significant difference (McKernan and Braden 2002), but further analysis is planned.

Nest building usually begins three to seven days after pair formulation. The SWFL build open cup nests that are approximately 7 cm high and wide with dangling material below. Nests are typically placed within the fork of branches with the nest cup supported by several stems. Nest height varies and can be anywhere from ground height to several meters high, depending on height of nest tree. Typical nest height is around 2-7 m. (Sogge et al. 1997a). Flycatchers nest in various tree species including Goodding's willow, coyote willow, cottonwood, tamarisk, boxelder, and other native and non-native tree species. Along the lower Colorado River, main nest substrates include Goodding's willow (20-30 percent), coyote willow (5-15 percent), Fremont cottonwood (5 percent), and tamarisk (50 percent-70 percent). In some areas, such as Topock Marsh, nearly 100 percent of the nests are in tamarisk (Koronkiewicz et al. 2004, 2006a; McKernan and Braden 2001; McLeod et al. 2005). On average, one egg is laid per day, with a typical clutch size of four eggs laid within five days. Egg laying can start as early as late May, but is usually in early to mid-June (Sogge et al. 1997a, b). Upon completion of egg laying, the female usually incubates the eggs for approximately 12 days, and all eggs usually hatch within 24-48 hours of one another. Nestlings fledge usually within 12-15 days (Paxton and Owen 2002). Chicks are usually present from mid-June through early August. The SWFL will re-nest, either after the first nest fledges or after failure, and have been documented to have up to four nesting attempts and three clutches (Koronkiewicz et al. 2006a; McKernan and Braden 2001b; Sferra et al. 1997,). Adults depart from breeding territories as early as mid-August, but may stay until mid-September if nesting was late. Fledglings usually leave the breeding areas a week or two after adults (Sogge et al. 1997a).

Nest success averaged from 40-50 percent through all years of study along the lower Colorado River (Koronkiewicz et al. 2004, 2006a; McKernan and Braden 1997, 1998, 1999, 2001, 2002, 2006; McLeod 2005) and approximately 25-70 percent over the complete range of the SWFL (FWS 2002b,c). Predation was the leading cause of nest failure at many study sites throughout the range (FWS 2002b,c, McKernan and Braden 2001b and 2002, Koronkiewicz et al. 2004, 2006a, McLeod 2005). Predation has averaged 33-65 percent along the lower Colorado River from 1996 through 2005 (Koronkiewicz et al. 2004, 2006a; McKernan and Braden 2001, 2006; McLeod 2005). For Arizona statewide surveys in 2005, approximately 77 percent of failed nests were due to depredation (English et al. 2006). Although these numbers are within the typical range for open-cup nesting passerine birds (FWS 2002c), this amount of predation increases the stress on a species already endangered.

Habitat

At most sites along the Colorado River and tributaries, occupied habitats usually have high canopy closure with no distinct understory, overstory, or structural layers (Koronkiewicz et al. 2006a). High vegetation volume may be more important than specific tree species type or habitat structure. High vegetation volume and high foliage density at nest sites and within breeding patches has been reported in other willow flycatcher breeding areas (Allison et al. 2003; Paradzick 2005; Sedgwick and Knopf 1992; Sogge and Marshall 2000; Stoleson and Finch 2003). This factor, along with the presence of water, was consistent throughout the range.

The presence of water is an important component of SWFL habitat (FWS 2002c; Sogge and Marshall 2000). Studies indicate that SWFL nest sites are usually closer to water than non-use sites (Koronkiewicz et al. 2006a; Paradzick 2005; Stoleson and Finch 2003). Nest sites are usually located within 200 m of open or standing water and usually contain soils that are higher in water content than non-use sites (Koronkiewicz et al. 2006a; McKernan and Braden 2002; Paradzick 2005; Stoleson and Finch 2003). Water or moist soils help regulate temperature and relative humidity within the stand, produce the right conditions for insect development and survival, and are associated with creating a greater foliage density (Koronkiewicz et al. 2006a; Paradzick 2005; FWS 2002c).

Diet

The SWFL is an insectivore that hawks insects while in flight, gleans insects from foliage, and occasionally captures them from the ground (FWS 2002c). Flycatchers forage from within the habitat or above the canopy, above water, or glean from trees and herbaceous cover (McCabe 1991; FWS 2002c; Sogge 2000,). The main diet of the flycatcher consists of small to medium size insects such as true bugs, Hemiptera, wasps and bees, Hymenoptera, flies, Diptera, beetles, Coleoptera, butterflies and caterpillars, Lepidoptera, and spiders, Araneae (DeLay et al. 2002; Drost et al. 1998, 2001; Durst 2004; McCabe 1991; Sogge 2000). Berries and small fruits have also been reported but are typically rare (McCabe 1991). The flycatcher can exploit a diverse array of insects depending on availability within the habitat (DeLay et al. 2002; Drost et al. 1998, 2001, 2003; Durst 2004). Diet may differ between sites and between years depending on abundance and availability of insects in and near the breeding habitat (DeLay et al. 2002; Drost et al. 2003; Durst 2004). Although there were differences in prey types consumed by the flycatcher among different habitats (e.g., native versus non-native), there was no significant differences in the abundance of insects available between habitats (Durst 2004) and there was no evidence that physiological condition of flycatchers was lower in saltcedar habitats (Owen et al. 2002).

Threats and Parasites

Habitat alteration, as well as loss and fragmentation are considered one of the greatest threats to the SWFL (Marshall and Stoleson 2000). Riparian habitats in the Southwest are naturally patchy and subject to periodic disturbance. Factors contributing to habitat loss include water management, such as dams and reservoirs, diversions and groundwater pumping, channelization and bank stabilization, agricultural development, livestock grazing, phreatophyte control, increased recreation, and urbanization. All of these cause loss of habitat, habitat fragmentation, loss of water underneath stands, and human disturbance (Marshall and Stoleson 2000).

Although the SWFL now nests in tamarisk, this has some disadvantages. Tamarisk exudes salts and creates soils that are too salty for other native species to propagate, thus reducing diversity in the stand which may affect prey base for flycatchers. Tamarisk also is much more adapted to disturbance (floods, fire) and reestablishes more readily than native species, thus changing the composition of the stand, and increasing the chance of greater habitat loss and degradation. Deep root systems and extended production and proliferation of seeds from March through October gives tamarisk selective advantage over natives under stressed conditions and may reduce soil moisture and standing water conditions needed for flycatcher habitat (Marshall and Stoleson 2000).

Parasitism by brown-headed cowbirds is another cause of nest failure. Cowbird parasitism may impact some SWFL populations enough to warrant management actions. The cowbird lays it eggs in the nest of the host species, and the host then incubates the cowbird eggs, which typically hatch prior to the hosts own young. Parasitism rates have ranged from 0-75 percent in some areas, with the average parasitism rate in 2005 at 32 percent for all sites (Koronkiewicz et al. 2006a). The Arizona statewide average for 2005 was 7 percent (English et al. 2006).

The SWFL has evolved with predation and cowbird parasitism, but increased populations of predators and cowbirds has become a major threat to some local populations. Predation is the leading cause of nest failure in many populations of SWFL (Marshall and Stoleson 2000; FWS 2002c), including those along the Colorado River and its tributaries (Koronkiewicz et al. 2006a; McKernan and Braden 2002). Known and suspected nest predators include snakes, predatory birds such as raptors, corvids, grackles and cowbirds, small mammals, and even ants (Marshall and Stoleson 2000). Cowbird populations have expanded greatly with the expansion of livestock grazing, agriculture, and deforestation (Marshall and Stoleson 2000; Siegle and Ahlers 2004).

Little is known of diseases and parasites within the SWFL population. McCabe (1991) reported a mite infestation in several willow flycatcher nests in Maryland, subsequently identified as *Ornithonyssus sylviarum*, the northern fowl mite. The SWFL is also known to host blood parasites such as Hemoproteus, Leucocytozoon, Microfilaria, Tyrpanosoma, and Plasmodium (FWS 2002c). Other parasites identified include blow fly, *Protocalliphora* sp., and nasal mites (FWS 2002c). It is unknown what effects these parasites have on the SWFL, but McCabe (1991) noted no significant effects from the mite infestations.

3 Sufficient Progress and New Information

3.1 Actions Taken in Response to the 1995 Biological Opinion

The RPA of the 1995 biological opinion included the following elements, which are followed in turn by a discussion of actions taken by Reclamation to date in response to the biological opinion:

3.1.1 Element 1: Development of an Adaptive Management Program

Progress to date

A common element of the 1995 EIS and a central theme of the 1995 biological opinion was an adaptive management program. The AMP was developed and implemented under the Federal Advisory Committee Act in 1997. The AMP retains the same organizational structure as presented in the fourth sufficient progress communication. The AMP Charter was renewed in 2006. New and continuing representatives to the Adaptive Management Work Group (AMWG) were confirmed by the Secretary of the Interior during 2004–2007; the Federation of Fly Fishers replaced Trout Unlimited and Grand Canyon Wildlands Council replaced Southwest Rivers.

A number of ad hoc committees have been formed under the AMP that address specific issues regarding dam operations and conservation of humpback chub. In response to a discovery that the endangered humpback chub population in Grand Canyon was in decline, the AMWG directed in January 2003 that an ad hoc committee be formed with the responsibility of developing a comprehensive plan for future research, monitoring, and management of the endangered fish. In August 2003, the HBC Ad Hoc Committee delivered the plan to the Science

Advisors (GCDAMP Science Advisors 2003) and then to AMWG (Humpback Chub Ad Hoc Committee 2003), and the plan was used to fund projects in the 2004 and 2005 fiscal years. The plan is presently being revised by the HBC Ad Hoc Committee and will be resubmitted to AMWG after projects are assessed by an AMWG ad hoc committee to determine which of them would be recommended for inclusion in the AMP.

The adaptive management program necessitated integration of scientific information into an ecosystem-based science program. This need was partially fulfilled through development of a conceptual model of the Colorado River ecosystem in the Grand Canyon region (Walters et al. 2000). During 2003 the TWG used knowledge gained from the conceptual model to evaluate a program of potential future experimental actions through a multi-attribute tradeoff analysis (Failing et al. 2003). A complimentary exercise has been the development of the AMP Strategic Plan, which was adopted by the AMWG and is available at http://www.usbr.gov/uc/envprog/amp/ strategic_plan.html.

Other aspects of the adaptive management planning process for humpback chub include development of a Strategic Science Plan, Core Monitoring Plan, several Beach Habitat Building Science Plans, a study plan for the 2000 Low Steady Summer Flows (Fritzinger et al. 2000) and Non-native Fish Mechanical Removal protocols (Coggins et al. 2002). Many of these efforts are presently ongoing.

In May and July of 2005, workshops to assess the knowledge gained through the AMP were conducted in Phoenix and Flagstaff, AZ, respectively (Melis et al. 2005). At the workshops all aspects of the Program were evaluated and assessed for the level of science and knowledge that had been gained to date. The workshops and resulting publication also helped to define and refine research questions and to prioritize research projects in the future.

Results of science investigations conducted under the auspices of the AMP were presented at a science symposium on October 25–27, 2005 , (Gloss et al. 2005), see also [online] http://www.gcmrc.gov/library/reports/synthesis/score2005.pdf. This publication is the second synthesis of research and monitoring in the Colorado River ecosystem and covers the years 1991-2004, though results regarding particular areas of investigation varied from resource to resource. For example, information for the endangered humpback chub was only referenced through 2001.

The FWS is a key stakeholder within the existing AMP and the FWS has previously concurred with Reclamation that sufficient progress has been made in the implementation of the AMP. Reclamation notes that the AMP currently retains the same organizational structure as presented in the fourth sufficient progress communication.

3.1.2 Element 1A: Program of Experimental Flows

Progress to date

This element was intended to continue research through the AMP to identify the effects of Glen Canyon Dam release patterns on listed species, and was "…to include high steady flows in the spring and low steady summer flows in summer and fall during [8.23 MAF] years…studies of high steady flows in the spring may include studies of habitat building and habitat maintenance flows...” Following the 1995 biological opinion and the 1996 ROD, Reclamation helped the AMP to coordinate a series of experimental flows on Glen Canyon Dam. The first large experiment was a week-long, 45,000 cfs beach habitat-building flow that occurred in March-April 1996. Objectives were to rebuild high-elevation sandbars, restore backwater channels, retain fine silts and clays, restore the pre-dam disturbance regime, preserve and restore camping beaches, displace non-native fishes, scour vegetation from camping beaches, and protect cultural resources, all without significant adverse impacts to endangered species, cultural resources, the Lees Ferry trout fishery, or hydropower production. Results of the 1996 experimental flood were documented by Webb et al. (1999).

In 1997 a fall flow test consisting of a powerplant release of 31,000 cfs for 48 hours was conducted. This action received its own consultation, however it is also consistent with RPA element 1A. While powerplant capacity releases were described in the 1995 EIS as Habitat Maintenance Flows, such a test in the fall was not addressed in the 1995 FEIS, which necessitated additional ESA consultation.

The steady flow requirement identified by the FWS was evaluated in the year 2000. In 1999 Reclamation funded a contractor to convene a panel of experts to develop a program of experimental flows for endangered and native fishes of the Colorado River in Grand Canyon (Valdez et al. 2000). As part of this program, the third large experiment conducted by the AMP was an experimental flow for native fishes from March-September 2000. Flow components included: (1) short-term 8,000 cfs initiating the study for aerial photography; (2) stable, spring flows of 14,000-19,000 cfs to measure hydraulics and water temperatures at the mouth of the Little Colorado River; (3) spring and autumn powerplant capacity spike flows; (4) an extended period of 8,000 cfs during May, June, July, and August; and (5) a period of 8,000 cfs steady flows following the autumn spike flow to measure its effects and to conduct a second round of aerial photography. In October 2003 GCMRC convened a science symposium that was largely directed at presentation of results from the low summer steady flows (LSSF) research and monitoring. Effects of the experiment on fish populations were documented by Trammell et al. (2002), Rogers et al. (2003) and Speas et al. (2004b; see Section 3.2.6).

In January 2002 the AMWG directed the Grand Canyon Monitoring and Research Center (GCMRC), in consultation with the Technical Work Group (TWG), to design an experiment to test how dam operations might be modified and other management actions taken to better conserve sediment and to benefit native fish. On March 25, 2002, the GCMRC provided a draft proposal for the requested experimental flows and management actions that formed the basis of the September 2002 Environmental Assessment on Proposed Experimental Releases from Glen Canyon Dam and Removal of Non-Native Fish (Reclamation, NPS and USGS 2002).

Mechanical removal of non-native fish from the Colorado River above and below the LCR was started in January 2003 (Coggins and others 2002, Coggins and Yard 2003) and was continued through 2006. Rainbow trout and brown trout were removed from a 10-mile reach adjacent to the LCR. Non-native suppression releases from Glen Canyon Dam were implemented from January to March 2003 to test the effectiveness of high fluctuating flows on limiting the recruitment of non-native fish (Davis and Batham 2003, Korman et al. 2003). The high fluctuating flows for non-native suppression were continued in 2004 and 2005.

In November 2004 a second high flow experiment was conducted. The duration of this release was reduced to 60 hours on peak and the magnitude was reduced to 41,500 cfs due to repairs being made on one of the dam turbines. Another important difference with the 1996 high flow experiment was that the 2004 release occurred only after sediment input triggers, based largely on antecedent input from the Paria River, had been met. The trigger required that at least 1 million metric tons of fine sediment had been received by the Colorado River prior to the high release.

In September and October of 2005, a series of two-week dam releases occurred that alternated between steady and fluctuating releases. The purpose of this short-term experiment was to examine the effects of daily fluctuations on water quality parameters and biotic constituents (phytoplankton, macroinvertebrates, and fishes) of associated shoreline habitats (Ralston et al. 2007).

In 2006, Reclamation initiated development of a long-term experimental plan which was proposed to include both dam releases and other management actions. This effort originated with a science planning group that produced four options which were recommended by the AMWG to the Secretary of the Interior. GCMRC provided an assessment of the effects of the four options (GCMRC 2006). Reclamation conducted public scoping meetings in December 2006 and January 2007 and identified the purpose and need for the Proposed Action as improving the understanding of the Colorado River ecosystem below Glen Canyon Dam and protection of key resources (humpback chub, sediment, and cultural resources). In April 2007, GCMRC convened a science workshop to evaluate the four options for their use in development of EIS alternatives. Workshop participants also developed a fifth alternative for consideration by Reclamation and its cooperating agencies.

In summary, Reclamation has, through the adaptive management program, conducted a series of experiments that featured varied dam operations in conjunction with non-flow actions (e.g., non-native fish removal, translocation of humpback chub and Kanab ambersnail). These experiments were conducted in an effort to improve the status of the humpback chub and increase our understanding of the relationship between dam releases, sediment conservation and humpback chub population dynamics. Reclamation believes that implementation of these experiments through adaptive management is in concert with the directive to develop a program of experimental flows and has contributed substantially to the new information presented in this biological assessment.

3.1.3 Element 1B: Feasibility Analysis of a Selective Withdrawal Program for Glen Canyon Dam

Progress to date

In January 1999, Reclamation released a draft environmental assessment on a temperature control device (TCD) for Glen Canyon Dam. Such a device is also referred to as a selective withdrawal structure as its utility extends to other water quality issues as well as temperature control. The preferred alterative was a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the environmental assessment (Mueller et al. 1999) for unintended negative effects (i.e., non-native fish proliferation) as a result of the operation of a TCD, as well as the lack of a detailed science plan to measure those effects, that the environmental assessment was withdrawn and not finalized. In 1999 and in 2001, Reclamation convened workshops at Saguaro Lake, AZ of scientists to evaluate the feasibility of a temperature control device and to further develop research and monitoring for evaluating ecosystem responses to warmer temperatures. One outcome of the 1999 workshop was the discovery that native fish data had not been brought together and analyzed. Opinions of native fish biologists on the status of endangered humpback chub differed sufficiently to make obvious the need for the analysis.

During development of the Interim Surplus Criteria EIS in 2000, Reclamation discovered that projections for utilization of the preferred alternative design for the temperature control device, previously estimated at 85 out of 100 years, were considerably overestimated and were closer to 45-50 percent of those years. This discovery prompted re-evaluation of the engineering designs for the temperature control device.

Another milestone in the feasibility assessment was a survey of operators of dams having selective withdrawal devices, including TCDs, to determine whether concerns evidenced by scientists and managers for effects of the Glen Canyon Dam TCD have been experienced at other facilities. Results of this survey and other related investigations were presented to the AMWG at their July 2002 meeting and were subsequently published in Vermeyen (2003). No major environmental complications were identified in the survey results; however, there was little dedicated evaluation of the biological efficacy of the TCDs from which to draw conclusions.

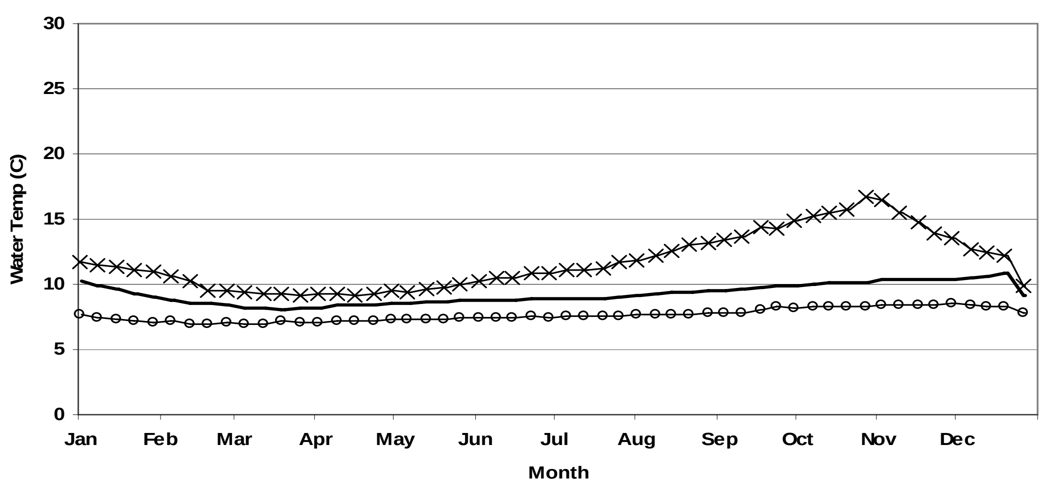
In summer 2002, the AMWG recommended that Reclamation should solicit a risk assessment of the Glen Canyon Dam TCD proposal from the AMP Science Advisors. Subsequently, the Advisors produced a report on their findings of risk assessment (Garrett and others 2003) which recommended the installation of a TCD for Glen Canyon Dam as soon as possible and the construction of a pilot TCD in the interim. The Science Advisors further recommended a strong leadership role from AMWG, TWG, and GCMRC related to the installation and operation of a TCD along with a commitment from all parties to incorporating the TCD into the AMP and the research required to evaluate the TCDs effects. At the August 13–14, 2003 meeting, the AMWG recommended to the Secretary of the Interior that Reclamation should initiate environmental compliance associated with the construction of a TCD. Reclamation initiated a feasibility-level construction design assessment for the TCD in spring of 2006, which was completed in November 2007.

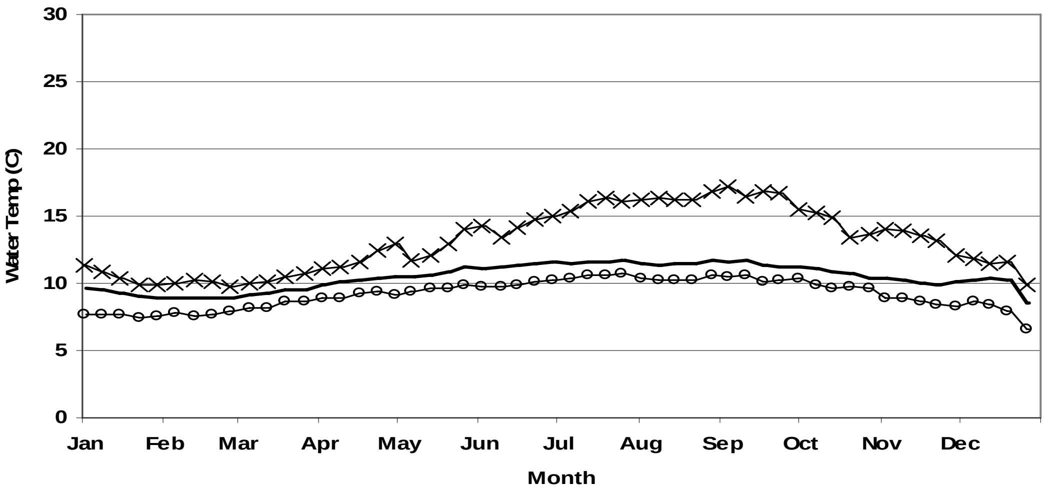
Reclamation has continued to work on the feasibility assessment since the decision was made to rescind the draft environmental assessment on the proposed TCD released in January 1999 (Reclamation 1999). In our 2004 sufficient progress letter, Reclamation indicated to FWS that following the results of scientific investigations, expert workshops, a risk assessment by the AMP Science Advisors, and a recommendation by AMWG, it was justified to proceed with environmental compliance on a selective withdrawal device for Glen Canyon Dam. In 2005 Reclamation initiated development of a new environmental assessment to provide NEPA compliance on a 2-unit selective withdrawal. This effort was discontinued when the decision was made to include compliance for a TCD within the Long-Term Experimental Plan EIS.
Several designs were considered for the selective withdrawal, including uncontrolled and controlled overdraw and internal and external frame devices. Based on projections for lower future reservoir levels arising from modeling in the Interim Surplus Criteria EIS and an extended

drought beginning in 1999, Reclamation chose an external frame design that would allow release of warmer water over a wide range of reservoir elevations from 3700 feet (full reservoir) down to 3520 feet elevation, 30 feet above the level of the penstocks (3490 feet elevation). The range of operation increased to 180 feet or 6 times that of the design proposed in 1999. Each of the two selective withdrawal devices would be 48 feet wide (cross canyon direction), 50 feet deep (stream direction) and 280 feet high. The external frame selective withdrawal devices would contain three sliding gates that would control the level of water withdrawal from the reservoir. They would be mounted to the upstream face of the dam by rigid frames attached near the top of the dam and guide girders connected to the dam along each side of the trashracks. The two generating units designed for placement of selective withdrawal are numbers 4 and 6, which lie near the center of the dam.

To evaluate the effectiveness and capability of this TCD design, Reclamation used the U.S. Army Corps of Engineers' CE-QUAL-W2 model (Cole and Wells 2000) to model Glen Canyon Dam release temperatures, the 1-D Generalized Environmental Modeling System for Surface waters model (GEMSS; Kolluru and Fichera 2003) to model flow temperatures from Glen Canyon Dam to Separation Canyon, and the 3-D GEMSS model to model backwaters below the confluence of the LCR. These models were calibrated for water temperature using temperature data at fixed stations in the reservoir and river.

Historic water temperature data during the period of 1990 to 2005 were used to calibrate and model dam release temperatures, with historic dam release temperatures varying from 8 °C to 16 °C. Graphical results of the historic data are displayed in Figure 6. The temperature of water released from Lake Powell (Figure 6 top) tended to approach ambient water temperature as it traveled downstream to Lake Mead. The rate at which the water increased in temperature depended on release temperature, flow magnitude, and atmospheric conditions. Water temperatures below the confluence of the Little Colorado River varied from 7 °C to 17 °C (Figure 6 middle) and were between 4 °C and 25 °C at the inflow to Lake Mead (Figure 6 lower) during this period of record.





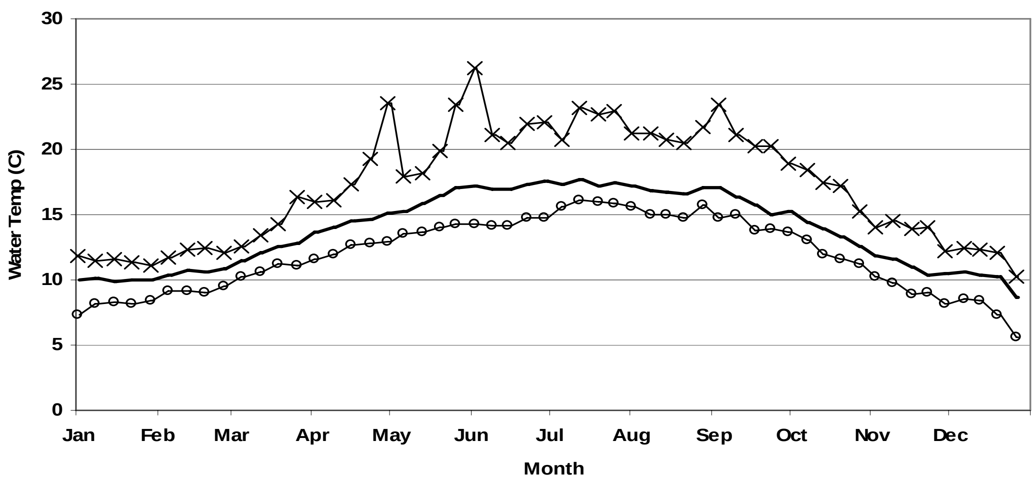


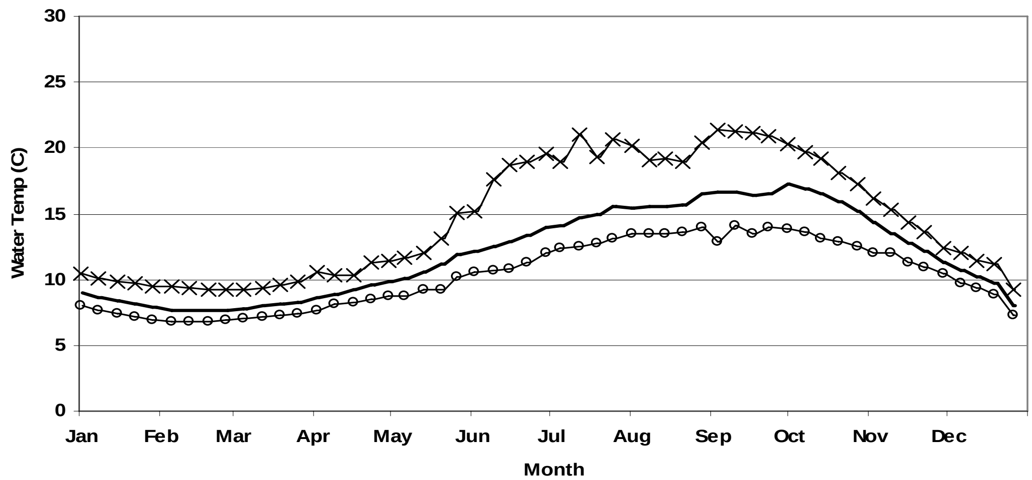
Figure 6. Upper, median, and lower bounds of 7-day moving average temperatures for Glen Canyon Dam releases (top), LCR confluence (middle), and Separation Canyon (lower) sites.

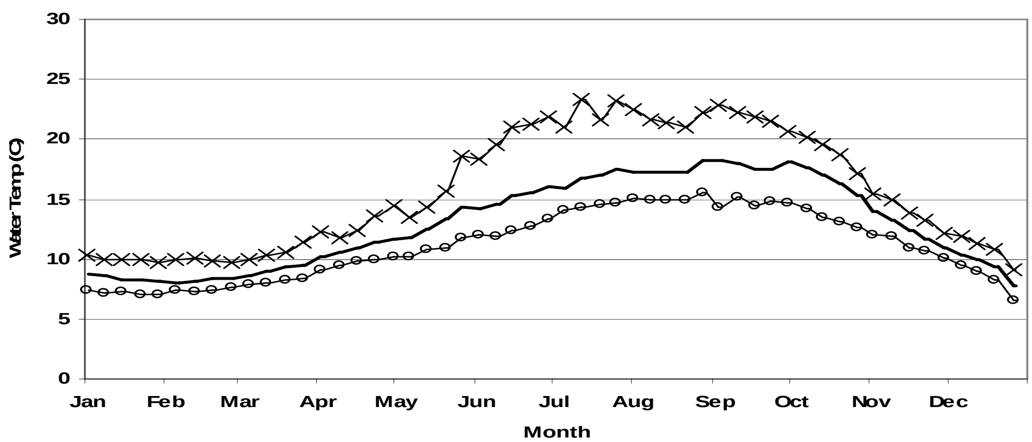
A 2-unit external frame TCD would allow releases to be selected at any elevation within the water column between 3,700-3,520 feet (Reclamation 2005). A maximum of 4,000 cfs could be released from each penstock fitted with a TCD, therefore releases above 8,000 cfs would require blending of water with releases from the remaining penstocks. When reservoir elevations dropped below 3,520 feet, releases would return to the current penstock intakes under the proposed TCD design. Below 3,490 feet elevation releases would have to be made from the hollow jet tubes, also known as the river outlet works. All TCD releases would be constrained using a 30-foot submergence criteria for the intake to avoid surface vortex formation (Reclamation 2005).

Using the period of record from 1990 to 2005 to model the effects of the two-unit TCD, CE-QUAL-W2 modeling predicted Glen Canyon dam release water temperatures would vary from 7 °C to 21 °C (Figure 7 top). Using the output from the CE-QUAL-W2 modeling, water temperatures were routed downstream using the GEMSS model. Water temperatures at the Little

Colorado River varied from 7 °C to 23 °C (Figure 7 middle) and 4 °C to 28 °C at the inflow to Lake Mead (Figure 7 lower) using a two-unit TCD. The analysis showed an average increase in release temperature of about 3 °C with installation of a 2-unit TCD. A better idea of the differences can be gained by assessing the variation among months (Figure 8). Considering the differences in median temperatures with and without a 2-unit TCD, positive deviations with the 2-unit TCD begin in late April, peak in late summer to early autumn at about 7° C, and remain positive until the end of November. The relationship between release temperature and downstream temperature is nonlinear and is limited by the ambient atmospheric conditions. During colder months release temperatures would cool as dam release waters moved downstream.

Releasing water from higher in the water column of a reservoir will reduce the heat budget within that body of water. Modeling impacts of a two-unit TCD showed an average temperature decrease of 2 °C for Lake Powell both at the surface and at a depth of 50 feet.





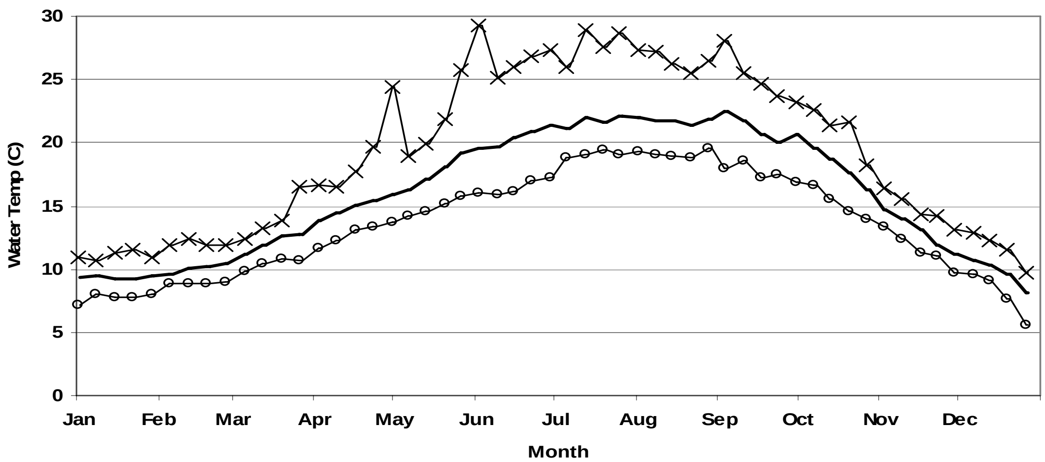


Figure 7. Upper, median, and lower bounds of 7-day moving average temperatures for Glen Canyon Dam releases (top), LCR confluence (middle), and Separation Canyon (lower) sites with a 2-unit TCD.

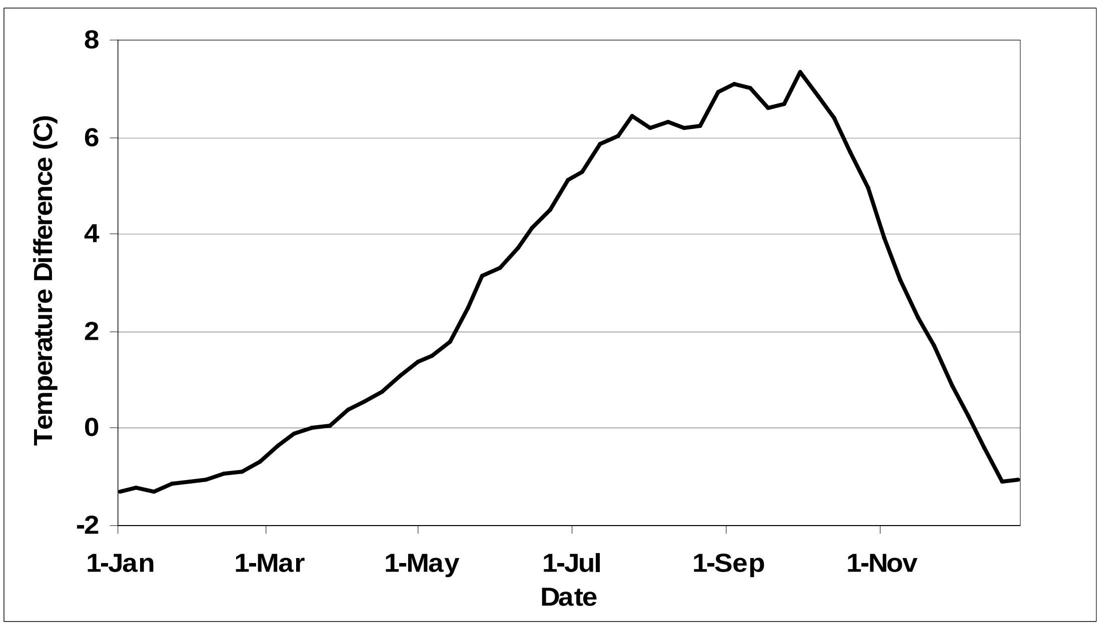


Figure 8. Absolute differences (ºC) in median release temperatures with a 2-unit TCD at Glen Canyon Dam over the course of an annual cycle.

Reclamation also completed a risk assessment to help evaluate responses of aquatic resources in Grand Canyon to the construction and implementation of a TCD (Valdez and Speas 2007). The risk assessment utilized standard EPA protocols (CENR 1999; NRC 1983; RAM 1998; USEPA 2000, 2005, 2006). A mathematical model was used as a tool to quantify risks and benefits to fish, fish parasites, zooplankton, and macroinvertebrates from water temperature changes resulting from modification of 2 of the 8 generation units on the dam. All taxa present or with known potential to access the area were inventoried for each of six regions, including lower Lake

Powell, Glen Canyon Dam to Paria River, Paria River to LCR, LCR to Bridge Canyon, and Bridge Canyon to Pearce Ferry.

The median, minimum, and maximum temperature results from the GEMSS modeling were used in this risk assessment evaluation, assuming both with and without a 2-unit TCD. Temperature degree days were computed for spawning, incubation, and growth for fish and life history requirements for other taxa and compared with the predicted water temperatures to determine if the temperature change would benefit particular taxa. Risk assessment scores were computed based on degree day accumulation and then calibrated for fish by comparing modeled fish composition with composition from four prior surveys reflecting a range of thermal regimes from the pre-dam era through recent years.

Results suggested benefits to all native fishes, but correspondingly higher benefits to many non-native fish species that may compete with or prey upon native species. Fish species carrying the highest risk for benefiting from warmer water were rainbow trout, brown trout, common carp, fathead minnow, red shiner, channel catfish, and smallmouth bass. Preliminary results also show more suitable conditions for warm-water fish parasites, including *Lernea* and Asian fish tapeworm *Bothriocephalus acheilognathi.*

Results also predicted an increase in periphyton biomass and diversity with warmer water, which could lead to increased food and/or substrate for epiphytes, aquatic invertebrates, fish, and waterfowl. Warm water impacts to macroinvertebrates include minor shifts in relative abundance of existing taxa with the possibility of increased taxa richness, which could be beneficial if limited to insect taxa. However, increased potential for invasion by crayfish and other nuisance species is significant.

In light of these concerns and with the recommendation of an independent scientist panel convened in April 2007 to discuss long-term experimental planning, Reclamation also briefly investigated whether construction of a TCD with both warm and cold water release capability is possible and under what circumstances cold water would be available for release. Due to the high cost of design investigation, no specific design work or feasibility analysis was completed on this option, pending a decision by FWS on whether to proceed with construction of a TCD as designed.

For the warm and cold water TCD to be viable, sufficient cold water must be available lower in Lake Powell when dam releases naturally warm due to drought induced draw down. CE-QUAL-W2 modeling was used to determine the reservoir elevation at which cold release temperatures persist when the river outlet works are operated. Model results indicate that at elevation 3530 feet, which is 10 feet above the lower cutoff elevation for TCD operation, release water temperatures from the level of the river outlet works (elevation 3370 feet) are colder, with July temperatures of 9 °C, September temperatures of 12.5 °C, and November temperatures of 16 °C. When the reservoir is at or above elevation 3530 feet sustained release of cold or cool water may be possible.

There is a slight probability (<0.5 percent) of Lake Powell elevation dropping below 3490 feet when the external frame TCD, as presently designed, would no longer be operable. Below this elevation water would be released through the river outlet works. Lake Powell’s capacity at this elevation is approximately 2.5 maf. Based on modeling with CE-QUAL-W2, dam release temperatures from the river outlet works below elevation 3490 would be about 13 °C in July, 20 °C in August, and 23 °C in September. The water temperature of Lake Powell would quickly increase in the spring and summer at this elevation as a result of the small reservoir capacity, directly affecting dam release temperatures.

The external frame design described above has undergone a full engineering and budget review by Reclamation's Denver Technical Services Center. The review has included a Value Engineering Study (June 2006), a Design, Engineering, and Cost Estimating Review (July 2006) and a Constructability Review (August 2006). The review process passed the 60 Percent Design Decision point in January 2007 and the final design specifications and drawings were completed in November 2007. Estimated cost (construction and non-construction) for installing a 2-unit warm water TCD was approximately $100 million in 2009 dollars.

If the decision is made to proceed, testing of the selective withdrawal would occur under the auspices of the AMP using a science plan developed by GCMRC, cooperating scientists, and the Technical Work Group. This would be accomplished by modifying two penstocks on Glen Canyon Dam and operating the dam for a minimum period of 3-4 years with assessment through the AMP before a subsequent decision is made on any potential further modification. Testing would be the next phase in the feasibility assessment called for by the FWS. Although many potential positive and negative effects of a TCD on endangered fish and other Colorado River resources have been postulated during investigations conducted to date, few of these projected outcomes can be known with certainty without specific testing through a research and monitoring program.

Reclamation engineers and managers now believe that a TCD designed to allow warmer water to be released downstream is technically feasible. With this consultation, Reclamation is reporting to the FWS that a TCD is technically feasible, but Reclamation is seeking the biological opinion of the FWS whether the risks of warming the water by modifying the dam's penstocks (as identified above regarding potential parasites and warm-water non-native enhancement) are worthwhile given the current status of listed species and their habitat below the dam. The question for the FWS is whether the potential benefits to the endangered fish of operating a TCD and warming the water outweigh the potential adverse effects from potential increases in non-native predators, parasites and diseases, or other unintended, systemic interactions in the downstream environment.

3.1.4 Element 1C: Determination of Native Fish Responses to Various Temperature and Flow Conditions

Progress to date

Various studies have addressed fish response to different temperature and flow conditions that are applicable to the Colorado River in Glen and Grand canyons. Ward et al. (2002) evaluated the effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker, and Ward and Bonar (2003) examined the effects of cold water on susceptibility of age-0 flannelmouth sucker to predation by rainbow trout. Vernieu (2003) evaluated warming of mainstem and nearshore habitats during the low steady flows of summer 2000. Rogers et al. (2003b) measured drift and benthic biomass under the low steady flows and powerplant-capacity spike flows in the steady flow experiment. Trammell et al. (2003) investigated responses of native fishes to the same low steady and spike flows. A report on the mechanical removal of non-natives coincident to warmer releases from Glen Canyon Dam in 2004-2005 was submitted by Coggins (2007). Rogers et al. (2003a) examined non-native salmonid distribution and abundance from RM 12 to 218. Johnstone and others (2003) reported on native fish monitoring efforts and made recommendations for approaches to setting up a standardized monitoring program with emphasis on shoreline and backwater fish communities. Ralston et al. (2007) compared the effects of steady and fluctuating flows on water quality parameters and biotic constituents (phytoplankton, macroinvertebrates, and fishes) of associated shoreline habitats. Petersen and Paukert (2005) developed a bioenergetics model for humpback chub and evaluated the effects of water temperature changes on energetic demand for the species.

One of the impediments to identifying responses of native fish to changes in water temperature regimes and river flows has been the lack of a consistent monitoring plan and assessment analysis. Under the auspices of GCMRC, with the aid of Dr. Carl Walters, University of British Columbia, an age-structured mark-recapture (ASMR) model was developed for both humpback chub and flannelmouth sucker. The ASMR uses the history of marks and recaptures for all PIT-tagged fish in the population and determines the population size for adults (age 4+) using variable mortality and constant mortality models.

Concern within the AMP arose over the controversy surrounding the different methods and models used to assess humpback chub populations in both the Upper Basin and in the Grand Canyon. In response to this concern, GCMRC convened a Panel of Independent Reviewers to meet with representatives of ongoing programs in the Upper Basin and Grand Canyon. The goal of this panel was to review current methods and make recommendations to improve the accuracy and precision associated with the parameter estimates (i.e., abundance, population growth rate, and recruitment) from the various models being used. The Panel of Independent Reviewers found that the competing models used in the Upper Basin and Grand Canyon were appropriate for their respective locations and made recommendations to improve their use in the future (Kitchell et al. 2003). A series of meetings was proposed to examine data on humpback chub collected in both the Upper Basin and in the Grand Canyon. An investigation into population estimation techniques was conducted and recommendations were made for the AMP by Dr. Otis of Iowa State University. A recent compilation of results of this work (Coggins 2007) addresses these concerns and is described in detail in Section 2.4.1.

Research and monitoring of native fishes in Grand Canyon, as well as their predators, competitors, diseases, and parasites is being carried out largely under the auspices of the GCMRC with funding provided to the AMP. Much of the research and monitoring work accomplished through GCMRC is accomplished through competitive proposals that are peer-reviewed by independent scientists. Results of this work are presented on a regular basis at TWG and AMWG meetings, and are published as reports and peer-reviewed articles in technical journals.

3.1.5 Element 2: Protection of the Humpback Chub Spawning Population in the Little Colorado River

Progress to date

Reclamation accepted this element of the RPA, despite lacking legal jurisdiction or discretionary authority over the LCR or surrounding lands and tributaries. Reclamation clearly identified the limits to the jurisdiction of the action agency with respect to this sub-element of the Biological Opinion in a letter to the FWS dated April 6, 1995. Moreover it is essential to emphasize that no single agency or entity has the authority or responsibility to implement a management plan that would protect the endangered humpback chub and its critical habitat from threats arising throughout the LCR basin. The LCR watershed is the second largest in Arizona, encompassing approximately 27,000 square miles in both Arizona and New Mexico. It crosses two state boundaries, seven counties, many local, state and federal agency jurisdictions, and three Native American Indian Reservations. Land ownership in the watershed includes 48 percent Indian Reservations, 19 percent federally owned, 10 percent State Trust Lands, and 23 percent privately owned.

The Little Colorado River Multi-Objective Management Watershed Group (LCRMOM) was formed in 1996 and as an umbrella watershed group having as members LCR basin subwatershed groups, Native American tribes, and city, county, state, and federal agencies. A draft Little Colorado River Management Plan was prepared in 1999 (SWCA 1999), reviewed by the FWS, and revised. A revised draft was completed (SWCA 2005) but not finalized given several changes and developments in the organization of groups involved in management of the Little Colorado River watershed. In March 2002, Reclamation made a presentation to the LCR-MOM on the need for a management plan for humpback chub and our efforts in that endeavor. At the meeting, LCR-MOM representatives indicated that they were interested in partnering with Reclamation and the FWS in the development of the management plan. Since that time, the LCR-MOM has become less active and other organizations have formed to coordinate water management activities in the LCR.

Currently, there is a Statewide Water Resources Advisory Group that provides technical assistance and advice to interested parties. The Little Colorado River Plateau Resources Conservation and Development (RC&D) is focused on implementing a strategic plan developed by sponsors and Council Members with the priority goal of formulating and publishing an all inclusive watershed management plan. There are 32 participants in the RC&D. The Little Colorado River watershed Coordinating Council operates under the umbrella of the RC&D and is developing the Little Colorado River Watershed Management Plan. The Bureau of Reclamation Lower Colorado Region has committed to fund 50 percent of the estimated $600,000 to develop the plan with the other 50 percent coming from the non-federal stakeholders. In addition, several partnerships have become established, including the Upper Little Colorado River Watershed Partnership and the Show Low Creek Enhancement Partnership to monitor, restore, and protect natural resources within the Upper Little Colorado River Watershed to enhance the quality of life in accordance with the diverse interests of the watershed residents.

Reclamation will continue to work with these organizations to better understand how to affect land and water management in the LCR watershed in a manner that conserves water quantity and quality to benefit the endangered humpback chub. Reclamation will continue to assist in developing a watershed management plan, emphasizing actions that could be accomplished to address the threats to the endangered humpback chub arising in the Little Colorado River Basin and the potential roles to be taken by various participants and watershed organizations. Because this is the extent of our authority regarding this element, Reclamation believes it has fulfilled this element of the 1995 biological opinion.

3.1.6 Element 3: Sponsor a Workshop for Development of a Razorback Sucker Management Plan for the Grand Canyon

Progress to date

Reclamation sponsored a workshop on the endangered razorback sucker on January 11 and 12, 1996. Workshop participants generally agreed that the razorback sucker was probably historically a transient through Grand Canyon between more suitable meandering river reaches located upstream and downstream (Wegner 1996; Valdez 1996). The workshop participants also recognized that the inflow of the Colorado River into Lake Mead provided the best potential habitat for the razorback sucker in Grand Canyon with its expansive areas of inundated and emergent vegetation and a complex channel with backwaters and embayments.

The results of the workshop (Wegner 1996) were sent to participants, including the FWS, on February 12, 1996. The FWS has not initiated development of the Memorandum of Understanding for razorback sucker management. In the FWS response to Reclamation's third progress evaluation, dated May 27, 1999, several action items of interest to the FWS were identified. Because the only known extant population of razorback sucker above Hoover Dam is in Lake Mead (Holden and others 2000), these actions should be addressed primarily by the Lower Colorado River Multi-species Conservation Program. However, we are partially addressing two of the actions—non-native fish control and provision of experimental flows that could affect habitat of razorback sucker in upper Lake Mead—through the AMP. In May of 1997, Hualapai Tribe biologists implanted 15 razorback sucker with radio transmitters for release at three locations of the Colorado River below Diamond Creek (Zimmerman and Leibfried 1999); Separation Canyon (RM 240), Spencer Creek (RM 246), and Quartermaster Creek (RM 260). The fish remained in their original locations and then gradually moved toward Lake Mead. Several radio-tagged fish remained in the inflow region, but eventually all fish moved into Lake Mead and contact was lost. None moved upstream into Grand Canyon proper. The AMWG recommended in 2004 that GCMRC develop a non-native fish control program in Grand Canyon working with the Technical Work Group. Reclamation has agreed to assist in the development of this non-native fish control program.

Reclamation has completed the workshop. It is our understanding that the next step is for the FWS to recommend a course of action and to develop a Memorandum of Understanding with Reclamation and other entities who may wish to participate.

3.1.7 Element 4: Establishment of a Second Spawning Aggregation of Humpback Chub Downstream of Glen Canyon Dam

Progress to date

In 1999, Reclamation funded a contractor to convene a panel of experts and develop a plan for establishing a second population of humpback chub in Grand Canyon. The plan evaluated four alternatives: (1) existing mainstem aggregation, (2) metapopulation approach, (3) tributaries, and (4) tributary and mainstem (Valdez et al. 2000). Preliminary habitat analyses showed that genetic criteria (i.e., target population size and structure) are unlikely to be met in a tributary, but may be met in two contiguous mainstem aggregations (Stephen Aisle/Middle Granite Gorge) or in the mainstem taken as a whole (the metapopulation concept). The metapopulation concept was thought to represent the greatest likelihood for success in establishing a new, genetically viable population of humpback chub in Grand Canyon if suitable conditions of flow, temperature, and low predator loads could be achieved. Reclamation has initiated investigations and actions to establish a second population of humpback chub as identified by Valdez et al. (2000). Reclamation believes that, in the aggregate, all of these activities represent a system-wide approach at improving humpback chub viability throughout the Grand Canyon ecosystem.

Impediments to establishment of a second spawning aggregation of humpback chub in the Colorado River include unsuitable environmental conditions, e.g., cold water temperature, and the presence of non-native competitors and predators. As indicated above, under element 1B (Section 3.1.3), Reclamation made an initial determination on feasibility of the TCD for Glen Canyon Dam in 2002 after a risk assessment (Garrett and others 2003) and AMWG recommendation to initiate environmental compliance necessary for the construction and testing of a TCD at Glen Canyon Dam. Brown trout control in Bright Angel Creek and a feasibility assessment of non-native control in other tributaries were conducted by GCNP (Leibfried et al. 2003) and Reclamation funded a project conducted by the Arizona Game and Fish Department to evaluate sampling gear for capture of channel catfish and carp in the LCR. Rogers et al. (2003a) evaluated the abundance and distribution of non-native predators related to mechanical removal efforts.

In 2003 the FWS began a translocation program funded by Reclamation for humpback chub above Chute Falls in the LCR and GCNP is examining other tributaries to the Colorado River in the park to assess their suitability for translocations. During 2003-05, a total of 1,150 YOY humpback chub were translocated from the lower LCR to the LCR above Chute Falls. Preliminary results indicate that translocated fish survival and growth rates are high; limited reproduction and downstream movement to below Chute Falls has also been documented (Sponholtz et al. 2005; Stone 2006, 2007).

The use of Glen Canyon Dam releases to negatively impact non-native fish has been assessed in the AMP (Davis and Batham 2003; Korman and others 2003). The use of high experimental flows for this purpose, in addition to directly improving habitat for native fish, has been incorporated into the development of a program of experimental flows to satisfy the needs of element 1A. Another impediment to establishment of a second spawning aggregation is the determination of genetic relatedness among aggregations of humpback chub in Grand Canyon. Valdez and Ryel (1995) established the presence of nine aggregations of humpback chub, including the individuals in the LCR. Genetic evaluations by Colorado State University (Douglas and Douglas 2003a, 2003b; Douglas and Douglas 2007) on the entire taxon and by the FWS on humpback chub collected in the LCR and held at Willow Beach National Fish Hatchery will provide important information in making these determinations.

Evaluating the feasibility of increasing the temperature of water released from Glen Canyon Dam was a common element in the Glen Canyon Dam EIS and one of the elements of the reasonable and prudent alternative in the 1995 biological opinion of that document. In 1999, Reclamation issued an environmental assessment regarding potential modification of Glen Canyon Dam to construct a selective withdrawal structure, and has subsequently continued to investigate various structural designs. The recent drought-induced drawdown of Lake Powell has resulted in warmer release temperatures, providing an opportunity to monitor and evaluate the effects on habitat, reproduction and recruitment.

Monitoring of fish populations since 2002 during MLFF releases shows that the numbers of young humpback chub in the mainstem have increased, most likely as a result of warmer releases from Glen Canyon Dam and/or mechanical removal of trout, though the cause is uncertain (USGS 2007). Further monitoring and investigation is needed of the mainstem aggregations of humpback chub to determine if a second self-sustaining population is becoming established outside of the LCR aggregation.

3.2 New Information Gathered Since the 1995 Biological Opinion

3.2.1 Fluvial Geomorphology and High Flow Tests

Glen Canyon Dam and Lake Powell traps most of the sediment transported by the Colorado River. Tributaries downstream of the dam are now the only renewable sediment source to Glen, Marble, and Grand canyons. The dam and reservoir have also reduced annual flood peaks and increased moderate flows. The altered flow releases from the dam have less capacity to transport sand and coarser sized sediments than under pre-dam conditions with frequent floods.

Sandbars, debris fans, and rapids are the most prominent geomorphic features in the Colorado River corridor. Sandbars in particular are inherently linked to the magnitude and timing of sediment supplied from the Paria and Little Colorado rivers, lesser tributaries, and the mainstream river channel; and to the magnitude and frequency of river flows (Griffiths et al., 2004; Melis 1997; Webb et al. 1999). Sandbars are formed in eddies, which are commonly associated with tributary debris fans (Schmidt and Graf 1990; Schmidt and Rubin 1995). These debris fans form the rapids of Grand Canyon (Griffiths et al. 2004; Webb et al. 2005; Melis 1997; Melis et al. 1994; Webb et al. 1989). Nearly all sandbars in Grand Canyon are associated with recirculation zones that consist of one or more eddies. Sandbars are highly valued for their role as camping beaches and their occurrence is frequently accompanied by backwaters in the eddy return channel. Backwaters are important rearing habitat for native fish due to low water velocity, warm water and high levels of biological productivity.

The 1995 EIS predicted that sediment would eventually accumulate over multiyear timescales in the eddies and other depositional areas of the Colorado River below the Paria River, and that the relationship between sediment transport and river discharge was constant through time. Both assumptions were refuted in the years following the 1996 high flow test and resulted in an entirely new paradigm of sediment transport and conservation. The assumption in the 1995 EIS of a constant relationship between river discharge and sediment transport has recently been determined incorrect (Topping et al. 2000a, b); instead, sediment transport rates vary significantly with river bed grain size, which in turn varies with tributary input of fine sediment. Dam releases under existing operating criteria, have typically resulted in little to no multiyear accumulated sand storage during years of average to below-average tributary sediment supply and less opportunity for sandbar deposition (Rubin et al. 2002; Schmidt et al. 2004; Wright et al. 2005). Sand supplied during tributary floods tends to accumulate in eddies only during low-flow periods (9,000 cfs or less; Topping et al. 2000a, b).

Sandbars between the 20,000- and 30,000-cfs levels have eroded and not been rebuilt, riparian vegetation encroached into the 20,000 to 30,000-cfs zone, and backwater habitats have filled with silt. The sand mass balance remained negative during water years 2000 through 2004, despite five consecutive years in which minimal release volumes (8.23 maf) from Lake Powell occurred during prolonged drought in the upper Colorado River Basin (Wright et al. 2005). These measurements and calculations of sand transport also show that tributary inputs are typically transported downstream and out of the canyon within a few months under typical ROD operations (Rubin et al. 2002).

One of the questions raised by geomorphologists (Andrews 1991; Goeking et al. 2003; Howard and Dolan 1981 Schmidt 1999; Schmidt and Goeking 2003) is what flow magnitude and duration is needed to resuspend sediment and create and maintain sandbars. One hypothesis is that without occasional periods of sustained high releases (powerplant capacity and above), high elevation sandbars will erode and not rebuild (Andrews 199l). In 1997, a habitat maintenance flow was conducted that indicated flows less than or equal to powerplant capacity could be used to redistribute sediment. Future experiments may include habitat maintenance flows (of lesser magnitude and duration), depending upon the results of the proposed experimental high flow in 2008.

The high flow tests of 1996 and 2004 were found effective at building or rebuilding sandbars, although persistence of the sandbars is variable. The 1996 beach/habitat-building flow deposited more sandbars and at a faster rate than predicted. Webb et al. (1999) contains a series of scientific articles that describe finding of the 1996 beach/habitat-building flow. Repeat topographic and hydrographic mapping of 33 sandbar-eddy complexes showed that the 1996 beach/habitat-building flow rebuilt previously eroded high-elevation sandbar, regardless of location, bar type, or canyon width (Hazel et al. 1999). More than half of the sand deposited at higher elevations was taken from the lower portions of the sandbars (Schmidt 1999) rather than being derived from tributary sand supplies accumulated on the channel bed, as originally hypothesized in the 1995 EIS (Wright et al.2005). Over time, however, this resulted in a net decrease in total eddy-sandbar area and volume (Topping et al. 2004); many sandbars built during the 1996 high flow test eroded in as little as several days following the experiment.

In contrast to the 1996 high flow test, the 2004 high flow test was strategically timed to take advantage of highly sediment-enriched conditions (Wiele et al. 2005). Suspended sediment concentrations during the 2004 experiment were 60 to 240 percent of those measured during the 1996 experiment, although there was less sand in suspension below RM 42 (Topping et al. 2004). This resulted in creation of larger sandbars than those observed during the 1996 experiment in Marble Canyon, but area and volume of sandbars downstream of RM 42 actually decreased due to comparatively less sand in that area in 2004 than in 1996. Thus, it was clear from results of the 2004 high flow test that high flows conducted under sediment-depleted conditions (such as 1996) cannot be used to sustain sandbar area and volume (Topping et al.

2004); additionally, it became evident that more sand would be needed during future high flow tests to restore sandbars throughout Marble and upper Grand canyons.

In 2007, sand inputs from the Paria River were at least 2.5 million metric tons, or about 2.5 times the historic average (Topping and Melis, 2007). Together with inputs from the Little Colorado River in 2006 and unexpected retention of sediment from both tributaries during 2006 (USGS 2006b), sand inputs are currently at least 3 times the amount that triggered the 2004 high flow test, and greater than since at least 1998. This presents a unique opportunity to evaluate effects of a high flow test under sand-enriched conditions greater than ever tested before.

Finally, as noted by Magirl et al. (2005), the water-surface profile in Grand Canyon has only been measured twice, once by USGS in 1923 and the second time as part of the experimental flow program of the AMP in 2000. Important new information from the USGS's comparison of 1923 with 2000 is that the profiles do not differ at the scale of the full length of the canyon and some rapids and other geomorphic features exhibit no change over time. However, changes in specific geomorphic features may be of importance within the overall critical habitat for endangered fish. One of the observed changes is that 66 percent of the drop in elevation occurs in 9 percent of the total river length, whereas in 1923, 50 percent of the cumulative drop through the river corridor occurred in the same 9 percent distance. This change has resulted in an enhanced pool-and-rapid morphology in the eastern portion of the canyon where humpback chub occur. The largest rise in elevation is at House Rock Rapid (+2.0 m), followed by Badger Rapid with a 1.8 m rise. While stability or change in individual rapids such as Badger or House Rock does not directly affect endangered fish, related changes in sandbars and debris fans associated with the rapids are important as fish habitat.

3.2.2 Backwaters

Backwaters are thought to be important rearing habitat for native fish due to low water velocity, warm water and high levels of biological productivity. They are created as water velocity in eddy return channels decline to near zero with falling river discharge, leaving an area of stagnant water surrounded on three sides by sand deposits and open to the mainchannel environment on the fourth side. Reattachment sandbars are the primary geomorphic feature which functions to isolate nearshore habitats from the cold, high velocity mainchannel environment.

Backwater numbers vary spatially among geomorphic reaches in Grand Canyon and tend to occur in greatest number in river reaches with the greatest active channel width, including the reach immediately downstream from the LCR (RM 61.5-77; McGuinn-Robbins 1995). Numbers and size also vary temporally as a function of sediment availability and hydrology, and their size can vary within a year at a given site. On short time scales (i.e., from one year to the next; Dr. John C. Schmidt, personal communication) backwater numbers appear to respond readily to sudden high sediment inputs and high flows regardless of antecedent sediment conditions. Backwaters declined in number from 1990 to 1992 under experimental high fluctuating flows and MLFF, but a rapid but short lived increase in backwater numbers resulted from high inputs and flows from the LCR in 1993 (Beus et al. 1994; McGuinn-Robbins 1995). Backwaters created in 1993 declined in 1994 under more average sediment and flow conditions (McGuinn-Robbins 1995). Backwater number can also vary tremendously depending on flow elevation during sampling and tend to be greatest at low flow elevations. Hoffnagle and Stevens (1999) noted that backwater numbers and area were reduced at flows greater than 10,000 cfs at any given point in time. McGuinn-Robbins found more backwaters during 1990 at the 5,000 cfs level than at the 8,000 cfs level, although area was greatest at the 8,000 cfs level.

Persistence of backwaters created during the 1996 high flow test appeared to be strongly influenced by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters, potentially available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999; Hazel et al. 1999; Parnell et al. 1997; Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones had eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999).

Goeking et al. (2003) found no relationship between backwater number and flood frequency, although backwater size tends to be greatest following high flows and less in the absence of high flows due to infilling. Considering both area and number, however, no net positive or negative trend in backwater availability was noted during 1935 through 2000. At the decadal scale, several factors confound interpretation of high flow effects on backwaters bathymetry, including site-specific relationships between flow and backwater size, temporal variation within individual sites, and high spatial variation in reattachment bar topography (Goeking et al. 2003). Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, hydrology of previous years (Rakowski and Schmidt 1999) and post-high flow river hydrology, which can shorten the longevity of backwaters to a few weeks depending on return channel deposition rates or erosion of reattachment bars (Brouder et al. 1999).

Biologically, the 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring (Brouder et al. 1999; Parnell et al. 1999). Invertebrates had rebounded to pre-test levels by September 1996, but it is thought that the rate of recolonization was hindered by a lack of FPOM. Still, recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer's cohort of YOY native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell et al. (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater.

In a study conducted in the upper Colorado River basin (middle Green River, Utah) Grand et al (2005) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2005). Potential geomorphic differences between the Grand Canyon and the Upper Colorado River basin underline the need for additional research investigation.

An outstanding information need for management of Grand Canyon backwaters is the relationship between backwater bathymetry and suitability as fish habitat, specifically the relationship between depth, area, volume and thermal characteristics. Goeking et al. (2003) point out large backwaters may not incur as many benefits to young native fish as smaller backwaters because the latter will warm faster and thus remain warmer over time than larger backwaters; however, due to their depth, they may be more frequently available as fish habitat over a greater range of flows. In the Upper Colorado River basin, Colorado pikeminnow were found to utilize backwaters with average depths greater than 0.3 m (Trammell and Chart 1999) and average areas of 992 m^2 (Dey et al 1999). The issue of backwater depth is a research need from the standpoint that while greater depths afford more availability over a wide range of flows (Muth et al. 2000), the concurrent increase in volume with depth may slow warming rates.

3.2.3 Water Temperature and Flow Regime

Glen Canyon Dam releases hypolimnetic water (the deeper layer of the reservoir) with a relatively constant temperature which ranges from 6-8 °C at high reservoir levels. In the summer, the surface layer (epilimnion) of Lake Powell warms to nearly 30 °C as a result of warm inflows, ambient air temperature, wind mixing and solar radiation. However, while release temperatures remain relatively constant, they are influenced by lake elevation, inflow hydrology, and to a lesser extent, release volumes and meteorological conditions. Release temperatures have varied from 7 to 16 °C through 2006 (Figure 9). Between 1999 and 2005, Lake Powell elevations dropped more than 140 feet as a result of a basin-wide drought. While winter release temperatures remained cold, Glen Canyon Dam release temperatures increased to 16 °C in the fall of 2005. The drop in Lake Powell elevation resulted in warmer releases because the epilimnion was closer to the penstock withdrawal zone. Release temperatures from Glen Canyon Dam during 2004 and 2005 were the highest since August 1971 when the reservoir was filling.

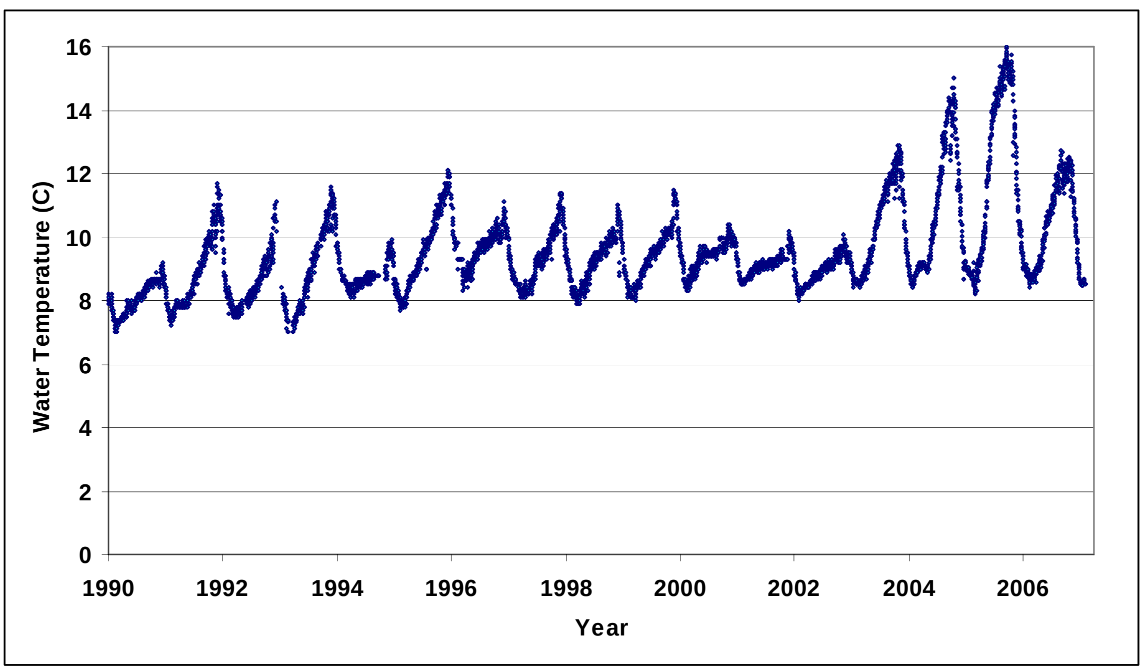


Figure 9. Release water temperature data from Glen Canyon Dam, AZ from 1990 to 2007.

As water travels downstream from Glen Canyon Dam to Lake Mead the water temperature increases by an average of 9 °C during summer months. The amount of warming is directly affected by seasonal air temperature, winds and water velocity, with highest warming rates occurring in mid-summer at low release volumes (Vernieu et. al. 2005). Generally, as air temperatures decrease during late fall, water released from Glen Canyon Dam cools as it moves downstream towards Diamond Creek. River temperatures across the channel are nearly uniform due to turbulence and mixing, but nearshore areas typically exhibit higher water temperatures during summer and early autumn months (Vernieu et al. 2005). Temperature differences between mainchannel and nearshore habitats are especially pronounced in backwaters and other low velocity areas. The amount of warming that occurs in backwaters is affected by daily fluctuations, which cause mixing with cold mainchannel waters (Arizona Game and Fish Department 1996).

Hoffnagle (1996) found that mean, minimum, maximum and diel range of backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C) under steady flows about 2.5 °C greater than those under fluctuating flows. Differences in the mainchannel temperatures during steady and fluctuating flows were also statistically significant, but mean temperatures differed by only 0.5 °C. Similar results were documented by Trammell et al. (2002), who found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C above those during 1991-1994 under fluctuating flows.

Korman et al (2006) also found warmer backwater temperatures under steady flow conditions, concluding that backwaters were cooler during fluctuations because of the daily influx of cold main channel water. These effects were documented during the months of August and September, but not October, when cooler air temperatures caused backwaters to be about 1 °C cooler than the mainchannel. However, they also noted that the extent of the effect was variable and depended on the timing of daily minimum and maximum flows, the difference between air and water temperatures, and the topography and orientation of the backwater.

Perhaps more importantly, Korman et al. (2006) also noted that nearshore areas affected by fluctuating flows (i.e., in the varial zone) warmed substantially for brief periods each day, which posits an ecological trade-off for fish utilizing these areas. On the one hand, fish may choose to exploit the warmer temperatures of the fluctuating zone on a daily basis and simply sustain any bioenergetic disadvantages of acclimating to rapidly changing discharge; or they may choose to remain in permanently wetted zone which is always wetted, but colder than the immediate near shore margin.

In a separate study, Korman et al (2005) observed that slightly more than half of observed YOY rainbow trout in the Lees Ferry reach maintained their position as flows fluctuated rather than follow the stream margin up slope. Thus, for trout, it appears that the bioenergetic cost of changing stream position with fluctuations in discharge perhaps outweighs the benefits of exploiting the slightly warmer stream margins. It is clear from this work that understanding the trade-off between temperature and fluctuating flows as it affects growth and survival of early life stages of Grand Canyon fish (native and non-native) is an important research question.

To assess the likelihood of water temperatures during the Proposed Action without a TCD installed on Glen Canyon Dam, the probabilities of cold (<11 °C), cool (>11 C - 17 °C) and warm (>17 °C) releases from the dam in July were estimated for the five-year period beginning in 2009. The analysis was based on 1,700 separate data points of reservoir elevations using sequential incremental methodology of calculating elevation with a given starting elevation.

Projected reservoir release temperatures were identified based on previous empirical data and modeling outputs. Reservoir elevation was used as the driving variable most affecting release temperature with consideration for the affects of runoff volume in affecting the depth of the reservoir thermocline. Larger runoff volumes deepen the epilimnion creating a larger, deeper body of warm water that is relatively closer to the penstocks at a given reservoir elevation, and therefore available to be released, than do smaller runoff volumes. Using this approach, the following elevations were determined likely to produce the associated dam release temperatures:

- > 3600 feet elevation produced cold releases
- > 3550 and < 3599 feet elevation produced cool releases
- > 3490 and < 3550 feet elevation produced warm releases

The overall probabilities for these three temperature ranges over the long term in the month of July were: (<11 °C) = 75 percent; (>11 °C and <17 °C) = 21 percent; and (> 17 °C) = 4 percent. Thus, the modeling output predicts that release temperatures in 3 out of 4 years in the time period of the Proposed Action will be cold.

To further differentiate the prospective release temperatures in the five-year period identified for the Proposed Action, we estimated the probabilities of delivering cold, cool, and warm waters for 2-5 year successive periods. Probabilities for the first two years using all combinations of cold, cool, and warm releases show that by far the highest likelihood is for two successive years of cold water, with the lowest probability being for a cold release year followed by a warm release year (Table 6).

Table 6. Probabilities of water temperatures for two succeeding years (2 years total)

	Succeeding Years Temperature (Probabilities in percent)		
Initial Water Temperature	Cold	Cool	Warm
Cold	90.9	8.9	0.2
Cool	32.6	52.8	14.5
Warm	4.2	63.8	31.9

The probabilities for the remaining three years are provided for cold to cold, cool to cool and warm to warm release temperatures (Table 7). Again, the highest probability is for release water remaining cold during the five year period and the lowest probabilities are for successive years of warm water. Based on this analysis, we predict that waters released from Glen Canyon Dam during the period 2009-2013 without selective withdrawal will most likely be cold (< 11 °C).

Table 7. Probabilities of similar water temperatures for two, three and four succeeding years when year one releases are cold, cool or warm

		Succeeding Years Temperature		
Initial Water Temperature	Succeeding Year	Cold	Cool	Warm
Cold	3	82.6		
	4	75.1		
	5	68.3		
Cool	3		27.9	
	4		14.7	
	5		7.8	
Warm	3			10.2
	4			3.3
	5			1.1

3.2.4 Humpback Chub

An overview of the information on the life history and ecology of the humpback chub in the action area is provided in Section 2.4.1, Species Accounts, Humpback Chub. The humpback chub presently occurs as nine aggregations within the action area. The largest aggregation is the LCR population which is self-sustaining and had an estimated 5,300-6,800 adults in 2006. Fish in the LCR aggregation spawn in the LCR in the spring. Evidence of reproduction was reported for the 30-Mile aggregation in 1994. At the time of the 1995 biological opinion, the distribution of humpback chub aggregation had just been reported and little was known about the habitat use of especially the young fish along shoreline habitats and their response to various flow regimes.

A considerable amount of new information has been gathered on the humpback chub since the 1995 biological opinion. This information has been summarized in various documents including Valdez and Carothers (1998), Gloss and Coggins (2005), and Coggins (2007). This new information has provided more reliable and precise estimates and trends of the humpback chub population in Grand Canyon, use of shoreline habitats by young humpback chub and their response to flow experiments such as high flow tests and steady summer flows, as well as the genetic character of humpback chub aggregations in Grand Canyon. There is also new information that suggests mainstem reproduction by humpback chub in one or more of the mainstem aggregations. Also, the nature of the Lake Mead inflow area, Lake Mead elevation, and the fish community has also changed considerably.

Apparent recruitment failure through the mid 1990s resulted in decline of the Little Colorado River humpback chub adult population to a low in 2001 of between 2,400 and 4,400 age 4+ fish (Gloss and Coggins 2005; Coggins et al. 2006). The population has since increased by approximately 20-25 percent and in 2006 consisted of about 6,000 individuals (Coggins 2007). This increase has previously been attributed in part to the results of non-native fish mechanical removal, increases in temperature due to lower reservoir elevations and inflow events, the 2000 low steady summer flow experiment, or other experimental flows (USGS 2006a). However, the most recent population modeling indicates that the increase was actually due to increased recruitment rates as early as 1996 but no later than 1999 (Coggins 2007). Thus, the increase in recruitment under MLFF began at least four and as many as nine years prior to implementation of non-native fish control, incidence of warmer water temperatures, the 2000 steady flow experiment, and the 2004 high flow test. To date, no analysis of humpback chub recruitment dynamics has been conducted during the early years of MLFF, and the reason for increased recruitment during those years is uncertain.

New information also shows greater numbers of young humpback chub in the mainstem than in previous years. During 2002-2006, a total of 442 humpback chub <100 mm TL was captured upstream of the Little Colorado River inflow (RM 61.3) as far upstream as RM 30.7 (Ackmerman 2007). Of the 442 fish, 225 (13-66 mm TL) were caught between RM 30 and RM 50. The 30-Mile aggregation is located 31 miles upstream of the Little Colorado River inflow and it is unlikely that the young humpback chub swam upstream for that distance, especially in the cool mainstem temperatures. Furthermore, the distribution of these fish, as well as averages size above (mean = 38 mm TL) and below the LCR (mean = 67 mm TL), indicate that the natal source is upstream of RM 50 and not from the LCR.

Young-of-year and juvenile humpback chub observed outside the LCR aggregation were most abundant at RM 110-130 (Stephen Aisle and Middle Granite Gorge aggregations) during 2000 and 2004 and RM 160-200 during 2000 (Ackerman 2007; AGFD 1996; Johnstone and Lauretta 2004, 2007; Trammell et al. 2002). However, seine catches of all young-of-year humpback chub outside the nine aggregations during 2004 were at their highest in 21 years (Johnstone and Lauretta 2007). Four humpback chub were also collected at Separation Canyon (RM 239.5) in 2005 (Ackerman et al. 2006). The Middle Granite Gorge aggregation (which includes adults) has been stable or increasing in size since 1993 (Trammell et al. 2002) and may be sustained via immigration from the LCR aggregation, as well as local reproduction. Valdez et al. (2000a) identified this aggregation as the most likely candidate for a second spawning population in the mainchannel given favorable conditions (mainly temperature). No humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Population estimates have not been made for other mainstream aggregations since 1993 (Trammell et al. 2002).

Studies to assess habitat of young humpback chub have revealed important information to help determine suitable flows for the species. Converse et al. (1998) identified shoreline habitats used by subadult humpback chub and related spatial habitat variability with flow regulation. Most humpback chub utilized talus, debris fans or vegetated shorelines in depths of water less than 1 m and velocities of 0.1 to 0.2 m/s, and that these parameters covaried by geomorphic reach. Korman et al. (2004) found that habitat stability as determined by flow was important to minimize displacement of young humpback chub. They also found that humpback chub suitable habitat (depth and velocity as based on Converse et al. 1998, among others) declines by about 78 percent as discharge increases from 3,000 to 32,000 cfs, but tends to increase slightly at higher elevations (Korman et al. 2004). As the role of backwaters and near shore areas in humpback chub survival and recruitment is presently unclear, this remains an important resource question to be addressed through the Proposed Action and ongoing monitoring and research.

There is also new information on our ability to translocate humpback chub, their survival, growth, and reproduction. As a conservation measure for humpback chub (Interior 2002), Reclamation, NPS, and USGS proposed to implement translocation of young humpback chub above Chute Falls in the Little Colorado River (ca. 16 km from the confluence). In August 2003, nearly 300 young humpback chub were translocated above a natural barrier in the Little Colorado River located 16 km above the confluence. This translocation was followed by another 300 fish in July 2004, and finally by another 567 fish in July 2005 (Sponholtz et al. 2005; Stone 2006). Results indicated that translocated fish survival and growth rates were high. Reproduction and downstream movement below Chute Falls has also been documented (Sponholtz et al. 2005; Stone 2006). The Chute Falls aggregation now appears to be a source of recruitment to the lower portions of the Little Colorado River and the mainstem Colorado River (Stone 2007).

Non-native removal has been conducted in Bright Angel Creek (Leibfried and others 2003) and the feasibility of extending this work to other tributaries to the Colorado River in Grand Canyon National Park (GCNP) is being investigated by NPS (Leibfried et al. 2006). If non-native removal is successful and suitable, additional translocations can be contemplated. Moving young HBC to other tributaries as *in-situ* refugia would decrease the risk of catastrophic events to the LCR humpback chub population and allow opportunities for translocated humpback chub to grow prior to migrating to the mainstream. The NPS is also exploring the possibility of translocating humpback chub to other tributaries, such as Shinumo Creek (SWCA and GCWC 2007).

Studies of effects of high experimental flows on young-of-year humpback chub dispersal rates have yielded conflicting results. Based largely on catch rate information, abundance of humpback chub and other native fish species did not differ following the 1996 experimental flow (Hoffnagle et al. 1999). Trammell et al. (2002) showed similar results during 2000 when habitat maintenance flows (ca. 30,000-31,000 cfs) were conducted during the month of September, although reinvasion of non-native fathead minnow was relatively rapid. Catch rates of humpback chub in hoopnets declined following the 2004 high flow test, however, and suggested that humpback chub may be vulnerable to displacement by such flows, at least for the smallest individuals during late autumn-early winter months (GCMRC, unpublished data). This apparent decline in humpback chub catch rates in 2004 may be partially attributed to variable capture probabilities between sample periods (turbid vs. clear water) (Lew Coggins, GCMRC, personal communication). Differences between the 1996 high flow and the 2004 high flow test may also be attributed to the time of year in which the high flow test occurred. The 1996 high flow was in April when the fish were about 10 months old and the 2004 high flow test was conducted in September when the fish were about 5 months of age and perhaps less able to maintain their position in the channel or adjust to more suitable water depths and velocities.

Significant information has also come forth recently on the genetic structure of humpback chub in Grand Canyon. Douglas and Douglas (2007) concluded that some differences among the Marble and Grand Canyon ‘aggregates’ of *G. cypha* were difficult to distinguish at the microsatellite level. Aggregates appeared to be connected by geneflow, suggesting downstream drift of larvae and juveniles as a likely scenario. The Little Colorado River population would be the primary source, but contribution from occasional local reproduction by mainstem aggregates cannot be excluded. The *G. cypha* population at 30-mile in Marble Canyon was recorded as having two individuals with *G. elegans* haplotypes, and the microsatellite profile for this population was intermediate between genotypes found in Desolation Canyon (a hypothesized hybrid population) and Grand Canyon. Although reproduction has been documented for the 30-mile population, it suffers from chronic low numbers (at least chronic low numbers of catchable fish). However, this is the only population in Grand Canyon that is upstream from the Little

Colorado River and is least likely to receive migrants from downstream locations. Douglas and Douglas (2007) recommended further study of the 30-mile aggregation to evaluate the potential distinctiveness of these fish.

Studies in western Grand Canyon show that the Lake Mead inflow has changed considerably with lower lake levels such that the former inflow has transformed from an expansive area of inundated vegetation to a narrow sand bed river. The lake fish community reported by Valdez (1994) and Valdez et al. (1995) in this inflow region is now a riverine community (Ackerman et al. 2006). Studies and monitoring should continue to evaluate the effect of this changed community on the fish community further upstream in Grand Canyon.

New information was also reported for infestation rates of Asian tapeworm and effects of this parasite on fish. Infestation rates were reported by Hoffnagle et al. (2006), Cole et al. (2002), and Choudhoury et al. (2001). Meretsky et al. (2000) reported a decline in condition factor of adult humpback chub not in immediate spawning condition from the Little Colorado River confluence from 1978 to 1996, hypothesizing that the decline could be caused by one or more factors; e.g., a recent invasion of the Asian tapeworm (*Bothriocephalus acheilognathi*), researcher variation in weighing fish, or natural population variation. Hoffnagle (2000) reported that condition and abdominal fat were greater in the mainstem Colorado River than in the Little Colorado River during 1996, 1998, and 1999 possibly because of an increased prevalence and abundance of parasites (especially *Lernaea cyprinacea* and *Bothriocephalus acheilognathi*) in the LCR fish and/or greater food availability in the Colorado River.

3.2.5 Non-Listed Native and Non-native Fish

Background. The Lee's Ferry Reach (dam to Paria River) supports a self-sustaining fishery of rainbow trout, *Oncorhynchus mykiss,* whose population and food base are influenced by dam operations (McKinney et al. 1999b; McKinney and Persons 1999; McKinney et al. 2001; Speas et al. 2004a, 2004b; Korman et al. 2005). Brown trout, *Salmo trutta,* occasionally move into the reach between the dam and the Paria River from downstream populations, but is not managed as part of the sport fishery and is not a desired species in this reach. The Lee's Ferry Reach also supports small numbers of flannelmouth suckers, bluehead suckers, and speckled dace. The flannelmouth sucker spawns in this reach (McIvor and Thieme 2000; McKinney et al. 1999c; Thieme 1998), although the water generally is too cold for survival of eggs and larvae. The flannelmouth sucker also spawns in the Paria River (Weiss 1993), where the inflow serves as a nursery habitat when impounded by mainstem flows above 11,866 cfs (Thieme 1998).

The 61-mile reach of the Colorado River from the Paria River to the Little Colorado River supports low to moderate numbers of flannelmouth suckers, bluehead suckers, speckled dace, and humpback chub. Most native fish in the mainstem are large juveniles and adults. Earlier life stages rely extensively on more protected nearshore habitats throughout the river, primarily backwaters (AGFD 1996; Lauretta and Serrato 2006; Maddux et al. 1987; Trammel et al. 2002). Native fish spawning may occur in warm springs at RM 30-32 (Valdez and Masslich 1999). Although their abundance has declined significantly over the last seven years, rainbow trout are still the dominant non-native species between the Paria River and the Little Colorado River (Ackerman 2007; Johnstone and Lauretta 2007). Other non-native species sporadically found in that reach include brown trout, common carp, channel catfish and fathead minnow, *Pimephales* *promelas*. Invasion of non-native fish from the upper LCR has recently been documented (Stone et al. 2007)

The 174 miles from the LCR confluence to Bridge Canyon has six major tributaries and supports a diverse fish fauna of cool- to warm-water species to about Havasu Creek, including the three non-listed native species and seven known aggregations of humpback chub (Section 2.4.1). Non-listed native fish are also well represented in Bright Angel, Shinumo, Tapeats, Kanab, and Havasu creeks (Leibfried et al. 2006), especially during spawning periods. The Little Colorado River supports comparatively large populations of the three non-listed species and the largest aggregation of humpback chub, all of which also inhabit the main channel near the LCR in comparable densities.

Below the Little Colorado River, rainbow trout numbers drop dramatically, although brown trout are common near Bright Angel Creek where they spawn and maintain a resident tributary population. Warm water species such as common carp, channel catfish, and fathead minnow increase in numbers downstream of the Little Colorado River and are most abundant between Shinumo and Diamond creeks. (Ackerman 2007). Red shiner and plains killifish, *Fundulus zebrinus*, are common in backwaters immediately below the Little Colorado River and occur sporadically downstream from that point (Johnstone and Lauretta 2007; Lauretta and Serrato 2006).

The 45-mi. reach of the Colorado River from Bridge Canyon to Pearce Ferry is flat and muddy due to high lake elevation sediment deposition on the old river channel. Abundance of flannelmouth suckers, speckled dace, and bluehead suckers are generally limited due to lack of spawning habitat and large numbers of predators (Valdez 1994; Valdez et al. 1995).

Distribution of fish parasites found in Grand Canyon fishes is related to thermal tolerances of host species along the longitudinal gradient of the river. *Trittaedacnitis truttae*, Nematoda, specifically affects rainbow trout and is prevalent in the Lees Ferry reach of the Colorado River below Glen Canyon Dam (McKinney et al. 2001). Whirling disease was discovered in the rainbow trout population below Glen Canyon Dam in June of 2007. Asian fish tapeworm, *Bothriocephalus acheilognathi*, and anchor worm, *Lernaea cyprinacea*, may pose threats to native fish below Glen Canyon Dam. Asian tapeworm is currently the most abundant fish parasite in the Little Colorado River, infecting 23-51 percent of all humpback chub (AGFD 1996; Choudhury et al. 2004; Clarkson et al. 1997) and also a variety of cyprinids. Main channel infestation rates are much lower and may be temperature-limited (4-22 percent) (AGFD 1996; Valdez and Ryel 1995). Optimal *B. acheilognathi* development occurs at 20-30 °C (Granath and Esch 1983). Choudhury et al. (2004) hypothesized that infection rates were positively related to both fish host and copepod density in the Little Colorado and parasitic fauna found there have diversified through invasion of non-native host fish species. *Lernae cyprinacea* infects humpback chub at a higher rate than other species of fish in Grand Canyon (Hoffnagle 2000) and favors temperatures greater than 18 °C (Grabda 1963), with 23-30 °C being optimum (Bulow et al. 1979). Post-dam mainstream temperatures have prevented *L. cyprinacea* from completing its life cycle and limited its distribution to warmer backwaters. Infestation apparently does not increase fish mortality in the Upper Colorado Basin (Valdez and Ryel 1995).

The Grand Canyon fish community has shifted over the past five years from one dominated by non-native salmonids to one dominated by native species (Ackerman 2007; AGFD 2006; Johnstone et al. 2003; Lauretta and Serrato 2006; Trammell et al. 2002). Electrofishing catch rates of flannelmouth and bluehead suckers have increased four to six-fold in the past seven years, whereas trout catch rates have correspondingly declined (AGFD 2006); a similar trend is evident from trammel net data (Johnstone et al. 2003; Lauretta and Serrato 2006). Riverwide, young flannelmouth suckers were more abundant in 2004 than the previous 16 years (Johnstone and Lauretta 2007) and speckled dace are abundant in hoop net and seining samples, particularly in downstream reaches (Ackerman 2007). It is hypothesized that the recent shift from non-native to native fish is due in part to warmer than average water temperatures, although the decline of coldwater salmonid competitors (due to mechanical removal or temperature increases) also has been implicated (Ackerman 2007; Persons and Rogers 2006; USGS 2006a). Population size of humpback chub has also increased from about 4,500 – 5,700 in 2001 to an estimated 5,300 – 6,800 adult fish in 2006 (Figure 26 in Coggins 2007; see Section 2.4.1).

The increase in native fish abundance apparently began about the year 2000 although increases in humpback chub abundance appear to have begun earlier (Section 3.2.4). Relative abundance of young-of-year (YOY) flannelmouth suckers was higher during the summer 2000 steady flow experiment than at any point during the previous 10 years, which was thought to be directly related to warmer than average temperatures associated with the steady flow experiment (Trammell et al. 2002). A similar trend was identified for fathead minnow, however, although both their abundance and that of flannelmouth sucker were subsequently reduced by a 30,000 cfs habitat maintenance flow in September 2000. Young bluehead sucker catch rates during 2000 were also among the highest on record (Johnstone and Lauretta 2007). Speckled dace catch rates have been variable over the past two decades or so, with no apparent trend (Johnstone and Lauretta 2007). Mainchannel YOY and juvenile flannelmouth suckers have remained abundant since 2000 in association with warmer water (Johnstone and Lauretta 2007; Lauretta and Seratto 2006). Catch rates of speckled dace in recent years have been generally higher than historical levels and were highest in the vicinity of tributaries. Juvenile and adult bluehead suckers continued to occur in low numbers, usually in association with tributaries.

Recent declines in trout abundance in the Lees Ferry tailwater are attributed less to increased daily fluctuations during 2003-2005 and more to increased water temperatures and trout metabolic demands coupled with a static or declining food base, periodic oxygen deficiencies and nuisance aquatic invertebrates (New Zealand mudsnails; AGFD unpublished; Persons and Rogers 2006). Concurrent with these declines in abundance, however, trout condition (a measure of plumpness or optimal proportionality of weight to fish length) has increased, reflecting a strongly density dependent fish population where growth and condition are inversely related to fish abundance (McKinney and Speas 2001; McKinney et al. 2001).

Whirling disease was discovered in the rainbow trout population below Glen Canyon Dam in June of 2007. Additionally, highly invasive quagga mussels (*Dreissena* sp.) were discovered in Lake Powell during the summer of 2007. Because of their high filtration and reproductive rates, quagga mussels frequently alter aquatic food webs and damage water supply infrastructure. Kennedy (2006) performed a risk assessment on establishment potential of quagga mussels in the Colorado River below Glen Canyon Dam, concluding that there is low risk of these mussels becoming established in high densities in the Colorado River or its tributaries below Lees Ferry.

In contrast, conditions in the clear tailwater reach below the dam appear more suitable for establishment of this species.

Korman et al. (2005) and Korman and Kaplinski (in preparation) documented increased mortality of rainbow trout eggs due to increased flow fluctuations (15,000 cfs/day) in 2003-2005, however survival rates of hatched fish compensated for these losses and did not affect abundance of young-of-year trout. Korman et al. (2005) and Korman and Campana (in preparation) also noted improved young-of-year growth rates during periods of stable daily flows due to lower water velocities and warmer temperatures at stream margins.

Korman et al. (2005) and Korman and Kaplinski (in preparation) also determined that most YOY rainbow trout maintained their position in the streambed as flows increased during the daily hydropower generation cycle. They hypothesized that during the 24 hour power generation cycle, fish are essentially faced with a series of choices imposed by hourly changes in discharge. Maintaining one's position in the streambed during fluctuating discharge ensures minimal bioenergetic expenditure in searching for a new stream position. While bioenergetic costs of maintaining stream position are uncertain, it is assumed that the larger proportion of fish which did move indicates a bioenergetic advantage to maintaining position. However, maintaining position also precludes fish from exploiting slightly warmer temperatures at the stream margins, which occur at higher elevations in the water column at peak discharge; this would require searching and movement.

The non-native fish fauna of the Lees Ferry reach historically included less frequent taxa including common carp, largemouth bass, golden shiner, *Notemigonus crysoleucas*, redside shiner, *Richardsonius balteatus*, striped bass, and threadfin shad (GCMRC unpublished data). In more recent years, however, YOY green sunfish, *Lepomis cyanellus*, smallmouth bass, brown trout, and channel catfish have been collected in this reach; mature smallmouth bass and walleye have also been collected (GCMRC unpublished data). Sources of these fish are unknown, but the closest source containing green sunfish, catfish and smallmouth bass would be Lake Powell; means of introduction is unknown, but Reclamation is currently assessing risk potential for entrainment of Lake Powell fish through the dam penstocks.

Recently, a few smallmouth bass and striped bass were collected in the vicinity of the Little Colorado River (GCMRC unpublished data), but no population-level establishment has been documented to date. There are also recent records of green sunfish, black bullhead, yellow bullhead, red shiner, plains killifish and largemouth bass downstream of the Little Colorado River, usually associated with warm springs, tributaries, and backwaters (Johnstone and Lauretta 2007; GCMRC unpublished data). Striped bass are found in relatively low numbers below Lava Falls (Ackerman 2007; Valdez and Leibfried 1999).

Stone et al. (2007) reported common carp, fathead minnow and red shiner below Grand Falls (an ephemeral reach of the river), which indicates that the LCR is a viable conduit for introduction of non-native fish from areas higher in the watershed. Other non-native fish documented in the upstream reaches of the Little Colorado River basin include golden shiner, black bullhead, yellow bullhead, channel catfish, rock bass *Ambloplites rupestris*, bluegill, green sunfish, smallmouth bass, and largemouth bass (Stone et al. 2007); thus these species could eventually occur in Grand Canyon.

Fish samples collected below Diamond Creek in 2005 (Ackerman et al. 2006) were comprised primarily of red shiner (28 percent), channel catfish (18 percent), common carp (12 percent), and striped bass (9 percent); smallmouth bass, mosquitofish, *Gambusia affinis*, and fathead minnow were also present in low numbers. Bridge Canyon Rapid impedes upstream movement of most fish species, except for the striped bass, walleye, and channel catfish (Valdez 1994; Valdez et al. 1995; Valdez and Leibfried 1999). Non-native fish species increased from 11 above to 18 below the rapid (Valdez 1994; Valdez et al. 1995). Above Bridge Canyon Rapid, the red shiner was absent, but below the rapid it comprised 50 percent and 72 percent of all fish captured in tributaries and the mainstream, respectively (Valdez 1994; Valdez et al. 1995). Other common fish species found below Bridge Canyon Rapid include the common carp, fathead minnow, and channel catfish; however, very little fish habitat exists in this reach due to declining elevations of Lake Mead and subsequent downcutting of accumulated deltaic sediments in inflow areas. Flannelmouth suckers comprised about 15 percent of the total catch from this reach during 2005 (Ackerman et al. 2006), several times greater than the 1.3 percent observed during 1992-1995 (Valdez et al. 1995). Percentage of speckled dace in the reach has not changed appreciably over the last decade, and no bluehead suckers were collected during 2005 (Ackerman et al. 2006; Valdez et al. 1995).

3.2.6 Non-native Fish Control Undertaken 2003-2006

In an attempt to benefit native species, mechanical removal targeted at non-native salmonid species in the mainchannel Colorado River and tributaries in Grand Canyon took place during 2003-2006 (Interior 2002; Coggins and Yard 2003). Removal of salmonids and other non-native fish (black bullhead, fathead minnow, common carp, brown trout) in the vicinity of the Little Colorado River by electrofishing contributed to a 90 percent reduction in rainbow trout over a four year period, although part of the decline is attributed to warmer main channel temperatures and higher flow daily fluctuations (GCMRC unpublished data). Main channel water temperatures during the removal period were as high as 6 °C above the 1990-2002 average. At the same time, electrofishing catch rates of YOY and age 1 flannelmouth sucker, bluehead sucker, and humpback increased by as much as a factor of ten; catch rates of speckled dace also increased.

Mechanical removal of spawning brown trout through weir operations in Bright Angel creek yielded inconclusive results. During operations in 2002 (November—January), over 400 brown trout were removed from Bright Angel Creek and euthanized (Leibfried et al. 2005). When a similar removal effort was conducted in November—January of 2006, only 54 brown trout were removed, and a rainbow trout catches were decreased by a similar proportion (Sponholtz and VanHaverbeke 2007). The decline cannot be attributed to weir operations alone, however, as both trout species experienced a considerable system-wide decline in abundance between the two removal periods.

Most brown trout from Bright Angel Creek were captured during the spawning period between late November and mid-December. The onset of rainbow trout spawning was documented in mid-January. For both species of trout, short term increases in water temperature (over the course of a week or less) were often associated with increases in catch rates. Returns of tagging data indicate that most spawning brown trout move 10 miles or less to access Bright Angel Creek, however some individuals were tagged over 32 river miles away.

Multi-pass backpack electrofishing was also evaluated as a mechanical control technique in Bright Angel and Shinumo Creeks. In a 3.35 km reach of Bright Angel Creek, approximately 55 percent and 57 percent of the brown and rainbow trout populations, respectively, were removed through as many as 4 electrofishing passes. At Shinumo Creek, 35 to 85 percent of rainbow trout were removed through similar methods (Leibfried et al. 2006). In both creeks, however, recolonization rates from upstream and downstream have not been evaluated.

Recently, GCMRC has proposed to implement a strategy to reduce warmwater non-native fish (including crayfish) abundance and negative impacts to native fish found in the Colorado River in Grand Canyon (Hilwig et al., in review). This strategy would very likely be needed to offset potential undesirable positive responses of non-native fish to artificial or natural increases in river temperatures. The draft plan consists of short-term (ca. 1-2 y) fulfillment of baseline information needs followed by implementation of longer-term (8+ y) non-native fish control and management programs.

The initial phase of the draft management plan (1-2 y) would identify the geographic extent of non-native fish occurrence in the watershed immediately surrounding the Colorado River below Glen Canyon Dam, assign risks posed by individual species, evaluate efficacy of current monitoring methods to detect changes, identify effective management methodologies, and assess feasibility of management options. “High risk” species are those (1) currently residing within the immediate Grand Canyon watershed with the strong potential for expansion during warm water periods; (2) possessing a strong proclivity for predation or aggressive behavior; and (3) displaying considerable spatiotemporal overlap with native species of concern. This assessment would likely be informed through bioenergetic investigations (e.g., Petersen and Paukert 2005) and be complemented by investigations into environmental tolerances, life histories and habits of problem species. Management options for high-risk species would include conventional “mechanical” approaches as well as hypothetical use of Glen Canyon Dam operations specifically targeted at disadvantaging non-native fish. Additionally, a more comprehensive system for reporting non-native fish would be developed to allow better information sharing and timelier reporting of new species occurrences to managers. Management of coldwater species (rainbow trout) would be reinitiated and used as an interim methodology to track warmwater occurrence in the Little Colorado River inflow reach.

The long-term aspects of the draft management plan would implement actions identified in the initial phase. Effective strategies for the control of high risk species would be developed and implemented. Considerable emphasis would be placed on implementation of cost-effective, sustainable management strategies. Control measures would focus on exploiting weaknesses of non-native fish life histories, which would likely involve recommendations for specific dam operations. As control measures are undetermined at this time, additional environmental compliance would likely be needed in the future. Management strategies would also be implemented to prevent invasions by source populations of non-native fish, particularly via the Little Colorado River watershed. Results of all management efforts (including response of native fish) would be evaluated at the population level.

4 Effects Analysis

4.1 Humpback chub analytical approach and assumptions

We identified five hypothetical mechanisms by which we expect the Proposed Action to affect humpback chub, two associated with the high flow test and three associated with steady fall flows. The mechanisms are listed below, followed by a description of the analytical approach and assumptions we made in their evaluation.

4.1.1 Displacement of young-of-year humpback chub by high flow tests

Small-bodied humpback chub may be vulnerable to displacement by high flows conducted during periods of cold dam releases (8-10 °C), when their swimming performance is reduced (Bulkley et al. 1982). Likewise, adverse effects of high flow tests on humpback chub during November-December was a concern of the FWS in their 2005 biological opinion and provisions for incidental take were made in the 1995 biological opinion. The high flow test proposed for 2008 wouldn't occur until March, which historically has been viewed as the timeframe posing the least amount of risk to a number of species, including humpback chub (Hoffnagle et al. 1999; Reclamation 1995), the young of which are generally thought to utilize deeper eddies and shoreline cover in the fall and winter months (Valdez and Ryel 1995). However as in 2004, the Colorado River currently supports high numbers of young-of-year humpback chub (Ackerman 2007; Andersen 2007) which would theoretically be vulnerable to displacement by high flow tests, and for that reason we present the following analysis.

Effects of high flows were evaluated by comparing retention rates (i.e., the opposite of displacement, or percentage of fish able to maintain their position in a given reach) expected during a high flow test to those predicted for the median monthly flow in March under MLFF. Retention rates over a range of flows was modeled using a particle tracking algorithm in conjunction with velocity predictions from a 2-D hydrodynamic model developed by Korman et al. (2004). This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5, below the LCR confluence. The model contains four assumptions of fish swimming behavior: 1) passive, no swimming behavior; 2) rheotactic, in which particles (or "fish") swim toward lower velocity currents at 0.1 to 0.2 m/s; 3) geotactic, in which particles swim toward the closest bank at 0.2 m/s; and 4) upstream, in which the particle attempts to move upstream at 0.2 m/s. Temperature of the Colorado River in the LCR inflow reach during the proposed time period for high flow tests (early March) typically ranges from 8 to 10 °C (AGFD 1996). At these levels, subadults and young of year may fatigue rapidly and may be unable to withstand swift currents, forage efficiently, or escape predators. Bulkley et al. (1982) reported that swimming ability of juvenile humpback chub (73–134 mm TL) in a laboratory swimming tunnel was positively and significantly related to temperature. Humpback chub forced to swim at a velocity of 0.51 m/sec fatigued after an average of 85 minutes at 20 °C, but fatigued after only 2 minutes at 14 °C, a reduction in time to fatigue by 98 percent. Time to fatigue is presumably further reduced below 14 °C, especially for the smallest individuals. For these reasons, and also to identify the "worst case scenario" of fish displacement, we focused primarily on results for passive swimming behavior in this analysis.

4.1.2 Creation or Improvement of Backwater Habitats

Impacts of high flow tests on backwater habitats manifest both at short-term (i.e., weeks to months following high flow tests) and long-term time scales. While a good deal of information exists on short-term impacts (Brouder et al. 1999; Parnell et al. 1997; Wiele et al. 1999), long-term impacts are more difficult to predict owing to varied sediment availability prior to the test and uncertainties of post-test flow regimes. Effects of high flow tests will be evaluated qualitatively and will weigh short-term impacts to backwater habitats against potential long-term outcomes, as well as impacts to the non-native fish community and other aspects of the Proposed Action.

In this biological assessment, the assumption is that number of backwaters is correlated with those of reattachment sandbars in eddy complexes. That is, since backwaters in Grand Canyon are mostly inundated, but non-flowing, eddy return current channels, sandbars are a requisite condition for their occurrence. Another assumption is that elevation of sandbars and depth of recirculation channels are significant correlates reflecting the availability of backwaters over range of flows (Dr. John C. Schmidt, Utah State University, pers. comm.). First, the higher the sandbar elevation, the more likely the separation of the backwater from mainchannel currents would occur over a range of flows. The depth of the recirculation channel serves the same function as height of the sandbar, with the greatest depths creating more frequent availability over the greatest range of flows. Finally, high flow tests tend to increase the elevation of the sandbar and deepen the return current channel (Andrews 1999; Goeking et al. 2003), although there are exceptions to this general pattern (Parnell et al. 1997).

4.1.3 Creation of More Persistent Suitable Habitat Conditions

The 2-D hydrodynamic model was used to predict two-dimensional fields of depth and velocity over the range of daily flow fluctuations and monthly volumes proposed under the various alternatives (Korman et al. 2004). Specifically, the model evaluated YOY fish habitat availability and suitable habitat persistence in Grand Canyon under MLFF and the Proposed Action. Depth and velocity at seven transects in the first 10 km below the LCR were modeled over the range of flows proposed in the alternative. This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5 (Wiele et al. 1996, 1999; Wiele, 1998; Appendix A). Transects ranged from 253 to 993 m in length and represented the full range of shoreline types typically utilized by YOY humpback chub: talus slopes, debris fans, vegetated shorelines, cobble bars, bedrock and sandbars. Descriptions of these shoreline types can be found in Converse et al. (1998). The hydrodynamic model was used successfully to predict patterns of sand deposition following the 1993 flood from the Little Colorado River and during and after the 1996 high flow test (Wiele et al. 1999; Wiele 1998; Wiele et al. 1996). Accuracy of these predictions of erosion and deposition provide a sensitive test of the accuracy of calculated flow fields.

The amount of total suitable habitat at a given flow elevation was computed by summing the total wetted area of each reach where velocity was less than or equal to critical values. Two criteria were evaluated for suitable water velocity: < 0.25 m/s and <0.10 m/s. The first criterion was a composite of several field and laboratory studies published previously, including Bulkley et al. (1982), Valdez et al. (1990) and Converse et al. (1998) (Figure 10). The second criterion was selected to be more representative of a suite of non-native species currently found in the

Little Colorado River or the adjacent mainchannel Colorado River (Table 8; see also Meffe and Minckley 1987; Minckley and Meffe 1987). Depths of <1 m (maximum depth of most HBC habitats sampled in Converse et al. 1998) were used to further restrict predictions on suitable HBC and non-native fish habitat. To further simulate YOY habitat availability, we limited habitat predictions to areas which intersected the streambed and computed habitat over shoreline types.

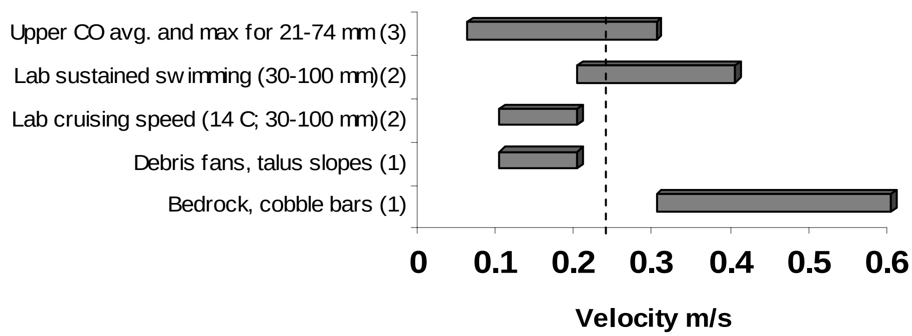


Figure 10. Velocity preference criteria for humpback chub in the Colorado River, Grand Canyon. Sources include (1) Converse et al 1998; (2) Bulkley et al. 1982; and (3) Valdez et al. 1990.

Persistent suitable habitat was used to determine the area of suitable habitat that is stable across daily ranges in discharge (Bowen et al. 1998; Freeman et al. 2001; Korman et al. 2004). The suitable habitat areas at 5,000 cfs, 8,000 cfs, and 15,000 cfs were calculated for each transect. The total area of habitat common to flow elevations is referred to as the amount of "persistent suitable habitat."

Table 8. Preferred water velocities (m/s) for non-native fish found in the vicinity of the Little Colorado River

Species	Velocity	Source
Rainbow trout	0.13	Moyle and Baltz 1985
Rainbow trout	0.07	Korman et al. 2005
Rainbow trout	0.1	Baltz et al. 1991
Brown trout	0.03	Heggenes et al. 1990
Common carp	0.11	Aadland 1993
Golden shiner	0.04	Aadland 1993
Green sunfish	0.05	Aadland 1993
Smallmouth bass	0.12	Aadland 1993
Black bullhead	0	Aadland 1993
Channel catfish	0.25	Aadland 1993
Smallmouth bass	0.1	Leonard and Orth 1988
Fathead minnow	0.15	Kolok and Oris 1995
Red shiner	0.15	Shyi-Liang and Peters 2002
Red shiner	0.09	Edwards 1997
Average NNF velocity	0.10	

Habitat predictions for discrete flow elevations during September and October were not available, so we used previously published predictions for flows to approximate effects of the Proposed Action (Korman et al. 2004). The assumption is that predictions for habitat persistence at a steady release of 8,000 cfs would approximate September and October steady releases in the Proposed Action (8,000 or 9,000 to 10,000 cfs per day), and that daily ranges between 5,000 cfs and 8,000 cfs would approximate MLLF conditions for the same period (5,000 to 12,000 cfs/day). Higher fluctuations of 8,000 cfs to 20,000 cfs were used to approximate fluctuations at higher flow elevations such as those in July and August. This demonstrated relationships across a range of flows.

We also present absolute values for suitable habitat specific to discrete shoreline types to show habitat availability over a range of discharge found in the Proposed Action and MLFF. We considered the three shoreline types most commonly utilized by humpback chub (talus, vegetated shorelines, debris fans) as well as the total habitat area (<0.25 m/s, <1 m depth) intersecting all shoreline types.

4.1.4 Creation of Warmer Nearshore Habitats

We hypothesized that young-of-year humpback chub growth rates would vary as a function of water temperatures, which in turn vary with flow regime (monthly volume, steady and fluctuating flows during September and October). Since monthly volumes in the Proposed Action and the MLFF are the same, we considered only steady versus fluctuating flows in this analysis. Both mainchannel and backwater temperatures were considered.

We analyzed effects of steady and fluctuating flows using modeled data and empirical backwater and mainchannel temperatures reported in Trammell et al. (2002) in relation to young-of-year humpback chub growth rates (Figure 11). We derived a relationship between water temperature and humpback chub growth rates (mm/day) using observations from laboratory and field studies (Peterson and Paukert 2005; Gorman and VanHoosen 2000; Clarkson and Childs 2000; Lupher and Clarkson 1995; Valdez and Ryel 1995). Test subjects in laboratory studies ranged from about 10 to 80 mm total length at the onset of each study. Growth rates were plotted against temperatures evaluated in each study and fitted the data with a logarithmic regression line (Figure 12). We then evaluated total growth during the month of September by substituting backwater and mainchannel temperatures into the equation shown in Figure 12.

We modeled water temperatures of nearshore habitats, including backwaters, using a 3-D temperature model (Generalized Environmental Modeling System for Surface waters model, or GEMSS; Kolluru and Fichera 2003) in conjunction with reservoir temperature predictions (CE-QUAL-W2; Cole and Wells 2000) routed through the Colorado River in Grand Canyon with a 1-D GEMMS model. The 3-D model focused on nearshore habitats in the Colorado River immediately below the LCR. We evaluated output from the 1-D model, which predicts mainchannel thalweg water temperatures for the LCR inflow reach (approximately RM 61.5).

The 3-D model underestimated water temperatures when compared with empirical observations (AGFD 1996; Trammell et al. 2002) and results are not presented here. This was due to the large cell size in the model (25 m X 25 m). These large cells are too large for fine-scale water temperature predictions, which were shown by Korman et al. (2006) to occur mainly in the zone of flow fluctuations as they intersect the backwater shoreline any backwater in stretch of river below the Little Colorado River. This is a fairly small spatial scale (1-10 m) which will require smaller model cell sizes and additional data collection for calibration.

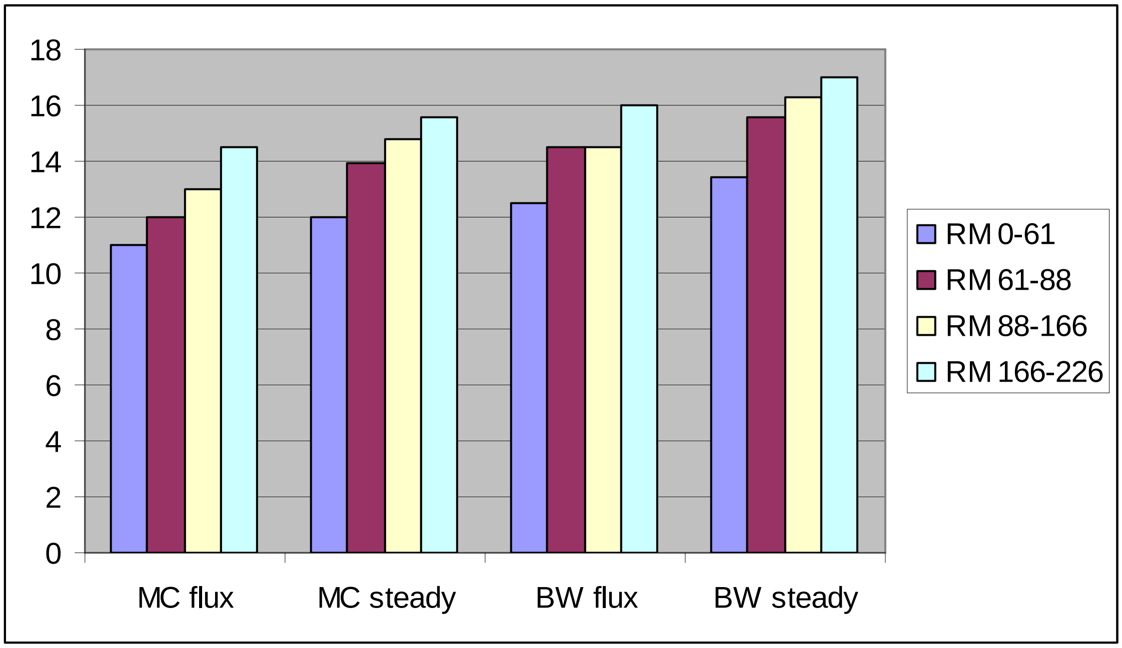


Figure 11. Average river temperatures in the mainchannel Colorado River (MC) and backwaters (BW) under fluctuating discharge (“flux”) and steady releases (“steady”). Fluctuating flow data are from 1991-1994 (AGFD, in Trammell et al. 2002) and steady flow observations are from 2000 (Trammell et al. 2002).

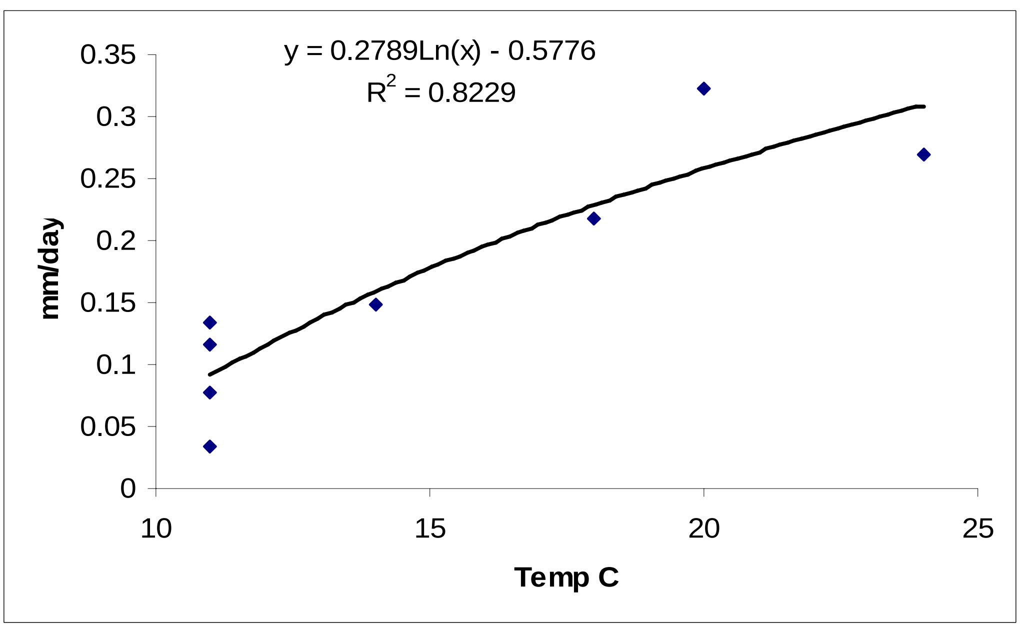


Figure 12. Growth rate of humpback chub (10-80 mm total length) in relation to temperature. Regression line is statistically significant ($P < 0.01$).

4.1.5 Creation of More Productive Nearshore Environments

The effects of the Proposed Action on the availability of invertebrate prey in backwater habitats is evaluated qualitatively in the following sections using existing literature. No modeling was performed for this part of the analysis.

4.2 Humpback Chub Effects Analysis

4.2.1 High Flow Tests and Displacement

Adult humpback chub are expected to be little affected by high flows (Hoffnagle et al. 1999; Valdez and Hoffnagle 1999), although high flows would occur at a time of the year prior to the rise of the pre-dam hydrograph. Little is known about the extent to which humpback chub rely on changes in flow as a reproductive cue. Valdez and Ryel (1995) held that neither water quantity or quality serve as cues for gonadal development or staging behavior in humpback chub; rather they hypothesized that climatic factors, such as photoperiod, were important. Humpback chub typically begin to spawn on the receding hydrograph as water temperatures start to rise (Tyus and Karp 1989, Kaeding and Zimmerman 1983, Valdez and Ryel 1995, Kaeding et al. 1990), but the LCR population also spawns in years with little appreciable runoff.

Korman et al. (2004) predicted that retention rates of small-bodied fish in the Colorado River immediately below the LCR will decrease with increased discharge, but that this pattern tended to vary considerably with reach geomorphology and assumptions on swimming behavior of the fish. Passively drifting fish were the most susceptible to displacement, but also the least sensitive to the effects of variable discharge magnitude. Assuming that passively drifting fish can be used to represent the poor swimming ability of humpback chub at low temperatures, then we would expect that about 21 percent of these fish would be able to maintain their position within a given river reach during high flow tests of 41,500 (Korman et al. 2004) (Figure 13). The retention rate at mean monthly flows for March under MLFF (about 9,400 cfs), by contrast, is predicted to be about 36 percent. Therefore we would expect retention to decrease by 15 percentage points during the Proposed Action; absolute numbers of fish swept downstream would be dependent on young of year population size during March 2008, although this information is unlikely to be available.

Total suitable habitat would also be at a low level across the continuum of flow elevations (Figure 14). However, available habitat over talus and debris fan substrates is not expected to change during high flows as compared to regular MLFF releases (about 9,700 cfs), and area of vegetated shorelines would actually be near its maximum predicted values. Thus if the fish could exploit these unchanged or improved habitats as refuge from high flows, displacement could be minimized (see also Converse et al. 1998).

Conducting a high flow test during the month of March nevertheless appears to pose the fewest risks to young-of-year humpback chub. During this period, occurrence of larval humpback chub in the Colorado River should be minimal or nonexistent. In contrast to the November 2004 high flow test, humpback chub would be about 10 months old in March (as opposed to 5 months), and presumably stronger and better able to adjust position with varying flows. Depending on habitat use and growth rate assumptions, humpback chub should be from 5 to 20 mm larger in March than in November at 8-12 °C (Petersen and Paukert 2005; Gorman and VanHoosen 2000; Valdez and Ryel 1995; Lupher and Clarkson 1994). Hoffnagle et al. (1999) reported no statistically significant change in catch rates of young humpback chub along shorelines before and after the March-April 1996 controlled flood of 45,000 cfs, although catch rates may have declined in 2004 (GCMRC, unpublished).

It is also very likely that non-native fish will experience negative impacts of the high flow tests, perhaps more so than humpback chub due to their preferences for lower water velocities (Table 8). Hoffnagle et al. (1999) noted that the 1996 test had few discernable effects on native fish, but reduced numbers of fathead minnow and plains killifish, presumably by downstream displacement. Trammell et al. (2002) found similar results for fathead minnow during the September 2000 habitat maintenance flow.

Predictions made in Korman et al. (2004) have not been validated via empirical data, so displacement rates of young-of-year humpback chub over a range of operational and experimental flows remain uncertain and should be evaluated. Furthermore, the fate of these fish in downstream reaches is unknown, as neither the exact river reaches they are likely to arrive at nor habitat conditions therein are known. Also, the exact number of fish displaced by high flows will vary markedly by the distribution of fish among discrete shoreline types, as certain shoreline types afford more refuge from high flow velocities than others (i.e., talus slopes as compared to sandbars, etc.). Downstream displacement could provide positive effects for some humpback chub if they are carried to downstream aggregations, survive, and increase the size of these groups.

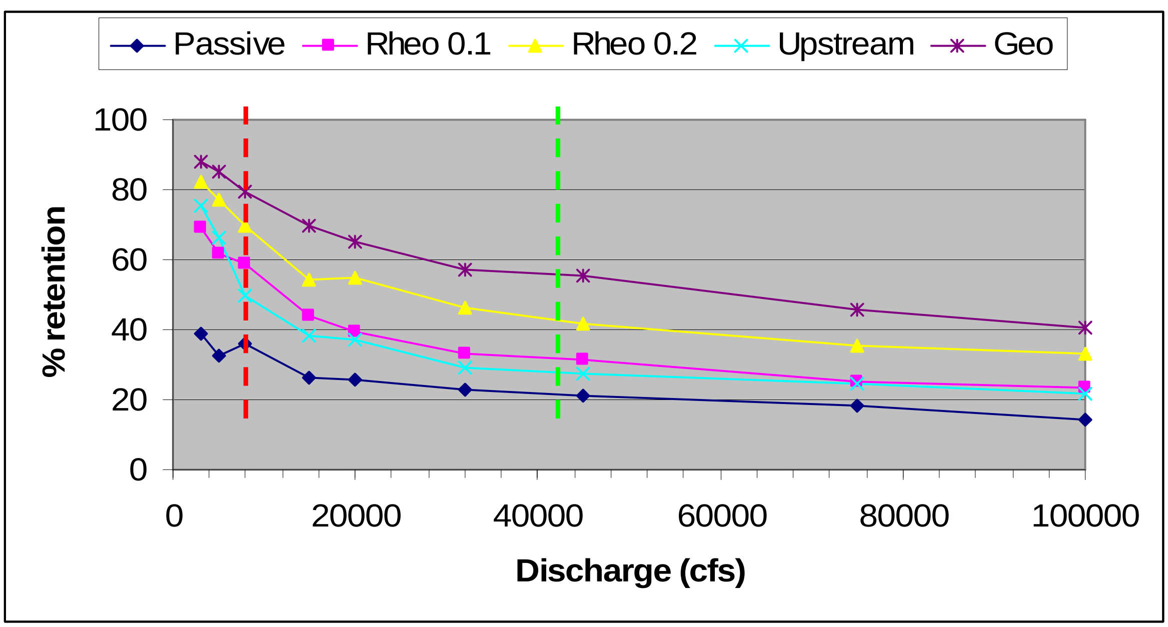


Figure 13. Average percent of simulated young-of-year fish retained within a given river reach over a range of river flows and swimming behavior assumptions. Red vertical line indicates mean flow for MLFF; the green vertical line indicates mean flow during a high flow test. Legend refers to swimming performance assumptions (see text). Data are from Korman et al. 2004.

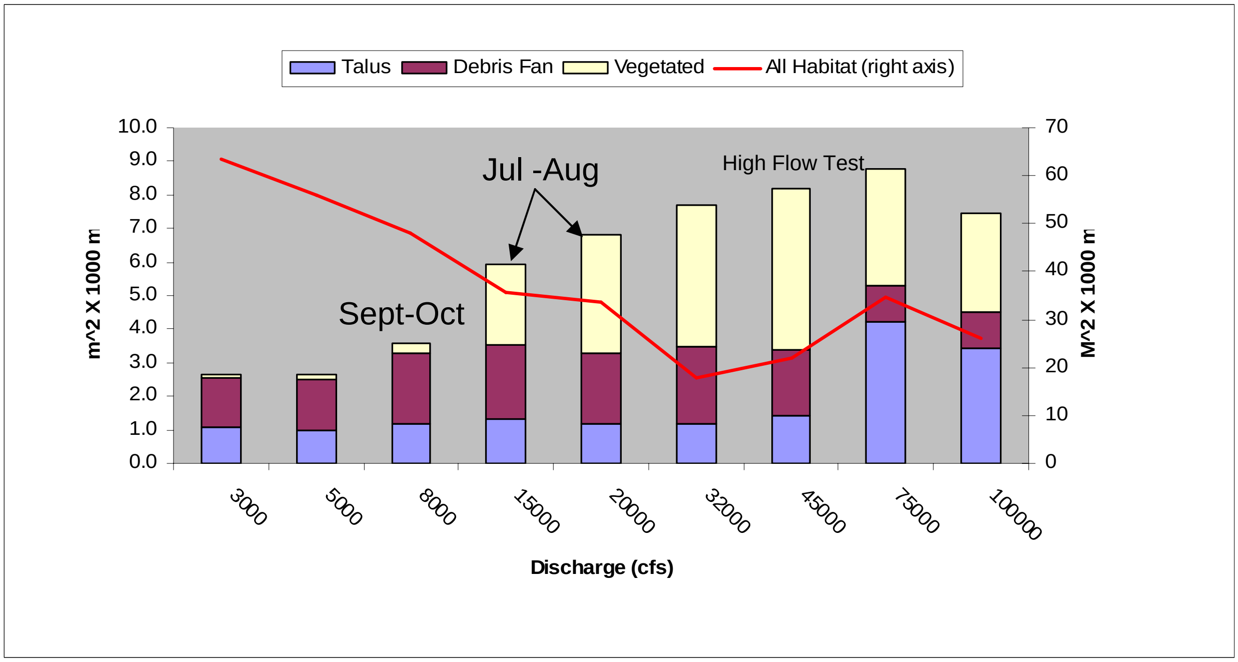


Figure 14. Total suitable habitat (line) and breakdown by shoreline types used by humpback chub. Not shown are habitat areas for cobble bars, sand and bedrock and unmapped portions of transects. 8,000 cfs and 15,000-20,000 cfs estimates approximate habitat conditions for July-August and September-October for both MLFF and the Proposed Action.

High flow tests and backwaters

Immediate physical impacts of high flow tests on backwater habitats include increased relief of bed topography, increased elevation of reattachment bars and deepened return current channels (Andrews et al. 1999). Biologically, the 1996 test significantly reduced backwater macroinvertebrate standing stocks due to scouring of the return current channel, but key taxa (i.e., chironomids) recovered to pre-flood levels within three months (Brouder et al. 1999). Nutrient enrichment due to burial and decomposition of organic matter during the high flow test (Parnell et al. 1999) probably enhanced recovery of benthic macroinvertebrates. As a result, reductions of invertebrate prey had little or no impact on food availability to fish (McKinney et al. 1999; Valdez and Hoffnagle 1999). Finally, since humpback chub probably do not commonly utilize backwaters in March (Valdez and Ryel 1995; proposed time frame for the 2008 high flow test), we do not expect negative effects due to reduced food availability.

One goal of test flows conducted during 1996 and 2004 was redistribution of channel bottom sediment to the channel margins to establish and maintain habitats for young life stages of humpback chub in the mainstream. The chief difference between the proposed 2008 high flow test and previous experiments is that the amount of fine sediment in the system is about 3 times greater than that which triggered the 2004 high flow test. We perceive no significant negative impact on humpback chub from this change. Instead, we anticipate that greater sediment availability during 2008 should lead to more widespread construction of sandbars (Schmidt 1999; Topping et al. 2006), which should increase the likelihood of backwater formation and more nursery habitat for humpback chub. This assumption is an uncertainty that should be framed as a research question and tested.

An outstanding information need for management of Grand Canyon backwaters is the relationship between backwater bathymetry and suitability as fish habitat, specifically the relationship between dam operations, depth, area, volume and thermal characteristics. Goeking et al (2003) point out that large backwaters may not incur as many benefits to young native fish as smaller backwaters because the latter will warm faster and thus remain warmer over time than larger backwaters; however, due to their depth, they may be more frequently available as fish habitat over a greater range of flows. In the Upper Colorado River basin, Colorado pikeminnow were found to utilize backwaters with average depths greater than 0.3 m (Trammell and Chart 1999) and average areas of 992 m^2 (Day et al 1999). The issue of backwater depth is a research need from the standpoint that while greater depths afford more availability over a wide range of flows (Muth et al. 2000), the concurrent increase in volume with depth may slow warming rates.

Persistence of backwaters created during 1996 appeared to be strongly governed by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999; Hazel et al. 1999; Parnell et al. 1997; Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones had eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999). Post-test flow regimes to minimize erosion have yet to be developed and tested.

Steady flows and persistent suitable habitat

The net effect of steady flows during September and October on habitat persistence is most likely to be positive. Depending on river location, the amount of persistent habitat increases by 63 to 400 percent when flows are held steady at 8,000 cfs as compared to fluctuations between 5,000 and 8,000 cfs (Korman et al. 2004) (Figure 15). The increase is even more dramatic when compared to higher fluctuations (8,000 to 20,000 cfs), so we assume that the predictions for persistent habitat for flows included under the Proposed Action are similar (i.e., relatively steady flows of 9,000-10,000 cfs as compared to fluctuations between 5,000 to 12,000 cfs per day).

The same benefits of a more stabilized nearshore environment would be accrued for non-native fish; however, their general preference for slightly lower water velocities restricts them to a smaller area than for humpback chub and perhaps other native fish, which tend to be more tolerant of higher velocities (Meffe and Minckley 1987; Minckley and Meffe 1987; Table 8; Figure 16). Depending on the transect, humpback chub have available for their use at any given point under steady flows 16 to 34 percent more habitat than non-native fish, which presumably translates into a competitive advantage for humpback chub and other native fish. Similar trends for both humpback chub and non-native fish are expected during dry years (7.48 maf).

During wet years and years of high reservoir elevation, flow volumes during the transition from September to October could diminish by over 50 percent depending on real-time dam operations decisions; similar transitions could occur between August and September. With that change comes a dramatic decrease in daily minimum flows, which is expected to increase available habitat for humpback chub (Figure 14). However, the rate at which this shift is expected to occur is very rapid and may entail bioenergetic costs to humpback chub forced to relocate in favorable habitat at low velocities. This effect could be exacerbated, for example, if chub are using the vegetated portion of the channel inundated at high flows but then need to readjust at the lower elevations (talus, debris fans; Figure 14). The risk of stranding is also appreciable, so more gradual transitions from one water year to the next during wet years may have important benefits (Section 1.4.1).

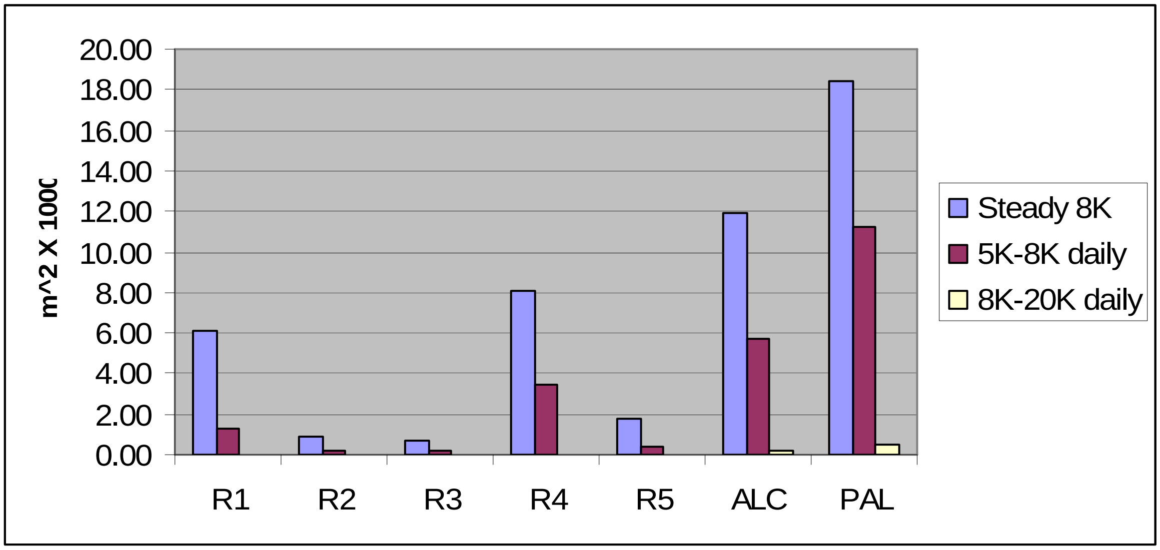


Figure 15. Predicted habitat persistence (m^2 X 1000) for humpback chub suitable habitat among transacts immediately below the Little Colorado River confluence under steady flow conditions (8K), low fluctuating flows (5,000-8,000 cfs daily) and high fluctuating flows (8,000-20,000 cfs). See Figure A.1 for locations of transects. Predictions are from Korman et al. 2004.

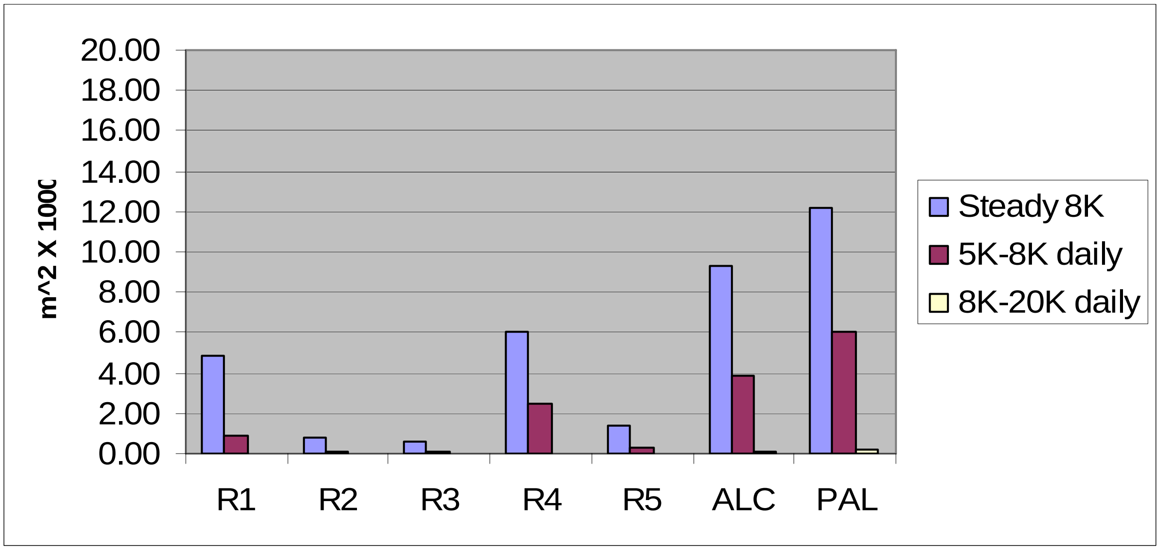


Figure 16. Predicted habitat persistence (m^2 X 1000) for non-native fish suitable habitat among transacts immediately below the Little Colorado River confluence under steady flow conditions (8K), low fluctuating flows (5,000-8,000 cfs daily) and high fluctuating flows (8,000-20,000 cfs). See Figure A.1 for locations of transects. Predictions are from Korman et al. 2004.

Steady flows and temperature

Based on historic data (Trammell et al. 2002), mainchannel water temperatures in September are predicted to be 1-2 °C warmer under steady flow conditions than under fluctuating flows, and backwater temperatures are predicted to be 0.9 to 1.8 °C warmer than the mainchannel. Depending on river reach, humpback chub growth rates during the month of September are predicted to increase by 12 to 36 percent in the mainchannel environment and 9 to 19 percent more in backwaters (Table 9). This increase in growth due solely to changes in temperature could be augmented by any bioenergetic benefits accrued through increased habitat stability and increased abundance in prey. No assessment was possible for October due to lack of information, although Korman et al. (2005) found backwaters to be about 1 °C cooler than the mainchannel during that period.

Modeling results predict much more modest increases in temperature under steady flows than under fluctuating flows, and mostly during the month of October (Figure 17). Thus, the actual warming rate of both the thalweg and backwaters is an uncertainty that should be addressed through monitoring and model validation.

Table 9. Expected changes in mainchannel and backwater temperatures and young-of-year humpback chub growth rates (mm/month) under MLFF and the Proposed Action among river reaches

	Mainchannel					Backwaters				
River Mile	Temperatures Sept 1991-94 (Fluctuating)	Expected growth (mm) under Fluctuating Flows	Temperatures in 2000 under Steady Flows	Expected growth (mm) under Steady Flows	Growth difference (percent), Increase under Steady Flows	Temperatures Sept 1991-94 (Fluctuating)	Expected growth (mm) under Fluctuating Flows	Temperatures in 2000 under Steady Flows	Expected growth (mm) under Steady Flows	Growth difference (percent), Increase under Steady Flows
0-61	11.0	2.7	12.0	3.5	26.6	12.5	3.8	13.4	4.4	15.3
61-88	12.0	3.5	13.9	4.7	35.5	14.5	5.0	15.6	5.7	12.1
88-166	13.0	4.1	14.8	5.2	26.3	14.5	5.0	16.3	6.0	19.4
166-226	14.5	5.0	15.6	5.7	12.1	16.0	5.9	17.0	6.4	8.6

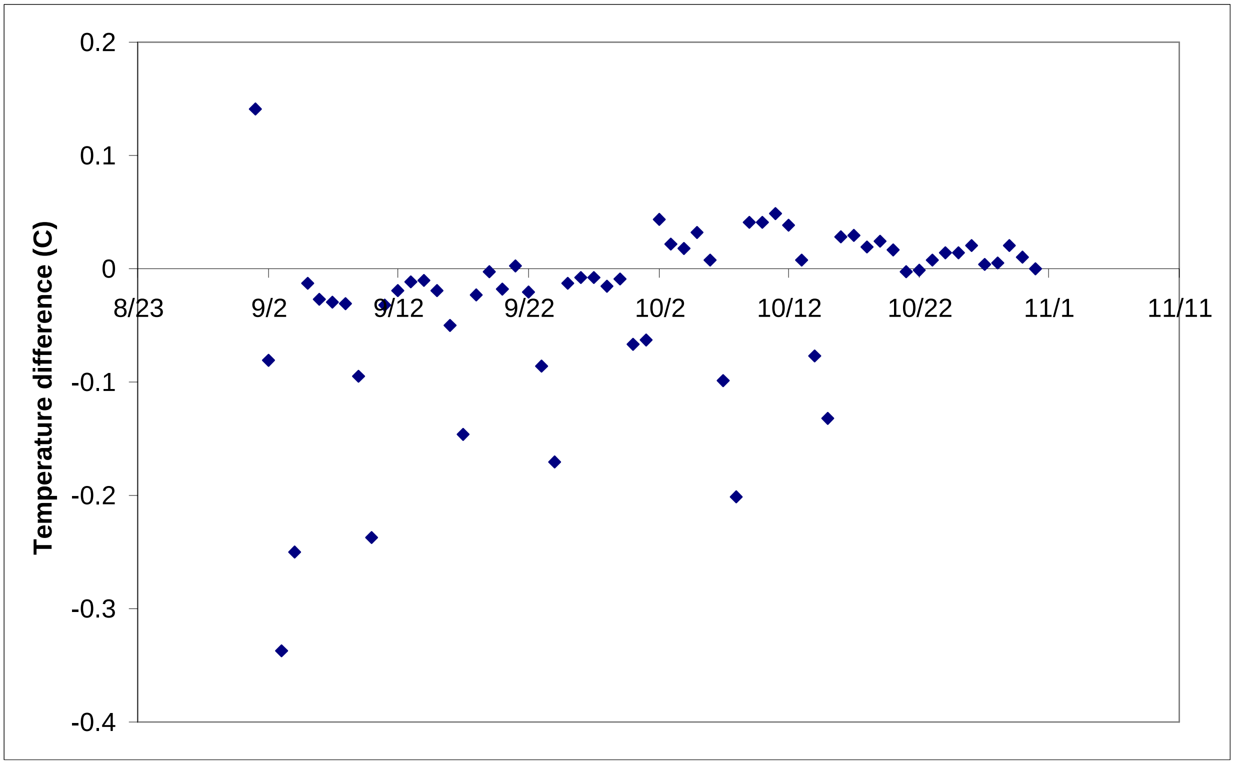


Figure 17. Difference in modeled mainchannel (thalweg) water temperatures between No Action and the Proposed Action at the LCR inflow reach (RM 61.5).

Steady flows and backwater prey availability

In a study conducted in the upper Colorado River basin (middle Green River, Utah) Grand et al (2005) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increase, so to does the proportion of backwater water volume, which results in a net export in as much as 30 percent of daily invertebrate production. Potential geomorphic differences between the Grand Canyon and the Upper Colorado River basin underline the need for additional research investigation.

Prey availability may be further enhanced by the creation and improvement of new backwaters from the proposed high flow tests in March 2008. Arizona Game and Fish Department (1996) hypothesized that the 1993 Little Colorado River flood expanded the availability of stable backwater habitats, which coincided with increases of benthic invertebrate standing stocks the following year. Also, Parnell et al. (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater.

Steady flows would occur during a period when benthic invertebrate standing stocks are declining to low winter levels (AGFD 1996). Thus, increases in benthic standing stocks during that period caused by stable flows (and perhaps greater availability of backwaters) would be beneficial to humpback chub as their potential for added growth prior to the onset of winter would be enhanced.

The role of non-native fish management

While effects of increased temperature and invertebrate prey availability are thought to benefit humpback chub, the same could be said of non-native fish, primarily small-bodied cyprinids which utilize the same backwater habitats as humpback chub. Thus, in order for the Proposed Action to be most beneficial to humpback chub, a non-native fish control plan (coldwater and warmwater) would need to be developed and implemented. Progress to this end is being made at this time by GCMRC, and active management of warm water non-native fish should begin as soon as possible.

In the Upper Colorado Basin, Trammell et al. (2004) investigated the feasibility of using mechanical removal to reduce non-native cyprinid fish species in backwater habitats. They concluded that their ability to reduce non-native cyprinid species was limited to short-lived, site-specific reductions in abundance. However, they concluded that such programs could be beneficial to native fish if efficiency was improved and reductions were made just as endangered fish begin to use backwaters in the early summer. They also recommended that additional efforts be conducted in the fall to reduce over-winter competition and suppress non-native fish abundance during the following spring. Finally, they recommended evaluation of additional methods including chemical treatment.

Backwaters tend to concentrate all Grand Canyon fishes. Investigations usually indicate that fish density in backwaters is invariably higher than adjacent mainchannel environments (AGFD 1996; Parnell et al. 1997). This relationship contrasts with the Upper Colorado River basin in that backwater temperatures are often very similar to the mainchannel, so non-native fish are not necessarily restricted to backwaters and, if removed, can recolonize these habitats rapidly. Thus, if sources of non-native fish for recolonization of backwaters in Grand Canyon are relatively infrequent, vulnerability of small-bodied non-native fish to mechanical or chemical renovation of backwaters could be high, and reductions through these means could be longer-lived than in the Upper Basin.

4.2.2 Summary of Effects: Humpback Chub

Some aspects of dam operations contained in the 1996 and 2007 RODs will continue (i.e., daily ramp rates, fluctuation ranges, etc.). The most recent and best available science (Coggins 2007) indicates that there has been increased recruitment into the population from some year classes starting in the mid- to late-1990s, during the period of MLFF operations. This improvement has added credibility to the estimates and contributed to a better understanding of the status and trends of the population. This increase has previously been attributed in part to the results of non-native fish mechanical removal, increases in temperature due to lower reservoir elevations and inflow events, the 2000 low steady summer flow experiment, and/or other experimental flows (USGS 2006a). However, the most recent population modeling indicates the increase was due to increased recruitment as early as 1996 but no later than 1999 (Coggins 2007). The increase in recruitment began at least four and as many as nine years prior to implementation of non-native fish control, incidence of warmer water temperatures, the 2000 low steady summer flow experiment, and the 2004 high flow test. It is also unclear as to whether this increase is attributable to conditions in the mainstem or in the LCR. Population dynamics of non-native fish, humpback chub, hydrology, and other environmental variables in the LCR may have influenced the observed recruitment trends. Nevertheless, we hypothesize that recent changes in non-native fish abundance, temperature, and habitat conditions resulting from natural and experimental actions will likely be beneficial to humpback chub, and the proposed experimental action should provide opportunities to test this hypothesis.

In the absence of conclusive information on factors governing humpback chub recruitment, Reclamation believes that those operational aspects of Glen Canyon Dam of the Proposed Action will not adversely affect humpback chub and hypothesize that the Proposed Action, when tested alongside current operational parameters from the 1996 and 2007 RODs, should actually cause further increases in humpback chub recruitment and abundance.

Table 10. Summary of effects on humpback chub expected to result from the Proposed Action

Proposed Action	Mechanism	Net result*	Duration
High flow test	displacement	negative	60 hours
High flow test	habitat improvement	positive	60 hours
Steady flows	stable habitat	positive	2 months/yr for 5 years
Steady flows	temperature	positive	2 months/yr for 5 years
Steady flows	prey abundance	positive	2 months/yr for 5 years

*assumes that non-native fish control actions are developed, implemented as necessary, and effective

With respect to the Proposed Action, there could be potential take associated with downstream transport of humpback chub during the high flow test; therefore, Reclamation's finding is the Proposed Action may affect, and is likely to adversely affect humpback chub. The Proposed Action is not expected to adversely modify or destroy critical habitat of humpback chub.

Adverse effects are likely to be short-term and outweighed by benefits derived over longer timeframes. The long-term effects on humpback chub from creation and improvement of rearing habitats are expected to be positive. Effects of the fall steady flows are expected to be positive and result in improved growth and survival of young-of-year humpback chub prior to the onset of winter. Beneficial effects of steady flows in fall months should be especially pronounced during the first few years following the 2008 high flow test. Creation and improvement of backwater rearing habitats expected from the high flow test would expand habitat spatial extent, and steady flow would improve overall habitat stability (persistence) and quality (temperature, prey availability). Implementation of conservation measures identified in the Shortage biological opinion (FWS 2007) is also expected to be positive.

4.2.3 Risks, Uncertainties, and Monitoring

The preceding analysis raises a number of uncertainties associated with the Proposed Action. These uncertainties need to be evaluated through the AMP. These include:

1) Relationship between antecedent sediment availability and backwater formation following a high flow test, including return channel depth and sandbar elevation.

2) Relationship between (1) and suitability of backwaters as humpback chub rearing habitat.

3) Persistence of backwaters created by a high flow test in relation to the post-test flow regime (downramp rates, daily fluctuations, steady fall flows, etc.), including erosion and sedimentation rates.

4) Response of young-of-year humpback chub to steady and fluctuating flows in terms of growth, bioenergetics, survival, behavior and habitat use.

5) Warming rates of mainchannel and nearshore habitats (including backwaters) under steady and fluctuating flows and response of native and non-native fishes.

6) Backwater primary and secondary production and standing mass under steady and fluctuating flows.

7) Future climatic changes throughout the Upper Colorado River basin are uncertain. Responses to increased duration or intensity of droughts are discussed in the Shortage EIS (Appendix N).

Risks have also been identified that are related to uncertainties and unknown responses. These include:

1) Responses by non-native fish to warmer releases from a TCD, or conversely, responses by non-native fish to cold releases in the absence of a TCD.

2) Displacement of humpback chub during high flows.

4.3 Razorback Sucker Effects Analysis

Razorback suckers have not been reported from the action area since 1995, and prior to that time, only 10 confirmed fish had been reported from Grand Canyon (Valdez 1996). The recent absence of wild razorback sucker in the action area has precluded studies of the species in the system and a better understanding of their ecology and life history, as well as habitat needs. The nearest occurrence of the species is downstream in Lake Mead proper with specimens rarely caught in the inflow. Radiotagged fish released in spring of 1997 in the Lake Mead inflow eventually moved into the reservoir and no specimens have been reported from the inflow in recent surveys (Ackerman et al. 2006; Van Haverbeke et al. 2007).

Based on what is known of the razorback sucker from other parts of the Colorado River system, the species has variable habitat requirements. Adults in rivers use deep runs, eddies, backwaters, and flooded off-channel environments in spring; runs and pools often in shallow water associated with submerged sandbars in summer; and low-velocity runs, pools, and eddies in winter. These habitats are limited in Grand Canyon and the lack of suitable habitat is probably responsible for the low numbers of historical captures.

Spring migrations of adult razorback sucker were associated with spawning in historic accounts and a variety of local and long-distance movements and habitat-use patterns have been documented. Spawning in rivers occurs over bars of cobble, gravel, and sand substrates during spring runoff at widely ranging flows and water temperatures and spawning in reservoirs takes place over rocky shoals and shorelines. Spawning habitat may be available for razorback suckers in Grand Canyon, but cool temperatures could limit spawning. Young razorback suckers require nursery environments with quiet, warm, shallow water such as tributary mouths, backwaters, or inundated floodplains in rivers, and coves or shorelines in reservoirs. These habitats are not readily and reliable available in Grand Canyon. In the upper basin, floodplains that become inundated with spring runoff are vital habitat for larvae and young.

High flow test and displacement

The high flow is not expected to affect razorback suckers because there are probably few, if any, fish in the action area. Nevertheless, if adults were in the action area, they would not be affected and should be able to sustain their position because they are regularly exposed to variable flows. Newly hatched razorback suckers typically become transported downstream with spring flows following emergence as larvae. This is part of the natural life history of the species and downstream transport is not considered detrimental. However, there are few if any floodplain habitats in Grand Canyon that provide quiet food-rich habitats for the young fish. Hence, if larvae were present, downstream transport would probably carry the young fish into Lake Mead. This is unlikely since reproduction in Grand Canyon is unlikely.

Steady median flows and persistent habitat

Fall steady flows are not likely to adversely affect razorback suckers in the action area. If young are in the area, they would be several months old and would likely benefit from the stable flows and possibly warm, productive shoreline habitats. Adults, if they were present in the action area, would also likely not be adversely affected by the steady flows, but could benefit from the more stable habitat.

In summary, the Proposed Action is not likely to adversely affect razorback sucker or adversely modify or destroy critical habitat.

4.4 Kanab Ambersnail Effects Analysis

Based on the following analysis, there is potential for take of individual ambersnail and Reclamation has concluded the Proposed Action may affect and is likely to adversely affect the Kanab ambersnail.

The Proposed Action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey’s paradise. Kanab ambersnail habitat can be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. The high flow test will increase flows to 41,500 cfs. These flows will inundate Kanab ambersnail habitat and likely scour the vegetation and carry the snails downstream. During the March 1996 high flow test (45,000 cfs) in the Grand Canyon, up to 17 percent of Kanab ambersnail habitat at Vaseys Paradise was lost or degraded, hundreds of snails were lost, and it took over two years for the habitat to recover to pre-flood conditions (IKAMT 1998; Stevens et al. 1997b). In 2004 during the high flow test, 120 m^2 of the habitat was temporarily removed previous to the high release and replaced following the high flow.

4.5 Southwestern Willow Flycatcher Effects Analysis

The Proposed Action may affect, but is not likely to adversely affect the southwestern willow flycatcher. Critical habitat for the Southwestern willow flycatcher is located beyond the action area. The northern boundary of the critical habitat forms the southern boundary for the action area. Downstream flows as a result of the Proposed Action are not expected to have adverse effects below Separation Canyon.

Southwestern willow flycatchers are known to nest in tamarisk along the Colorado River in the Grand Canyon. The southwestern willow flycatcher can be affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat. Conversely, a reduction in flows could have adverse effects on riparian and marsh vegetation, which could adversely affect southwestern willow flycatcher. Willow flycatcher nests in the Grand Canyon are typically above the 45,000 cfs stage (Gloss et al. 2005), which will not be exceeded for the high-flow test. Furthermore, the time frame for the planned high-flow test is outside of the nesting period for southwestern willow flycatchers. Southwestern willow flycatcher nest in primarily tamarisk shrub in the lower Grand Canyon which is quite common along the Colorado River in the Grand Canyon. Tamarisk is not an obligate phreatophtye and is capable of surviving lowered water levels. Therefore, the potentially lower flows in September and October associated with the Proposed Action are not expected to kill tamarisk and thus no loss of southwestern willow flycatcher nesting habitat is anticipated.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions. Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage. During September and October steady flow periods flows will likely be lower than those found under the no-action peak releases. The potential exists for groundwater elevations adjacent to the channel to decline through the steady flows, which could desiccate nesting habitat and result in take of southwestern willow flycatcher. The probability for such take is considered to be low since the period for the Proposed Action is outside of the normal nesting period for southwestern willow flycatcher and the level of any such take would be low because only a few nest sites are known from this reach of the Colorado River and. The level of this effect is not expected to substantively affect the abundance or distribution of southwestern willow flycatcher in the action area or regionally.

4.6 Effects of Climate Change

The Fourth Assessment Report (Summary for Policymakers) of the Intergovernmental Panel on Climate Change (IPCC 2007), presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of unmitigated climate changes projected over the next century. Although annual average river runoff and water availability are projected to decrease by 10-30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins is not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid 21st century range from approximately 45 percent by Hoerling and Eischeid (2006), to approximately 6 percent by Christensen and Lettenmaier (2006), but, as documented in the Shortage EIS (Appendix N), these projections are not at the spatial scale needed for CRSS, the model used to project future flows.

The hydrologic model, CRSS, used as the primary basis of the effects analysis does not project future flows or take into consideration projections such as those cited above, but rather relies on the historic record of the Colorado River Basin to analyze a range of possible future flows. Using CRSS, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100-year historic record. This record includes periods of drought and periods with above average flow. However, studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River Basin indicate that droughts lasting 15-20 years are not uncommon in the late Holocene. Such findings, when coupled with today's understanding of decadal cycles brought on by ENSO and PDO (and upstream consumptive use), suggest that the current drought could continue for several more years, or the current dry conditions could shift to wetter conditions at any time (Webb et al. 2005). Thus, the action period may include wetter or drier conditions than today. An analysis of hydrologic variability and potential alternative climate scenarios is more thoroughly discussed in the Shortage EIS (Appendix N) and is incorporated by reference here.

Although precise estimates of the future impacts of climate change throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual inflow to Lake Powell, including more frequent and more severe droughts. Such droughts may decrease the average storage level of Lake Powell, which could correspondingly increase the temperature of dam releases. Increased release temperatures have been cited as one potential factor in the recent increase of juvenile humpback chub (USGS Fact Sheet 2007) but concerns also exist that warmer aquatic habitat will also increase the risk of warm water non-native fish predation. To allay this risk if such warming occurs, in the Shortage biological opinion Reclamation has committed to the monitoring and control of non-native fish as necessary, in coordination with other Department of the Interior agencies and working through the AMP (FWS 2007).

5 Incidental Take

The Reasonable and Prudent alternative of the 1995 biological opinion (FWS 1995) includes habitat/beach building flows; however, the FWS determined some humpback chub and Kanab ambersnail would be taken during such an event. Similar judgments accompanied the 2004 high flow test. The discussion of incidental take in the 1995 biological opinion considers testing and studies to determine impacts of flows on young humpback chub. We anticipate a similar requirement for take under the current Proposed Action to evaluate the fate of humpback chub and Kanab ambersnail displaced by high flow tests, including numbers displaced and final disposition (location and habitat availability) of surviving humpback chub individuals.

6 Conservation Measures

Reclamation recognizes that conservation measures contained in the Shortage biological opinion (Section 2.1.5) will materially contribute to the conservation and protection of listed species in the action area. In addition, Reclamation offers the following conservation measures to enhance humpback chub conservation and reduce incidental take of Kanab ambersnail.

Humpback chub

In addition to the anticipated positive benefits to humpback chub conservation that have been used to develop the Proposed Action, during the five year experimental period, Reclamation will also use its available discretion in determining monthly release volumes so that monthly releases during the proposed steady flow months of September and October remain fairly similar. Our ability to achieve this transition depends not only on the state of the reservoir and on any need for equalization releases, but also the official inflow forecast received from the Colorado River Forecast Center throughout the water year and consultation within the Colorado River Management Work Group. A more gradual transition in the dam release volumes of those months should minimize sudden changes in humpback chub habitat type and any bioenergetic costs associated with their adaptation to the change. Notwithstanding the potential for modest variation in the monthly volumes during September and October, Reclamation will implement the steady flow element of the Proposed Action set forth in Section 1.3.1 above.

Kanab ambersnail

Prior to the high flow test, Reclamation proposes to move approximately 25 percent of the area of Kanab ambersnail habitat (150 m^2; watercress, monkeyflower, and other plants) and the ambersnails living in that habitat at Vaseys Paradise from below the zone of inundation prior to an above power plant capacity experimental flow. This action would be conducted only during March 2008 under the current proposal. The habitat and ambersnails would be held locally above the level of inundation until the experimental flow, which has an expected duration of 60 hours, has receded. At that time, the habitat and associated ambersnails would be replaced in such a manner as to facilitate the regrowth of the vegetation forming the habitat for the ambersnails. Past experience gained during the 1996 high flow test (45,000 cfs) revealed that nearly all vegetation and ambersnails below the level of inundation were scoured and carried downstream. This experience also indicated that, without supplementation, it took approximately two years for the vegetation to reach its former area and volume. The proposed conservation measure is designed decrease the incidental take from mortality during experimental flows, which will be particularly important if the action agencies and the AMP propose even higher experimental flows in the future. Subsequent monitoring of the effects of this action conducted under the auspices of the GCMRC would be used to determine the survivorship of ambersnails and the rate of regrowth of the replaced vegetation.

A second potential agency action for Kanab ambersnail, which was identified in the September 2002 environmental assessment/biological assessment, was to augment the Elves Chasm population that was established by translocation of individuals from Vaseys Paradise in 1998. Periodic augmentation of translocated populations by Kanab ambersnails from Vaseys Paradise was identified in the biological opinion on the 1998 translocation as an action that the National Park Service may undertake. The primary purpose of augmentation would be to help ensure that the genetic identity of the translocated population does not deviate from the source population at Vaseys Paradise.

The Elves Chasm translocation was one of three undertaken by the National Park Service, AGFD and cooperators in an attempt to achieve a goal of redundant populations in the recovery plan and to address a reasonable and prudent measure in the February 1996 biological opinion on the 1996 high flow test. Reclamation has supported monitoring of both Vaseys Paradise and Elves Chasm populations of Kanab ambersnail through the AMP. This reasonable and prudent measure was removed by the FWS on July 12, 2000, pursuant to their discovery that the level of incidental take for the beach habitat building flow had been underestimated.

In addition, the FWS is in the process of evaluating the genetic status of the Vaseys Paradise population of ambersnail. Reclamation suggests that at the conclusion of this work that Reclamation and the FWS discuss what measures, if any, should be taken with respect to the Elves Chasm population of ambersnail.

7 Literature Cited

Aadland, L. P. 1993. Stream habitat types: their fish assemblages and relationship to flow. North American Journal of Fisheries Management 13:790-806

Abate, P. D., T. Welker, and P.B. Holden. 2002. Razorback sucker studies on Lake Mead, Nevada and Arizona 2001 - 2002 annual report PR 578-6. Department of Resources; Southern Nevada Water Authority, Las Vegas, NV.

Ackmerman, M. W. 2007. Native fish monitoring activities in the Colorado River, Grand Canyon. Draft Report to Grand Canyon Monitoring and Research Center from SWCA, Inc., Flagstaff, Arizona.

Ackerman, M. W., D. Ward, T. Hunt, R. S. Rogers, D. R. VanHaverbeke, A. Morgan, and C. Cannon. 2006. 2006 Grand Canyon long-term fish monitoring in the Colorado River, Diamond Creek to Lake Mead. Annual report to the Grand Canyon Monitoring and Research Center, Flagstaff.

Ackmerman, M. W. 2007. 2006 native fish monitoring activities in the Colorado River, Grand Canyon. Draft Report to Grand Canyon Monitoring and Research Center from SWCA, Inc., Flagstaff, Arizona.

Albrecht, B., and P. B. Holden. 2006. Razorback Sucker studies on Lake Mead, Nevada and Arizona. 2005-2006 Annual Report. Prepared for the Department of Resources, Southern Nevada Water Authority. Prepared by Bio-West, Inc. Logan, Utah. PR-977-1.

Allison, L. J., C. E. Paradzick, J. W. Rourke, and T. D. McCarthey. 2003. A Characterization of Vegetation in Nesting and Non-Nesting Plots for Southwestern Willow Flycatchers in Central Arizona. Studies in Avian Biology 26:81-90.

Andersen, M. E. 2007. Preliminary data regarding young humpback chub in Marble Canyon. Letter to the GCDAMP Technical Work Group. Grand Canyon Monitoring and Research Center, Flagstaff.

Andrews, E. D. 1991. Sediment transport in the Colorado River basin. Pp. 54-74 in Marzolf, G.R. and others, Colorado River ecology and dam management. National Academy Press, Washington DC. 276 p.

Andrews, E. D., C. E. Johnston, J. C. Schmidt, and M. Gonzales. 1999. Topographic evolution of sandbars. Pages 117-130 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Archer, D. L., L. R. Kaeding, B. D. Burdick, and C. W. McAda. 1985. A study of the endangered fishes of the upper Colorado River. Final Report of U.S. Fish and Wildlife Service, Grand Junction, Colorado, to Northern Colorado Water Conservancy District.

Arizona Game and Fish Department. 1994. Glen Canyon Environmental Studies Phase II, 1993. Draft Annual Report to U.S. Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Flagstaff, Arizona.

Arizona Game and Fish Department. 1996a. The ecology of Grand Canyon backwaters. Final Report to U.S. Bureau of Reclamation, Upper Colorado Region, Glen Canyon Environmental Studies, Flagstaff, Arizona.

Arizona Game and Fish Department. 1996b. The effects of an experimental flood on the aquatic biota and their habitats in the Colorado River, Grand Canyon, Arizona. Final Report. Arizona Game and Fish Department, Phoenix.

Arizona Game and Fish Department. 1996c. Ecology of Grand Canyon backwaters. report to Bureau of Reclamation, Glen Canyon Environmental Studies, Flagstaff, AZ. 155 pp.

Arizona Game and Fish Department AGFD. 1998. Environmental Assessment: Establishment of new populations of Kanab ambersnail in Grand Canyon (Coconino County , Arizona). Prepared by AGFD for the National Park Service.

Arizona Game and Fish Department. 2006. Development of fish monitoring (electrofishing) and recent trends in the Grand Canon fish community. Presentation to the GCDAMP Technical Work Group, November 2006. cited December 17, 2007. Available from http://www.usbr.gov/uc/rm/amp/twg/mtgs/06nov08/Attach_07.pdf

Baltz, D. M., B. Vondracek, L. R. Brouwn, and P. B. Moyle. 1991. Seasonal changes in microhabitat selection by rainbow trout in a small stream. Transactions of the American Fisheries Society 120:166-176.

Bestgen, K. R. 1990. Status review of the razorback sucker, *Xyrauchen texanus*. Final Report of Colorado State University Larval Fish Laboratory to U.S. Bureau of Reclamation, Salt Lake City, Utah.

Bestgen, K. R., D. W. Beyers, G. B. Haines, and J. A. Rice. 1997. Recruitment models for Colorado squawfish: tools for evaluating relative importance of natural and managed processes. Final Report of Colorado State University Larval Fish Laboratory to U.S. National Park Service Cooperative Parks Study Unit and U.S. Geological Survey Midcontinent Ecological Science Center, Fort Collins, Colorado.

Beus, S. S., M. A. Kaplinksi, J. E. Hazel, and L. Kearsley. 1994. Monitoring the effects of interim flows from Glen Canyon Dam on sand bar dynamics and campsite size in the Colorado River corridor, Grand Canyon National Park, AZ. Draft final report submitted to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Blinn, W. J. P. Shannon, L. E. Stevens and J. P. Carder. 1995. Consequences of fluctuating discharge for lotic communities. Journal of the North American Benthological Society 14(2):233-248.

Bowen, Z. K., M. C. Freeman, and K. D. Bovee. 1998. Evaluation of generalized habitat criteria for assessing impacts of altered flow regimes on warmwater fishes. Transactions of the American Fisheries Society 127:455-468.

Bozek, M. A., L. J. Paulson, and J. E. Deacon. 1984. Factors affecting reproductive success of bonytail chubs and razorback suckers in Lake Mohave. Technical Report No. 12. Lake Mead Limnological Research Center, Department of Biological Sciences, University of Nevada, Las Vegas.

Bozek, M. A., L. J. Paulson, and J. E. Deacon. 1991. Spawning season of the razorback sucker, *Xyrauchen texanus*, in Lake Mohave, Arizona and Nevada. Journal of Freshwater Ecology 6:61–73.

Bozek, M. A., L. J. Paulson, and G. R. Wilde. 1990. Effects of ambient Lake Mohave temperatures on development, oxygen consumption, and hatching success of the razorback sucker. Environmental Biology of Fishes 27:255–263.

Bradford, R. H., S. D. Gurtin, and B. R. Vlach. 1999. Habitat use by razorback suckers, *Xyrauchen texanus*, implanted with ultra-sonic transmitters and released into the Imperial Division, Lower Colorado River. Proceedings of the Desert Fishes Council 29:4.

Brouder, M. J. 1997. Glen Canyon Environmental Studies Colorado River native fish study, 1995 annual report. Arizona, Arizona Game and Fish Department. Research Branch, Phoenix, AZ.

Brouder, M. J. 1999. Paria River native fish monitoring 1996-98. Annual report. Arizona Game and Fish Department. Research Branch, Phoenix, AZ.

Brouder, M. J., D. W. Speas and T. L. Hoffnagle. 1999. Changes in number, sediment composition and benthic invertebrates of backwaters. Pages 241-248 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Brouder, M. J., and T. L. Hoffnagle. 1997. Distribution and prevalence of the Asian tapeworm, *Bothriocephalus acheilognathi*, in the Colorado River and tributaries, Grand Canyon, Arizona, including two new host records. Journal of Helminthological Society of Washington 64:219–226.

Browning, M. R. 1993. Comments on the Taxonomy of *empidonax traillii* (Willow Flycatcher). *Western Birds* 24:241-57.

Bulkley, R. V., C. R. Berry, R. Pimental, T. Black. 1982. Tolerance and preferences of Colorado River endangered fishes to selected habitat parameters. Colorado River Fishery Project Final Report Part 3. Bureau of Reclamation, Salt Lake City.

Bulkley, R. V., C. R. Berry, R. Pimentel, and T. Black. 1981. Tolerance and preferences of Colorado River endangered fishes to selected habitat parameters. Pages 185–241 in Part

3, Colorado River Fishery Project, Final Report. U.S. Fish and Wildlife Service and Bureau of Reclamation, Contracted Studies, Salt Lake City, Utah.

Bulkley, R. V., and R. Pimentel. 1983. Temperature preference and avoidance by adult razorback suckers. Transactions of the American Fisheries Society 112:601–607.

Bulow, F. J., J. R. Winningham, and R. C. Hooper. 1979. Occurrence of copepod parasite *Lernaea cyprinacea* in a stream fish population. Transactions of the American Fisheries Society 108:100–102.

Burke, T. 1994. Lake Mohave native fish rearing program. U.S. Bureau of Reclamation, Boulder City, Nevada.

Burke, T., and G. Mueller. 1993. Native Fish Work Group, 1992 Annual Report. U.S. Bureau of Reclamation, Boulder City, Nevada.

Carothers, S. W., and C. O. Minckley. 1981. A survey of the fishes, aquatic invertebrates and aquatic plants of the Colorado River and selected tributaries from Lees Ferry to Separation Rapids. Final Report to U.S. Bureau of Reclamation, Museum of Northern Arizona, Flagstaff.

CENR (Committee on Environment and Natural Resources). 1999. Ecological risk assessment in the federal government. Executive Office of the President of the United States, National Science and Technology Council, Report CENR/5-99/001, Washington, D.C.

Childs, M.R., R.W. Clarkson, and A.T. Robinson. 1998. Resource use by larval and early juvenile native fishes in the Little Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 127:620–629.

Choudhury, A., T.L. Hoffnagle, and R.A. Cole. 2003. Parasites of Native and Non-native Fishes of Lower Little Colorado River, Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Choudhoury, A., T. L. Hoffnagle, and R. A. Cole. 2001. Parasites of Native and Non-native Fishes of the Little Colorado River, Grand Canyon, Arizona. Journal of Parasitology 90 (5):1042-1053.

Choudhury, A., T. L. Hoffnagle, and R. A. Cole. 2004. Parasites of Native and Non-Native Fishes of the Little Colorado River, Grand Canyon, Arizona. Journal of Parasitology 90:1042-53.

Christensen, N. and D. P. Lettenmaier. 2006. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin, Hydrology and Earth System Sciences Discussion 3:1-44.

Clarke, A. H. 1991. Status Survey of Selected Land and Freshwater Gastropods in Utah. Denver, CO: U.S. Department of the Interior, U.S. Fish and Wildlife Service.

Clarkson, R. W. 1993. Unpublished data on fecundity of humpback chub in the Little Colorado River, Grand Canyon, Arizona. Arizona Game and Fish Department, Phoenix.

Clarkson, R. W., A. T. Robinson, and T. L. Hoffnagle. 1997. Asian tapeworm, *Bothriocephalus acheilognathi*, in native fishes from the Little Colorado River, Grand Canyon, Arizona. Great Basin Naturalist 57:66–69.

Clarkson, R. W., E. D. Creef, and D. K. McGuinn-Robbins. 1993. Movements and habitat utilization of reintroduced razorback suckers (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) in the Verde River, Arizona. Special Report. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix.

Clarkson, R. W. and M. R. Childs. 2000. Temperature effects of hypolimnial-release dams on early life stages of Colorado River basin big-river fishes. Copeia 2000(2):402-412.

Coggins, L. G. 2007. Abundance trends and status of the Little Colorado River population of humpback chub: an update considering 1989-2006 data. United States Geological Survey open file report 2007-1402.

Coggins, L., C. Walters, C. Paukert, and S. Gloss. 2003. An overview of status and trend information for the Grand Canyon population of the humpback chub, Gila cypha. [online] http://www.gcmrc.gov/library/reports/biological/Fish_studies/GCMRC/coggins2003a.pdf .

Coggins, L.G., Jr., and D.R. Van Haverbeke. 2001. Fisheries Monitoring Activities in the Little Colorado River within Grand Canyon During 2000. Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Coggins, L. and M. Yard. 2003. Non-native fish removal efforts in Grand Canyon: A proposed modification to ongoing activities. Grand Canyon Monitoring and Research Center, Flagstaff.

Coggins, L., and M. Yard. 2003. Mechanical removal of non-native fishes in the Colorado River in Grand Canyon: update of winter operations and findings. U.S. Geological survey, Flagstaff, AZ. [online] http://www.gcmrc.gov/library/reports/biological/Fish_studies/ GCMRC/coggins2003.pdf.

Coggins, L., M. Yard, and C. Paukert. 2002. Piscivory by non-native salmonids in the Colorado River and an evaluation of the efficacy of mechanical removal of non-native salmonids. Grand Canyon Monitoring and Research Center, Flagstaff, AZ. [online] http://www.usbr.gov/uc/ envprog/amp/amwg/mtgs/03mar28/lc_mod_fishremprop_attach10.pdf.

Coggins, L. G., W. E. Pine III, C. J. Walters, and S. J. D. Martell. 2006. Age-Structured Mark-Recapture Analysis: A Virtual-Population-Analysis-Based Model for Analyzing Age-Structured Capture-Recapture Data. North American Journal of Fisheries Management 26:201-205.

Coggins, L. G., W. E. Pine III, C. J. Walters D. R. Van Haverbeke, D. Ward, and H. C. Johnstone. 2006. Abundance Trends and Status of the Little Colorado River Population of Humpback Chub. North American Journal of Fisheries Management 26:233-245.

Cole, R. A., A. Choudhury, and T. L. Hoffnagle. 2002. Parasites of Native and Non-native Fishes of Lower Little Colorado River, Arizona. National Wildlife Health Center, Biological Resources Division, USGS, Madison, Wisconsin.

Cole, T.M. and S. Wells. 2000. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.

Converse, Y. K., C. P. Hawkins, and R. A. Valdez. 1998. Habitat Relationships of Subadult Humpback Chub in the Colorado River through Grand Canyon: Spatial Variability and Implications of Flow Regulation. Regulated Rivers 14(3):267-284.

Creef, E. D., R. W. Clarkson, and D. K. McGuinn-Robbins. 1992. Razorback sucker (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) reintroduction and monitoring, Salt and Verde Rivers, Arizona, 1991–1992. Arizona Game and Fish Department, Research Branch Completion Report to U.S. Fish and Wildlife Service, Office of Endangered Species, Albuquerque, New Mexico.

Davis, E., and W. W. Batham. 2003. Stranding of rainbow trout during experimental fluctuating releases from Glen Canyon Dam on the Colorado River. Final Report. EcoPlan Associates, Inc., Mesa, AZ. [online] http://www.gcmrc.gov/library/reports/biological/Fish_studies/Ecoplan/Davisw2003.pdf.

Day, K. S. K. D. Christopherson, and C. Crosby. 1999. An assessment of young-of-year Colorado pikeminnow *Ptychocheilus lucius* use of backwater habitats in the Green River, Utah. Report B in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

DeLay, L. S., S. H. Stoleson, and M. Farnsworth. 2002. A Quantitative Analysis of the Diet of Southwestern Willow Flycatchers in the Gila Valley, New Mexico. Cortaro, AZ: T&E Inc. 13 pp.

Dill, W. A. 1944. The fishery of the lower Colorado River. California Fish and Game 30(2):109–211.

Douglas M. R., M. E. Douglas M.E. 2000. Late season reproduction by big river Catostomidae in Grand Canyon. Copeia, 2000:238—244.

Douglas, M. R. and M. E. Douglas. 2003a. Genetic interrelationships of *Gila cypha* in the Colorado River ecosystem. Abstract, The Colorado River: an ecosystem science symposium. Tucson, AZ, October 28-30, 2003. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Douglas, M. E. and M. R. Douglas. 2003b. Effective population sizes for *Gila cypha* in the Colorado River ecosystem. Abstract, The Colorado River: an ecosystem science symposium. Tucson, AZ, October 28-30, 2003. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Douglas, M. R., and M. E. Douglas. 2007. Genetic structure of humpback chub Gila cypha and roundtail chub G. robusta in the Colorado River ecosystem. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Douglas M. E., and P. C. Marsh. 1996. Population estimates/ population movements of Gila cypha, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia, 1996, 15-28.

Douglas, M. E., and P. C. Marsh. 1998. Population and survival estimates of *Catostomus latipinnis* in northern Grand Canyon, with distribution and abundance of hybrids with *Xyrauchen texanus*. Copeia 1998:915–925.

Dowling, T. E., and W. L. Minckley. 1993. Mitochondrial DNA diversity within and among populations of the razorback sucker, *Xyrauchen texanus.* Proceedings of the Desert Fishes Council 24: 64.

Drost, C. A., E. H. Paxton, M. K. Sogge, and M. J. Whitfield. 2001. Food Habitats of the Endangered Southwestern Willow Flycatcher." In final report to the U.S. Bureau of Reclamation, 24. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Colorado Plateau Field Station.

Drost, C. A., E. H. Paxton, M. K. Sogge, and M. J. Whitfield. 2003. Food Habitats of the Southwestern Willow Flycatcher During the Nesting Season. Studies in Avian Biology 26:96-103.

Drost, C. A., M. K. Sogge, and E. Paxton. 1998. Preliminary Diet Study of the Endangered Southwestern Willow Flycatcher. Phoenix, AZ: U.S. Department of the Interior, U.S. Geological Survey, Colorado Plateau Research Station.

Durst, S. L. 2004. Southwestern Willow Flycatcher Potential Prey Base and Diet in Native and Exotic Habitats. M.S. Thesis, Northern Arizona University.

Durst, S. L., M. K. Sogge, H. C. English, S. O. Williams III, B. E. Kus, and S. J. Sferra. 2005. Southwestern Willow Flycatcher Breeding Site and Territory Summary – 2004. In report to U.S. Bureau of Reclamation, 18. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Southwest Biological Science Center, Colorado Plateau Research Station.

Edwards, R. J. 1997. Ecological profiles for selected stream-dwelling Texas freshwater fishes. Report to the Texas Water Development Board. University of Texas-Pan American, Edinburg.

English, H. C., A. E. Graber, S. D. Stump, H. E. Telle, and L. A. Ellis. 2006. Southwestern Willow Flycatcher 2005 Survey and Nest Monitoring Report. In Nongame and Endangered Wildlife Program Technical Report 248. Phoenix, AZ: Arizona Game and Fish Department.

Failing, L., J. Korman, and C. Walters. 2003. Summary of results from AMP TWG multi-attribute evaluation workshop. Ecometrics, Inc., Vancouver, British Columbia. 24 p.

Flagg, R. 1982. Disease survey of the Colorado River fishes. Pages 177–184 *in* Colorado River Fishery Project, Final Report, Part 3: Contracted Studies. U.S. Fish and Wildlife Service, Salt Lake City, Utah.

Freeman, M. C., Z. H. Bowen, K. D. Bovee, and E. R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. Ecological Applications 11(1):179-190.

Garrett, D., J. Baron, V. Dale, L. Gunderson, A. Howard, D. Hulse, J. Kitchell, J. Loomis, M. Palmer, R. Parker, D. Robertson, D. Schwartz, and J. Watkins. 2003. Evaluating a Glen Canyon Dam temperature control device to enhance native fish habitat in the Colorado River: a risk assessment by Adaptive Management Program Science Advisors. July 2003.

GCDAMP (Glen Canyon Dam Adaptive Management Program) Science Advisors. 2003. Grand Canyon Dam Adaptive Management Program Science Advisor review comments on the report; “Status and management strategy for humpback chub in Grand Canyon.” Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ and Bureau of Reclamation, Salt Lake City, UT. July 2003.

Gloss, S. P., and L. G. Coggins. 2005. Fishes of Grand Canyon. Pages 33-56 in Gloss, S.P., J.E. Lovich, and T.S. Melis (editors). The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Gloss, S. P., J. E. Lovich, and T. S. Melis (editors). 2005. The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Goeking, S. A., J. C. Schmidt and M. K. Webb. 2003. Spatial and temporal trends in the size and number of backwaters between 1935 and 2000, Marble and Grand Canyons, AZ. Progress report submitted to Grand Canyon Monitoring and Research Center. Department of Aquatic, Watershed and Earth Resources, Utah State University, Logan.

Gorman, O. T. 1994. Habitat use by humpback chub, *Gila cypha*, in the Little Colorado River and other tributaries of the Colorado River. Glen Canyon Environmental Studies Phase II Final Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Flagstaff, Arizona.

Gorman, O. T., D. M. Stone, and J. M. Seals. 1999. Ecology of razorback sucker during early spring in upper Lake Mohave, 1994–1997. Proceedings of the Desert Fishes Council 29:17–18.

Gorman, O., and L. Coggins. 2000. Status and trends of native and non-native fishes of the Colorado River in Grand Canyon 1990-2000. Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Gorman, O., and L. Coggins. 1999. Ecology of spawning humpback chub, Gila cypha, in the Little Colorado River near Grand Canyon, Arizona. Environmental Biology of Fishes 55:115-133

Gorman, O. T., R. G. Bramblett, R. M. Hervin, D. R. VanHaverbeke, and D. M. Stone. 2005. Distribution and Abundance of native and non-native fishes of the Colorado River Ecosystem in Grand Canyon, Arizona : pages 78-94 in M.J. Brouder, C. L. Springer and S. C. Leon, editors. Proceedings of two symposia: Restoring native fish to the lower Colorado River: interactions of native and non-native fishes. July 13-14, 1999, Las Vegas, NV.

Gorman, O. T. and R. R. VanHoosen. 2000. Experimental growth of four native Colorado River fishes at temperatures of 12, 18 and 24 °C. Draft final report submitted to Grand Canyon Monitoring and Research Center, Flagstaff. U.S. Fish and Wildlife Service, Willow Beach AZ.

Grabda, J. 1963. Life cycle and morphogenesis of *Lernaea cyprinacea* L. Acta Parasitologica Polonica XI:169–199.

Grabowski, S. J., and S. D. Hiebert. 1989. Some aspects of trophic interactions in selected backwaters and the main channel of the Green River, Utah, 1987–1988. U.S. Bureau of Reclamation, Salt Lake City, Utah.

Granath, W. O., Jr., and G. W. Esch. 1983. Seasonal dynamics of *Bothriocephalus acheilognathi* in ambient and thermally altered areas of a North Carolina cooling reservoir. Proceedings of the Helminthological Society Washington 50:205–218.

Grand Canyon Monitoring and Research Center. 2007. Draft USGS workshop on scientific aspects of a long-term experimental plan for Glen Canyon Dam, April 10–11, 2007, Flagstaff, Arizona: U.S. Geological Survey Scientific Investigations Report 2007–xxx, 60 p.

Grand Canyon Protection Act of 1992. Public Law No. 102-575.

Grand, T. C. S. F. Railsback, J. W. Hayse and K. E. LaGory. 2006. A physical habitat model for predicting the effects of flow fluctuations in nursery habitats of the endangered Colorado pikeminnow *Ptychocheilus lucius*. River Research and Applications 22:1125-1142.

Grannath, W. O., and G. W. Esch. 1983. Seasonal Dynamics of bothriocephalus acheilognathi in Ambient and Thermally Altered Areas of a North Carolina Cooling Reservoir. Proceedings of the Helminthological Society of Washington 50:205-18.

Griffiths, P. G., R. H. Webb and T. S. Melis. 2004. Frequency and initiation of debris flows in Grand Canyon, AZ. Journal of Geophysical Research 109: F04002

Hamman, R.L. 1982. Spawning and culture of humpback chub. Progressive Fish-Culturist 44:213–216.

Hazel, J. E., M. Kaplinksi, R. Parnell, M. Manone and A. Dale. 1999. Topographic and bathymetric changes at thirty-three long-term study sites. P 161-183 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Heggenes, J. A. Brabrand and S. J. Saltveit. 1990. Comparison of three methods for studies of stream habitat use by young brown trout and Atlantic salmon. Transactions of the American Fisheries Society 119:101-111.

Hoerling, M. and J. Eischeid. 2006. Past Peak Water in the Southwest. Southwest Hydrology 6(1).

Hendrickson, D. A. 1993. Progress report on study of the utility of data obtainable from otoliths to management of humpback chub (*Gila cypha*) in the Grand Canyon. Non-Game and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix.

Hendrickson, D. A. 1994. Evaluation of the razorback sucker (*Xyrauchen texanus*) and Colorado squawfish (*Ptychocheilus lucius*) reintroduction programs in central Arizona based on surveys of fish populations in the Salt and Verde rivers from 1986–1990. Final Report. Non-Game and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix.

Hoffnagle, T. L. 1996. Changes in water quality parameters and fish usage of backwaters during fluctuating vs. short-term steady flows in the Colorado River, Grand Canyon. Arizona Game and Fish Dept. Prepared for Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Hoffnagle, T. L. 1999. Paria River native fish monitoring. 1998 annual report. Arizona Game and Fish Department. Research Branch, Phoenix, AZ.

Hoffnagle, T. L., 2000. Spring Fish Monitoring in the Little Colorado River, Grand Canyon. Draft Final Report, Arizona Game and Fish Department.

Hoffnagle, T. L. 2000. Humpback chub *Gila cypha* health and parasites, 1998–1999. Final Report of Arizona Game and Fish Department to Grand Canyon Fishery Resource Office, U.S. Fish and Wildlife Service, Flagstaff, Arizona.

Hoffnagle, T. L., A. Choudhury, and R. A. Cole. 2006. Parasitism and Body Condition in Humpback Chub from the Colorado and Little Colorado Rivers, Grand Canyon, Arizona. Journal of Aquatic Animal Health 18:184-193.

Hoffnagle, T. L., R. A. Cole, and A. Choudhury. 2000. Parasites of native and non-native fishes of the lower Little Colorado River, Arizona. 1999 Annual Report. National Wildlife Health Center, U.S. Geological Survey - Biological Resources Division, Madison, Wisconsin, and Arizona Game and Fish Department, Phoenix.

Hoffnagle, T. L., R. A. Cole, and A. Choudhury. 2000. Parasites of Native and Non-native Fishes of Lower Little Colorado River, Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Hoffnagle, T. L., R. A. Valdez, and D. W. Speas. 1999. Fish abundance, distribution, and habitat use. Pages 273–287 *in* R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez (eds.). The controlled flood in Grand Canyon. Geophysical Monograph 110, The American Geophysical Union, Washington, D.C.

Holden, P. B. 1994. Razorback sucker investigations in Lake Mead, 1994. Report of Bio/West, Inc., Logan, Utah, to Southern Nevada Water Authority.

Holden, P. B., P. D. Abate, and J. B. Ruppert. 1997. Razorback sucker studies on Lake Mead, Nevada, 1996–97. Annual Report PR-578-1, Bio/West, Inc., Logan, Utah.

Holden, P. B., P. D. Abate, J. B. Ruppert, and J.E. Heinrich. 1999a. Razorback sucker studies on Lake Mead, Nevada, 1996–97. Proceedings of the Desert Fishes Council 29:25–26.

Holden, P. B., P. D. Abate, J. B. Ruppert, and J. E. Heinrich. 1999b. Razorback sucker studies on Lake Mead, Nevada, 1997–98. Proceedings of the Desert Fishes Council 30:20–21.

Holden, P. B., P. D. Abate, and J. B. Ruppert. 2000. Razorback sucker studies on Lake Mead, Nevada. 1998-1999 Annual Report PR-578-3 to Southern Nevada Water Authority, Las Vegas. 49 pp.

Horn, M. J. 1996. Nutritional limitation of recruitment in the razorback sucker (*Xyrauchen texanus*). Doctoral Dissertation. Arizona State University, Tempe.

Howard, A., and R. Dolan. 1981. Geomorphology of the Colorado River in the Grand Canyon. Journal of Geology 89:269-298.

Hubbs, C. L., and R. . Miller. 1953. Hybridization in nature between the fish genera *Catostomus* and *Xyrauchen.* Papers of the Michigan Academy of Arts, Science and Letters 38:207–233.

Humpback Chub Ad Hoc Committee. 2003. Status and management strategy for humpback chub in Grand Canyon. Draft report to Adaptive Management Work Group, Glen Canyon Dam Adaptive Management Program. May 22, 2003. [online] http://www.usbr.gov/uc/envprog/amp/amwg/mtgs/03mar28/HBC_Rpt_may22.pdf

IKAMT, Interagency Kanab Ambersnail Monitoring Team. 1998. The Endangered Kanab Ambersnail at Vaseys Paradise, Grand Canyon, Arizona: 1997 Final Report. In final report. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Intergovernmental Panel on Climate Change (IPCC). 2007. IPCC Fourth Assessment Report: Climate Change 2007, Climate Change Impacts, Adaptation and Vulnerability - Summary for Policymakers.

Jahrke, E., and D. A. Clark. 2000. Razorback sucker and Colorado pikeminnow (formerly squawfish) reintroduction and monitoring in the Salt and Verde Rivers. Paper presented at the 33rd Joint Annual Meeting of the Arizona/New Mexico Chapter of the American Fisheries Society and Arizona and New Mexico Chapters of The Wildlife Society, February 3–5, 2000, Sierra Vista, Arizona.

James, A. E. 1968. *Lernaea* (Copepod) infection of three native fishes from the Salt River basin, Arizona. Master's Thesis. Arizona State University, Tempe.

Johnstone, H. C., and M. Lauretta. 2004. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2003. Final Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, AZ.

Johnstone, H. C., and M. V. Lauretta. 2007. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2004. Final Report to the Grand Canyon Monitoring and Research Center. SWCA Environmental Consultants, Flagstaff.

Johnstone, H. C., M. Lauretta, and M. Trammell. 2003. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2002. Final Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, AZ. [online] http://www.gcmrc.gov/library/reports/biological/Fish_studies/swca/01WRAG0046/johnstone2003.pdf

Jonez, A., and R. C. Sumner. 1954. Lakes Mead and Mohave investigations: a comparative study of an established reservoir as related to a newly created impoundment. Final Report. Federal Aid Wildlife Restoration (Dingell-Johnson) Project F-l-R, Nevada Game and Fish Commission, Carson City.

Jordan, D. S., and B. W. Evermann. 1896. The fishes of North and Middle America. Bulletin of the U.S. National Museum 47:1–1240.

Kaeding, L. R., B. D. Burdick, P. A. Schrader, and C. W. McAda. 1990. Temporal and spatial relationships between the spawning of humpback chub and roundtail chub in the Upper Colorado River. Transactions of the American Fisheries Society 119:135-144.

Kaeding, L. R., and M. A. Zimmerman. 1982. Life history and population ecology of the humpback chub in the Little Colorado and Colorado rivers of the Grand Canyon, Arizona. Pages 281-365 in U.S. Fish and Wildlife Service. Colorado River Fishery Project Final Report, Field Investigations. U.S. Fish and Wildlife Service, Utah.

Kaeding, L. R., and M. A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado Rivers of the Grand Canyon. Transactions of the American Fisheries Society 112:577–594.

KAIMG. 1997. The Impacts of an Experimental Flood from Glen Canyon Dam on the Endangered Kanab Ambersnail at Vaseys Paradise, Grand Canyon, Arizona: Final Report. I*n final report*, 43. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Karp, C. A., and Tyus, H. M. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green Rivers, Dinosaur National Monument, with observations on roundtail chub (*G. robusta*) and other sympatric fishes. Great Basin Naturalist 50:257–264.

Kennedy, T. A. 2007. A *Dreissena* Risk Assessment for the Colorado River ecosystem. United States Geological Survey open file report 2007-1085.

Kidd, G. 1977. An investigation of endangered and threatened fish species in the upper Colorado River as related to Bureau of Reclamation Projects. Final Report of Northwest Fisheries Research, Clifton, Colorado, to U.S. Bureau of Reclamation.

Kitchell, J. F., C. Grimes, S. T. Lindley, D. Otis, and C. Schwartz. 2003. An independent review of ongoing proposed scientific methods to assess the status & trends of the Grand Canyon population of the humpback chub. Report to the Adaptive Management Work Group: Glen Canyon Dam Adaptive Management Program. Grand Canyon Monitoring and Research Center, Flagstaff, AZ. December 2003.

Kolluru, V. and M. Fichera. 2003. Development and Application of Combined 1-D and 3-D Modeling System for TMDL Studies. Reprinted from Estuarine and Coastal Modeling Proceedings of the Eight International Conference American Society of Civil Engineers, Monterey, CA.

Kolok, A. S. and J. T. Otis. 1995. The relationship between specific growth rate and swimming performance in male fathead minnows *Pimephales promelas*. Canadian Journal of Zoology 73:2165-2167.

Korman, J., M. Kaplinski and J. Buszowski. 2006. Effects of Air and Mainstem Water Temperatures, Hydraulic Isolation, and Fluctuating Flows From Glen Canyon Dam on Water Temperatures in Shoreline Environments of the Colorado River in Grand Canyon. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Korman, J., M. Kaplinski, and J. Hazel, Jr. 2003. Spatial and temporal patterns in rainbow trout redds and fry in the Lees Ferry reach of the Colorado River: implications for fluctuating flows from Glen Canyon Dam. Abstract, The Colorado River: an ecosystem science symposium. Tucson, AZ, October 28-30, 2003. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Korman, J., M. Kaplinski, J. E. Hazel III, and T. S. Melis. 2005. Effects of the Experimental Fluctuating Flows from Glen Canyon Dam in 2003 and 2004 on the Early Life History

Stages of Rainbow Trout in the Colorado River. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Korman, J., M. Yard, and D. Speas. 2006. An Evaluation of the Utility of Snorkel Surveys for Estimating Population Size and Tracking Trends in Relative Abundance of Rainbow Trout in the Lee's Ferry Reach of the Colorado River. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Korman, J., M. Yard, and D. Speas. 2006. An Evaluation of the Utility of Snorkel Surveys for Estimating Population Size and Tracking Trends in Relative Abundance of Rainbow Trout in the Lee's Ferry Reach of the Colorado River. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Korman, J., and P.S. Higgins. 1997. Utility of escapement time series data for monitoring the response of salmon populations to habitat alteration. Canadian Journal of Fisheries and Aquatic Sciences 54(9):2058-2067.

Korman, J., S. M. Wiele, and M. Torizzo. 2004. Modeling Effects of Discharge on Habitat Quality and Dispersal of Juvenile Humpback Chub (*Gila cypha*) in the Colorado River, Grand Canyon. Regulated Rivers 20:379-400.

Koronkiewicz, J. J., M. A. McLeod, B. T. Brown, and S. W. Carothers. 2004. Southwestern Willow Flycatcher Surveys, Demography, and Ecology Along the Lower Colorado River and Tributaries, 2003. In report from SWCA Environmental Consultants Inc. Boulder City, NV: U.S. Department of the Interior, Bureau of Reclamation. 125 pp.

Koronkiewicz, T. J. and M. J. Whitfield. 1999. Surveys for Wintering Willow Flycatchers (E*mpidonax traillii*) in Costa Rica and Panama. In *Canadian Journal of Zoology*, 91. Phoenix, AZ: U.S. Department of the Interior, Bureau of Reclamation.

Koronkiewicz, T. J. and M. K. Sogge. 2000. Willow Flycatcher (E*mpidonax traillii*) Winter Ecology in Costa Rica: 1999/2000. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Colorado Plateau Field Station. 28 pp.

Koronkiewicz, T. J., M. A. McLeod, B. T. Brown, and S. W. Carothers. 2006a. Southwestern Willow Flycatcher Surveys, Demography, and Ecology Along the Lower Colorado River and Tributaries, 2005. In report from SWCA Environmental Consultants Inc., 176. Boulder City, NV: U.S. Department of the Interior, Bureau of Reclamation.

Koronkiewicz, T. J., M. K. Sogge, C. Van Riper III, and E. H. Paxton. 2006b. Territoriality, Site Fidelity, and Survivorship of Willow Flycatchers Wintering in Costa Rica. Condor 108:558-70.

Kubly, D. M. 1990. The endangered humpback chub (*Gila cypha*) in Arizona: a review of past studies and suggestions for future research. Arizona Game and Fish Department, Phoenix.

Lanigan, S. H., and H. M. Tyus. 1989. Population size and status of razorback sucker in the Green River basin, Utah and Colorado. North American Journal of Fisheries Management 9:68–73.

Lauretta, M. V. and K. M. Serrato. 2006. Native Fish Monitoring Activities in the Colorado River within Grand Canyon During 2005. In Draft annual report. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Leonard, P. M. and D. J. Orth. 1988. Use of habitat guilds of fishes to determine instream flow requirements. North American Journal of Fisheries Management 8:399-409.

Leibfried, W. C., H. Johnstone, S. Rhodes, and M. Lauretta. 2003. A study to determine the efficacy of removing brown trout in Bright Angel Creek, Grand Canyon, Arizona. Report submitted to Grand Canyon National Park Science Center. SWCA Environmental Consultants, Inc., Flagstaff, AZ.

Leibfried, W.C., H. Johnstone, S. Rhodes, and M. Lauretta. 2005. Feasibility study to determine the efficacy of using a weir in Bright Angel Creek to capture brown trout. Final Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, AZ.

Liebfried, B., K. Hilwig, K. Serrato, and M. Lauretta. 2006. Restoring native fish habitat in selected tributaries of Grand Canyon National Park. Draft Report to the National Park Service from SWCA, Inc., Flagstaff, Arizona.

Lupher, M. L., and R. W. Clarkson. 1994. Temperature tolerance of humpback chub (*Gila cypha*) and Colorado squawfish (*Ptychocheilus lucius*), with a description of culture methods for humpback chub. Glen Canyon Environmental Studies phase II 1993 annual report. Arizona Game and Fish Department, Phoenix.

Lynn, J. C. and M. J. Whitfield. 2002. Winter Distribution of the Willow Flycatcher (E*mpidonax traillii*) in Mexico. Weldon, CA: Southern Sierra Research Station. 45 pp.

Lynn, J. C., T. J. Koronkiewicz, M. J. Whitfield, and M. K. Sogge. 2003. Willow Flycatcher Winter Habitat in El Salvador, Costa Rica, and Panama: Characteristics and Threats. Studies in Avian Biology 26:41-51.

Mabey, L. W., and D. K. Shiozawa. 1993. Planktonic and benthic microcrustaceans from floodplain and river habitats of the Ouray Refuge on the Green River, Utah. Department of Zoology, Brigham Young University, Provo, Utah.

Maddux, H. R, D. M. Kubly, J. C. deVos, W. R. Persons, R. Staedicke, and R. L. Wright. 1987. Evaluation of varied flow regimes on aquatic resources of Glen and Grand Canyon. Final Report of Arizona Game and Fish Department to U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Salt Lake City, Utah.

Maddux, H. R., L. A. Fitzpatrick, W. R. Noonon. 1993. Colorado River endangered fishes critical habitat. U.S. Fish and Wildlife Service, Salt Lake City, Utah.

Magirl, C. S., R. H. Webb, and P. G. Griffiths. 2005. Changes in the Water Surface Profile of the Colorado River in Grand Canyon, Arizona, between 1923 and 2000. Water Resources Research 41: W05021.

Marsh, P. C. 1985. Effect of incubation temperature on survival of embryos of native Colorado River fishes. Southwestern Naturalist 30:129–140.

Marsh, P. C. 1987. Food of adult razorback sucker in Lake Mohave, Arizona-Nevada. Transactions of the American Fisheries Society 116:117–119.

Marsh, P. C. 1993. Draft biological assessment on the impact of the Basin and Range Geoscientific Experiment (BARGE) on federally listed fish species in Lake Mead, Arizona and Nevada. Arizona State University, Center for Environmental Studies, Tempe, Arizona.

Marsh, P. C. 2000. Fish population status and evaluation in the Cibola High Levee Pond. Final Report to U.S. Bureau of Reclamation, Boulder City, Nevada.

Marsh, P. C. 1994. Abundance, movements, and status of adult razorback sucker in Lake Mohave, Arizona-Nevada. Proceedings of the Desert Fishes Council 25:35–36.

Marsh, P. C., and M.E. Douglas. 1997. Predation by introduced fishes on endangered humpback chub and other native species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126:343–346.

Marsh, P. C., and D. R. Langhorst. 1988. Feeding and fate of wild larval razorback sucker. Environmental Biology of Fishes 21:59–67.

Marsh, P. C., and W. L. Minckley. 1989. Observations on recruitment and ecology of razorback sucker: Lower Colorado River, Arizona-California-Nevada. Great Basin Naturalist 49:71–78.

Marshall, R. M. and S. H. Stoleson. 2000. Status, Ecology, and Conservation of the Southwestern Willow Flycatcher. edited by D. Finch and S. Stoleson. Albuquerque, NM.

McAda, C. W., and R. S. Wydoski. 1980. The razorback sucker, *Xyrauchen texanus*, in the Upper Colorado River Basin, 1974-76. Technical Papers of the U.S. Fish and Wildlife Service 99. U.S. Fish and Wildlife Service, Washington, D.C.

McCarthy, M. S., and W. L. Minckley. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. Journal of the Arizona-Nevada Academy of Science 21:87–97.

McCabe, R. A. 1991. The Little Green Bird, Ecology of the Willow Flycatcher. Madison, Wisconsin.

McGuinn-Robbins, D. K. 1995. Comparisons in the number and area of backwaters associated with the Colorado River in Glen, Marble and Grand Canyons, AZ. Draft report to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation. Arizona Game and Fish Department, Phoenix.

McIvor, C. C., and M. L. Thieme. 1999. Flannelmouth Suckers: Movement in the Glen Canyon Reach and Spawning in the Paria River. In The Controlled Flood in Grand Canyon. pages 289-296 in Geophysical Monograph 110, J. C. Schmidt R. H. Webb, G. R. Marzolf, and R. A. Valdez, (eds). The American Geophysical Union, Washington, DC.

McKernan, R. L and G. Braden. 1997. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 2 – 1997. In report to Bureau of Reclamation, Lower Colorado River Region and U.S. Fish and Wildlife Service. Redlands, CA: San Bernardino County Museum. 64 pp.

McKernan, R. L and G. Braden. 1998. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 3 – 1998. In report to U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service and U.S. Bureau of Land Management. Redlands, CA: San Bernardino County Museum. 94 pp.

McKernan, R. L. and G. Braden. 1999. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 4 – 1999. In report to U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service and U.S. Bureau of Land Management. Redlands, CA: San Bernardino County Museum. 83 pp.

McKernan, R. L and G. Braden. 2001. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 5 – 2000. In report to U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service and U.S. Bureau of Land Management. Redlands, CA: San Bernardino County Museum. 86 pp.

McKernan, R. L and G. Braden. 2006a. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 6 – 2001. In report to U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service and U.S. Bureau of Land Management. Redlands, CA: San Bernardino County Museum. 58 pp.

McKernan, R. L and G. Braden. 2006b. Status, Distribution, and Habitat Affinities of the Southwestern Willow Flycatcher Along the Lower Colorado River Year 7 – 2002: Final Report - Revised. In report to U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service. Redlands, CA: San Bernardino County Museum. 93 pp.

McKinney, T. and D. W. Speas. 2001. Observations of size-regulated asymmetries in diet and energy intake of rainbow trout in a regulated river Environmental Biology of Fishes 61: 435-444

McKinney, T., D. W. Speas, R. S. Rogers and W. R. Persons. 1999b. Rainbow trout in the Lees Ferry recreational fishery below Glen Canyon Dam, Arizona, following establishment of minimum flow requirements. Final report submitted to Grand Canyon Monitoring and Research Center. Arizona Game and Fish Department, Phoenix.

McKinney, T., D. W. Speas, R. S. Rogers and W. R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

McKinney, T., R. S. Rogers, A. D. Ayers and W.R. Persons. 1999a. Lotic community responses in the Lees Ferry reach. Pages 249-258 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

McKinney, T., and W. R. Persons. 1999. Rainbow Trout and Lower Trophic Levels in the Lee's Ferry Tailwater Below Glen Canyon Dam, Arizona: A Review. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

McKinney, T., W. R. Persons, and R. S. Rogers. 1999. Ecology of Flannelmouth Sucker in the Lee's Ferry Tailwater, Colorado River, Arizona. Great Basin Naturalist 59:259-65.

McLeod, M. A., T. J. Koronkiewicz, B. T. Brown, and S. W. Carothers. 2005. Southwestern Willow Flycatcher Surveys, Demography, and Ecology Along the Lower Colorado River and Tributaries, 2004. In annual report SWCA Environmental Consultants Inc., 155. Flagstaff, AZ: U.S. Department of the Interior, Bureau of Reclamation.

Meffe, G. K., and W. L. Minckley. 1987. Persistence and stability of fish and invertebrate assemblages in a repeatedly disturbed Sonoran Desert stream. American Midland Naturalist. 117:177-191.

Meko, D., Woodhouse, C., Baisan, C., Knight, T., Lukas, J., Hughes, M., and Salzer, M., 2007. Medieval Drought in the Upper Colorado River Basin. Geophysical Research Letters. Vol 34, L10705.

Melis, T. S. 1997. Geomorphology of debris flows and alluvial fans in Grand Canyon National Park and their influence on the Colorado River below Glen Canyon Dam, AZ. PhD thesis, University of Arizona. 490 p.

Melis, T. S., J. Korman, and C. J. Walters. 2005. Active Adaptive Management of the Colorado River Ecosystem Below Glen Canyon Dam, USA: Using Modeling and Experimental Design to Resolve Uncertainty in Large-River Management. Proceeding of the International Conference on Reservoir Operations & River Management, Guangzhou, China, September 18-23, 2005.

Melis, T. S., R. H., Webb, P. G. Griffiths, and T. J. Wise. 1994. Magnitude and frequency data for historic debris flows in Grand Canyon National Park and vicinity, AZ. U.S. Geological Survey Water Resources Investigations Report 94-4214. 285 p.

Melis, T. S., S. A. Wright, B. E. Ralston, H. C. Fairley, T. A. Kennedy, M. E. Andersen, and L. G. Coggins, Jr. 2005. 2005. Knowledge Assessment of the Effects of Glen Canyon Dam on the Colorado River Ecosystem: An Experimental Planning Support Document Grand Canyon Monitoring and Research Center, Flagstaff.

Melis, T. S., W. M. Phillips, R. H. Webb, and D. J. Bills. 1997a. When the Blue-Green Waters Turn Red: Historical Flooding in Havasu Creek, Arizona. In Water Resources Investigations Report #96-4115. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey 85 pp.

Melis, T. S., W. M. Phillips, R. H. Webb, and D. J. Bills. 1997b. Geomorphology of Debris Flows and Alluvial Fans in Grand Canyon National Park and Their Influence on the Colorado River Below Glen Canyon Dam, Arizona. University of Arizona Press. 490 pp.

Melis T. S., S. A. Wright, B. E. Ralston, H. C. Fairley, T. A. Kennedy, M. E. Andersen, and L. G. Coggins, Jr. 2005. Knowledge Assessment of the Effects of Glen Canyon Dam on the Colorado River Ecosystem : An Experimental Planning Support Document. Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Meretsky, V. 2000. Population Ecology and Management for Oxyloma in Kanab Canyon, Kane Co., Utah. In report to the Bureau of Land Management. Kanab, UT: U.S. Department of the Interior, Bureau of Land Management.

Meretsky, V. and D. Wegner. 1999. Kanab Ambersnail at Vaseys Paradise, Grand Canyon National Park, 1998 Monitoring and Research. In report SWCA Environmental Consultants Inc., 9. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey.

Meretsky, V. J., R. A. Valdez, M. E. Douglas, M. J. Brouder, O. T. Gorman and P. C. Marsh. 2000. Spatiotemporal variation in length-weight relationships of endangered humpback chub: implications for conservations and management. Transactions of the American Fisheries Society 129:418-429.

Miller, R. R. 1946. *Gila cypha*, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of the Washington Academy of Sciences 36:409–415.

Minckley, W. L. 1983. Status of the razorback sucker, *Xyrauchen texanus* (Abbott), in the Lower Colorado River Basin. Southwestern Naturalist 28:165–187.

Minckley, W. L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Sims Printing Company, Inc., Phoenix.

Minckley, W. L. and G. K. Meffe. 1987. Differential selection for native fishes by flooding in streams of the arid American Southwest. P. 93-104 in W.J. Matthews and D.C. Heins, eds., Ecology and Evolution of North American Stream Fish Communities. University of Oklahoma Press, Norman.

Minckley, W. L. 1991. Native fishes of the Grand Canyon region: an obituary? Pages 124–177 *in* National Research Council Committee (eds.). Colorado River ecology and dam management. Proceedings of a symposium, May 24–25, 1990, Santa Fe, New Mexico, National Academy Press, Washington, D.C.

Minckley, W. L., P. C. Marsh, J. E. Brooks, J. E. Johnson, and B. L. Jensen. 1991. Management toward recovery of the razorback sucker. Pages 303–357 in W.L. Minckley and J.E. Deacon (eds.). Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

Minckley, C. O. 1992. Observed growth and movement in individuals of the Little Colorado population of the humpback chub (*Gila cypha*). Proceedings of the Desert Fishes Council 22:35–36.

Minckley, C. O. 1996. Observations on the biology of the humpback chub in the Colorado River Basin, 1908–1990. Doctoral Dissertation. Northern Arizona University, Flagstaff.

Modde, T., and D. Wydoski. 1995. *Xyrauchen texanus*, razorback sucker/matalote jorobado, catostomidae - suckers. Desert Fish Council website http://www.utexas.edu/depts/tnhc/. www/fish/dfc/na/catostom/xyrauche/xtexanus/xtexanus.html (accessed March 22, 2000)

Modde, T., and E. J. Wick. 1997. Investigations of razorback sucker distribution movements and habitats used during spring in the Green River, Utah. Final Report of U.S. Fish and Wildlife Service, Vernal, Utah, to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Modde, T., K.P. Burnham, and E.J. Wick. 1996. Population status of the razorback sucker in the middle Green River. Conservation Biology 10:110–119.

Modde, T., R. T. Muth, and G. B. Haines. 1999b. Floodplain wetlands as nursery habitat for razorback suckers in the middle Green River. Proceedings of the Desert Fishes Council 30:30.

Moore, D. 2005. Status and Monitoring of Southwestern Willow Flycatchers within Elephant Butte Reservoir, New Mexico. In report from Denver Technical Service Center, prepared for Albuquerque Area Office, 34. Albuquerque, NM: U.S. Department of the Interior, Bureau of Reclamation.

Moyle, P. B. and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114:695-704.

Mpoame, M. 1981. Parasites of some fishes native to Arizona and New Mexico, with ecological notes. Doctoral Dissertation. Arizona State University, Tempe.

Mueller, G. 1995. A program for maintaining the razorback sucker in Lake Mohave. American Fisheries Symposium 15:127–135.

Mueller, G. 1995. Scientific panel eview of the Glen Canyon Dam modifications to control downstream temperatures, plan and draft environmental assessment (EA) / Gordon

Mueller, Carl Walters, Paul Holden, Pete Walker, Jerry Landye and Brett Johnson. Report prepared for Grand Canyon Monitoring and Research Center. 5 pp. Accessed December 17, 2007. online http://www.gcmrc.gov/library/reports/synthesis/Mueller1999.pdf

Mueller, G., T. Burke, and M. Horn. 1993. A program to maintain the endangered razorback sucker in a highly modified riverine habitat. Pages 77–85 in W. O. Deason and S. S. Anderson (eds.). Environmental enhancement of water projects. U.S. Committee on Irrigation and Drainage, Denver, Colorado.

Mueller, G. A. 2006. Ecology of bonytail and razorback sucker and the role of off-channel habitats in their recovery. U.S. Geological Survey Investigations Report 2006-5-65.

Mueller, G., P. C. Marsh, and G. W. Knowles. 1998. Distribution, migratory behavior, and habitat use of razorback sucker (*Xyrauchen texanus*), in Lake Mohave, Arizona-Nevada. U.S. Geological Survey, Biological Resources Division, Denver, Colorado.

Mueller, G. 1999. Scientific Panel Review of the Glen Canyon Dam Modifications to Control Downstream Temperatures, Plan and Draft Environmental Assessment (EA) / Gordon Mueller, Carl Walters, Paul Holden, Pete Walker, Jerry Landye and Brett Johnson. Bureau of Reclamation, Salt Lake City, Utah.

Muth, R. T. 1990. Ontogeny and taxonomy of humpback chub, bonytail, and roundtail chub larvae and early juveniles. Doctoral Dissertation. Colorado State University, Fort Collins.

Muth, R. T., L. W. Crist, K. E. LaGory, J. W. Hayse, K. R. Bestgen, T. P. Ryan, J. K. Lyons, and R. A. Valdez. 2000. Flow and temperature recommendations for endangered fishes in the Green River downstream of Flaming Gorge Dam. Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Muth, R. T., G. B. Haines, S. M. Meismer, E. J. Wick, T. E. Chart, D. E. Chart, D. E. Snyder, and J. M. Bundy. 1998. Reproduction and early life history of razorback sucker in the Green River, Utah and Colorado, 1992–1996. Final Report of Colorado State University Larval Fish Laboratory to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Nelson, C. 2001. Life history of the Kanab ambersnail on native and non-native host plants in Grand Canyon, Arizona. M. S. Thesis, Northern Arizona University, Flagstaff. 98 pp.

Nelson, C. B. and J. A. Sorensen. 2002. Investigations of the Endangered Kanab Ambersnail: Monitoring of Translocated Populations and Surveys of Additional Habitat. In Nongame and Endangered Wildlife Program Technical Report 200. Phoenix, AZ: Arizona Game and Fish Department.

Nishida, C. and M. J. Whitfield. 2004. Winter Distribution of the Willow Flycatcher (E*mpidonax traillii*) in Ecuador and Southern Mexico. In Canadian Journal of Zoology, 70. Phoenix, AZ.

NRC (National Research Council). 1983. Risk Assessment in the Federal Government: Managing the Process. National Academy Press, Washington, DC.

Osmundson, D. B., and L. R. Kaeding. 1989. Studies of Colorado squawfish and razorback sucker use of the "15-Mile Reach" of the upper Colorado River as part of conservation measures for the Green Mountain and Ruedi Reservoir water sales. Final Report. U.S. Fish and Wildlife Service, Colorado River Fishery Project. Grand Junction, Colorado.

Osmundson, D. B., P. Nelson, K. Fenton, and D. W. Ryden. 1995. Relationships between flow and rare fish habitat in the '15-Mile Reach' of the upper Colorado River. Final Report. U.S. Fish and Wildlife Service, Grand Junction, Colorado.

Owen, J. C., M. K. Sogge, and M. D. Kern. 2002. Habitat and Sex Differences in Physiological Condition of Breeding Southwestern Willow Flycatchers (*empidonax traillii extimus*). *The Auk* 122: 1261-70.

Pacey, C. A., and P. C. Marsh. 1998a. Resource use by native and non-native fishes of the Lower Colorado River: literature review, summary, and assessment of relative roles of biotic and abiotic factors in management of an imperiled indigenous icthyofauna. Final Report of Arizona State University, to U.S. Bureau of Reclamation, Boulder City, Nevada.

Pacey, C. A., and P. C. Marsh. 1998b. Growth of wild adult razorback suckers in Lake Mohave, Arizona-Nevada. Proceedings of the Desert Fishes Council 30:31–32.

Pacey, C. A., and P. C. Marsh. 1999. A decade of managed and natural population change for razorback sucker in Lake Mohave, Colorado River, Arizona and Nevada. Report to the Native Fish Work Group, Arizona State University, Tempe.

Papoulias, D., and W. L. Minckley. 1990. Food limited survival of larval razorback sucker, *Xyrauchen texanus*, in the laboratory. Environmental Biology of Fishes 29:73–78.

Papoulias, D., and W. L. Minckley. 1992. Effects of food availability on survival and growth of larval razorback suckers in ponds. Transactions of the American Fisheries Society 121:340–355.

Paradzick, C. E. 2005. Southwestern Willow flycatcher habitat selection along the Gila and Lower San Pedro Rivers, Arizona: Vegetation and Hydrogeomorphic Considerations. M.S. Thesis, Arizona State University.

Parnell, R. A. Springer and L. Stevens. 1997. Flood-induced backwater rejuvenation along the Colorado River n Grand Canyon, AZ: 1996 final report. Northern Arizona University, Flagstaff. 67 p.

Parnell, R. A. and J. B. Bennet. 1999. Mineralization of riparian vegetation buried by the 1996 controlled flood. Pages 225-239 in Webb, R. H., J. C. Schmidt, G. R. Marzolf, and R. A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Paukert, C. P., L. G. Coggins, Jr., and C. E. Flaccus. 2006. Distribution and Movement of Humpback Chub in the Colorado River, Grand Canyon, Based on Recaptures. Transactions of the American Fisheries Society 135 (1):539-544

Paukert, C. P., and R. S. Rogers. 2004. Factors Affecting Condition of Flannelmouth Suckers in the Colorado River, Grand Canyon, Arizona. North American Journal of Fisheries Management 24:648-653.

Paxton, E. H. 2000. Molecular genetic structuring and demographic history of the willow flycatcher (*Empidonax traillii*).Master's Thesis. Northern Arizona University, Flagstaff. May 2000. 42 pp.

Paxton E. H. and J. C. Owen. 2002. An aging guide for willow flycatcher nestlings. Colorado Plateau Field Station, Northern Arizona University, Flagstaff, AZ. 18 pp.

Persons, W. R. and R. S. Rogers. 2006. Lees Ferry trout fishery status and trends update January 2006. Presentation to the GCDAMP Technical Work Group. Available at http://www.usbr.gov/uc/rm/amp/twg/mtgs/06jan25/Attach_07b.pdf (accessed 12/07).

Pearson, T. 2002. Polygyny and Extra-Pair Paternity in a Population of Southwestern Willow Flycatchers (E*mpidonax traillii extimus*). M.S. Thesis, Northern Arizona University.

Peterson, J. H., and C. P. Paukert. 2005. Development of a Bioenergetics Model for Humpback Chub and Evaluation of Water Temperature changes in the Grand Canyon, Colorado River. Transactions of the American Fisheries Society 134: 960-974

Peterson, R. V. 2002. Memorandum on conservation measures for the Proposed Action of mechanical removal of non-native fish and experimental flows in the Colorado River below Glen Canyon Dam. Memorandum to Field Supervisor, U.S. Fish and Wildlife Service, Phoenix, AZ. December 6, 2002.

Peterson, R. V. 2003. Memorandum on reinitiation of Section 7 consultation. Memorandum to Field Supervisor, U.S. Fish and Wildlife Service, Phoenix, AZ. March 17, 2003.

Phillips, A. J., J. Marshall, and G. Monson. 1964. The Birds of Arizona. University of Arizona Press. 212 pp.

Pilsbry, H. A. 1948. Land Mollusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II: 521-1113.

Rakowski, C. L., and J. C. Schmidt. 1999. The geomorphic basis of Colorado pikeminnow nursery habitat in the Green River near Ouray, Utah. Report A in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Ralston, B. E. 2005. Riparian vegetation and associated wildlife. Pages 103-122, in Gloss, S. P., J. E. Lovich, and T. S. Melis. (eds), The state of the Colorado River ecosystem in Grand Canyon. U.S. Geological Survey, USGS Circular 1282.

Ralston, B. E., M. V. Loretta, and T. A. Kennedy. 2007. Draft report on comparisons of water quality and biological variables from Colorado River shoreline habitats in Grand Canyon, Arizona, under steady and fluctuating discharges from Glen Canyon Dam. Grand Canyon Monitoring and Research Center, Flagstaff, AZ. 29 pp.

RAM (Risk Assessment and Management) Committee. 1998. Generic nonindigenous aquatic organisms risk analysis review process (for estimating risk associated with the introduction of nonindigenous aquatic organisms and how to manage for that risk). Report to the Aquatic Nuisance Species Task Force. U.S. Government Printing Office, 1998—693-132/62087, Region No. 10, Washington, D.C. Available: www.anstaskforce.gov/gennasrev.htm. (April 2004). (Front cover with date of October 1996, actual year of publication 1998).

Reclamation, U.S. Bureau of. 1995a. Biological assessment of the potential effects of a one-time test of a beach/habitat building flow from Glen Canyon Dam. U.S. Bureau of Reclamation, Salt Lake City.

Reclamation, U.S. Bureau of. 1995b. "Operation of Glen Canyon Dam. In Final Environmental Impact Statement. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Reclamation.

Reclamation, U.S. Bureau of. 1995c. Response letter to final Biological Opinion on Operations of Glen Canyon Dam EIS. U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, UT.

Reclamation, U.S. Bureau of. 1996a. Description and Assessment of Operations, Maintenance, and Sensitive Species of the Lower Colorado River: Final Biological Assessment. In report U.S. Fish and Wildlife Service and Lower Colorado River Multi-Species Conservation Program. Lower Colorado Region. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Reclamation.

Reclamation, U.S. Bureau of. 1996b Record of Decision on the Operation of Glen Canyon Dam. In *Final Environmental Impact Statement*. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Reclamation.

Reclamation, U.S. Bureau of. 2002. Proposed Experimental Releases from Glen Canyon Dam and Removal of Non-Native Fish. Salt Lake City, UT: U.S. Department of the Interior, Bureau of Reclamation, Upper Colorado Region.

Reclamation, U.S. Bureau of. 2004. Supplement to the feasibility design report Glen Canyon Dam temperature control device. U.S. Department of the Interior, Bureau of Reclamation, Salt Lake City, UT. 22 pp + appendices.

Reclamation, U.S. Bureau of. 2005. Supplement to the feasibility design report Glen Canyon Dam temperature control device. U.S. Department of the Interior, Bureau of Reclamation, Denver, CO. 22 pp + appendices.

Reclamation, U.S. Bureau of. 2007a. Colorado River interim guidelines for Lower Basin shortages and coordinated operations for Lake Powell and Lake Mead: Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Reclamation, Boulder City, NV.

Reclamation, U.S. Bureau of. 2007b. Record of Decision on Colorado River interim guidelines for Lower Basin shortages and coordinated operations for Lake Powell and Lake Mead: Final Environmental Impact Statement. U.S. Department of the Interior, Bureau of Reclamation, Boulder City, NV.

Reclamation, National Park Service, and US Geological Survey. 2002. Finding of No Significant Impact (FONSI) for proposed experimental releases from Glen Canyon Dam and removal of non-native fish.

Reclamation, National Park Service, and US Geological Survey. 2003. Finding of No Significant Impact (FONSI) for proposed modification to removal of non-native fish from the Colorado River in Grand Canyon.

Reclamation, National Park Service, and US Geological Survey. 2004. Supplemental environmental assessment for proposed experimental actions for water years 2005-2006, Colorado River, Arizona, in Glen Canyon National Recreation Area and Grand Canyon National Park. 26 pp.

Robinson, A. T. and M. R. Childs. 2001. Juvenile growth of native fishes in the Little Colorado River and in a thermally modified portion of the Colorado River. North American Journal of Fisheries Management 21:809-815.

Robinson, A. T., R. W. Clarkson, and R. E. Forrest. 1998. Dispersal of larval fishes in a regulated river tributary. Transactions of The American Fisheries Society 127:722–786.

Rogers, R. S., D. W. Speas, D. L. Ward, and A. S. Makinster. 2003a. Grand Canyon long-term non-native fish monitoring, 2002 annual report. Cooperative Agreement # 02WRAG0030. Arizona Game and Fish Department, Flagstaff, AZ. [online] http://www.gcmrc.gov/library/reports/biological/fish_studies/AZGame&Fish/2003/Rogers2003a.pdf.

Rogers, R. S., W. R. Persons, and T. McKinney. 2003b. Effects of a 31,000-cfs spike flow and low steady flow on benthic biomass and drift composition in the Lees Ferry tailwater. Cooperative Agreement 1425-98-FC-40-22690 (mod3). Arizona Game and Fish Department, Flagstaff, AZ. [online] http://www.gcmrc.gov/library/reports/foodbase/Rogers2003.pdf

Rubin, D. M., D. J. Topping, J. C. Schmidt, J. Hazel, K. Kaplinski, and T. S. Melis. 2002. Recent Sediment Studies Refute Glen Canyon Dam Hypothesis. EOS, Transactions, American Geophysical Union 83, no. 25: 273, 77-78.

Ruppert, J. B., P. B. Holden, and P. D. Abate. 1999. Age estimation and growth of razorback sucker, *Xyrauchen texanus*, in Lake Mead, Nevada. Proceedings of the Desert Fishes Council 30:40–41.

Ryden, D. W. 2000. Monitoring of experimentally stocked razorback sucker in the San Juan River: March 1994 through October 1997. U.S. Fish and Wildlife Service, Colorado River Fishery Project, Grand Junction, Colorado.

Schmidt, J. C. 1999. Summary and synthesis of geomorphic studies conducted during the 1996 controlled flood in Grand Canyon. P 329-342 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Schmidt, J. C., D. J. Topping, P. E. Grams, and J. E. Hazel. 2004. System wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, AZ. Final Report of the Fluvial Geomorphology Laboratory, Utah State University, Logan. 99 p.

Schmidt, J. C., and D. M. Rubin. 1995. Regulated streamflow, fine-grained deposits, and effective discharge in canyons with abundant debris fans. Pages 177-195 in J. E. Costa, A. J. Miller, K. W. Potter, and P. R. Wilcox (eds.). Natural and anthropogenic influences in fluvial geomorphology. American Geophysical Union Monograph 89.

Schmidt, J. C. and J. B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. U.S. Geological Survey Professional Paper 1493. 74 p.

Schmidt., J. C. and S. A. Goeking. 2003. Stream flow and sediment data collected to determine the effects of low summer steady flows and habitat maintenance flows in 2000 on the Colorado River between Lees Ferry and Bright Angel Creek, AZ. Draft report to the Grand Canyon Monitoring and Research Center, Flagstaff. Department of Aquatic, Watershed and Earth Resources, Utah State University, Logan.

Schrader, P. A. 1991. Endangered and threatened wildlife and plants: the razorback sucker (*Xyrauchen texanus*) determined to be an endangered species. Federal Register 56:54957–54967.

Sedgwick, J. A. and F. L. Knopf. 1992. Describing Willow Flycatcher Habitats: Scale Perspectives and Gender Differences. Condor 94:720-33.

Sferra, S. J., T. E. Corman, C. E. Paradzick, J. W. Rourke, J. A. Spencer, and M .W. Sumner. 1997. Arizona Partners in Flight Southwestern Willow Flycatcher Survey: 1993-1996 Summary Report. In Nongame and Endangered Wildlife Program Technical Report 113. Phoenix, AZ: Arizona Game and Fish Department.

Siegle, R. and D. Ahlers. 2004. Brown-Headed Cowbird Management Techniques Manual. Denver, CO: U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center. 58 pp.

Snyder, D. E., and R. T. Muth. 1990. Descriptions and identification of razorback, flannelmouth, white, Utah, bluehead, and mountain sucker larvae and early juveniles. Colorado Division of Wildlife, Technical Publication No. 38.

Sogge, M. K. "Breeding Season Ecology. 2000. In Status, Ecology, and Conservation of the Southwestern Willow Flycatcher, edited by D. Finch and S. Stoleson. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Sogge, M. K. and R. M. Marshall. 2000. A Survey of Current Breeding Habitats. In Status, Ecology, and Conservation of the Southwestern Willow Flycatcher, edited by D. Finch and S. Stoleson. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Sogge, M. K., R. M. Marshall, S. J. Sferra, and T. J. Tibbitts. 1997a. A Southwestern Willow Flycatcher Natural History Summary and Survey Protocol. In National Park Service Technical Report NPS/NAUCPRS/NRTR-97/12, 37: U.S. Department of the Interior, NPS.

Sogge, M. K., T. J. Tibbitts, C. Van Riper III, and T. May. 1995. Status of the southwestern willow flycatcher along the Colorado River in Grand Canyon National Park - 1995. Summary Report. National Biological Service Colorado Plateau Research Station/Northern Arizona University. 26 pp.

Sogge, M. K., T. J. Tibbitts, and J. R. Petterson. 1997b. Status and Breeding Ecology of the Southwestern Willow Flycatcher in the Grand Canyon. Western Birds 28:142-57.

Sorensen, J. 2007. Kanab Ambersnail *(oxyloma haydeni kanabensis)* Arizona Game and Fish Department. [cited December 17, 2007]. Available from http://www.azgfd.gov/w_c/nongame_kanab_ambersnail.shtml.

Sorensen, J. A. and C. B. Nelson. 2002. Interim Conservation Plan for Oxyloma (haydeni) kanabensis complex and related ambersnails in Arizona and Utah . Nongame and Endangered Wildlife Program Technical Report 192. Arizona Game and Fish Department, Phoenix , Arizona .

Sorensen, J. A. and D. M. Kubly. 1997. Investigations of the Endangered Kanab Ambersnail: Monitoring, Genetic Studies, and Habitat Evaluation in Grand Canyon and Northern Arizona. In Nongame and Endangered Wildlife Program Technical Report 122. Phoenix, AZ: Arizona Game and Fish Department.

Sorensen, J. A. and D. M. Kubly. 1998. Monitoring and Habitat Surveys of the Endangered Kanab Ambersnail in Grand Canyon and Northern Arizona. In Nongame and Endangered Wildlife Program Technical Report 125. Phoenix, AZ: Arizona Game and Fish Department.

Spamer, E. E. and A. E. Bogan. 1993. Mollusca of the Grand Canyon and Vicinity, Arizona: New and Revised Data on Diversity and Distributions with Notes on Pleistocene-Holocene Mollusks of the Grand Canyon. Academy of Natural Sciences of Philadelphia 144: 21-68.

Speas, D. W. 2004. Effects of Low Steady Summer Flows on Rainbow Trout in the Lee's Ferry Tailwater, 2000. Flagstaff, AZ: Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Speas, D. W., W. R. Persons, R. S. Rogers, D. L. Ward, A. S. Makinster, and J. E. Slaughter, IV. 2004. 2001 Fish Investigations in the Lee's Ferry Tailwater. U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Sponholtz, P. J., D. M. Stone and J. David. 2005. Monitoring for Humpback Chub (G*ila cypha*) above Chute Falls, Little Colorado River. In Presentation to the GCAMP Technical Work Group. Phoenix, AZ.

Sponholtz, P. J. and D. R. VanHaverbeke. 2007. Bright Angel Creek Trout Reduction Project. In Summary report on fall 2006 weir and electrofishing efforts. U.S. Department of the Interior, National Park Service, Grand Canyon, AZ.

Stevens, L. 1983. The Colorado River in Grand Canyon. A Guide. 5th ed. Flagstaff, AZ: Red Lake Books.

Stevens, L. E. 1996. Flood-induced backwater rejuvenation, along the Colorado River in Grand Canyon, Arizona. 1996 draft final report. Submitted to: Terry May, Sponsored Projects Office, Northern Arizona University, Flagstaff, AZ.

Stevens, L. E., F. R. Protiva, D. M. Kubly, V. J. Meretsky and J. Petterson. 1997a. The Ecology of Kanab Ambersnail (*succineidae: oxyloma haydeni kanabensis pilsbry*, 1948) at Vaseys Paradise, Grand Canyon, Arizona: 1995 Final Report. edited by Glen Canyon Environmental Studies Program Report. Flagstaff, AZ: U.S. Department of the Interior, Bureau of Reclamation, Glen Canyon Environmental Studies Program Report.

Stevens, L. E., J. P. Shannon and D. W. Blinn. 1997b. Colorado River Benthic Ecology in Grand Canyon Arizona: USA; Dam, Tributary and Geomorphic Influences. Regulated Rivers 13:129-49.

Stevens, L. E., and T. L. Hoffnagle. 1999. Spatio-Temporal Changes in Colorado River Backwaters Downstream from Glen Canyon Dam, Arizona, 1965-1997. Report to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Stoleson, S. H. and D. M. Finch. 2003. Microhabitat Use by Breeding Southwestern Willow Flycatchers on the Gila River, New Mexico. Studies in Avian Biology 26:91-95.

Stone, D. M. 1999. Ecology of Humpback Chub (Gila cypha) in the Little Colorado River, near Grand Canyon, Arizona. M. S. Thesis. Northern Arizona University, Flagstaff, AZ.

Stone, D. M. 2006. Monitoring of Humpback Chub (*gila cypha*) and Other Fishes above Lower Atomizer Falls of the Little Colorado River, Arizona. U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Stone, D. 2007. Fall monitoring of humpback chub Gila cypha and other fishes in the lower 13.57 km of the Little Colorado River, Arizona. Trip Report submitted to Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Stone, D. M., and O. T. Gorman. 2006. Ontogenesis of Endangered Humpback Chub (Gila cypha) in the Little Colorado River. American Midland Naturalist 155 (1):123-135.

Stone, D., and P. Sponholtz. 2003. Translocation of young-of-year humpback chub above Chute Falls in the Little Colorado River, AZ: 2003 Interim Report. Prepared for Grand Canyon Monitoring and Research Center, Flagstaff, AZ. U.S. Fish and Wildlife Service, Arizona Fishery Resources Office-Flagstaff. AZFRO Document # USFWS-AZFRO-FL-04-006. 20 pp.

Stone, D., and P. Sponholtz. 2004. Translocation of young-of-year humpback chub above Chute Falls in the Little Colorado River, AZ: 2004 Interim Report. Prepared for Grand Canyon Monitoring and Research Center, Flagstaff, AZ. U.S. Fish and Wildlife Service, Arizona Fishery Resources Office-Flagstaff. AZFRO Document # USFWS-AZFRO-FL-05-002. 23 pp.

Stone, D. M., D. R. VanHaverbeke, D. L. Ward, and T. A. Hunt. 2007. Dispersal of non-native fishes and parasites in the intermittent Little Colorado River, Arizona. Southwestern Naturalist 52(1):130-137.

Suttkus, R. D., G. H. Clemmer, C. Jones, and C. Shoop. 1976. Survey of the fishes, mammals and herpetofauna of the Colorado River in Grand Canyon. Colorado River Research Series Contribution 34. Grand Canyon National Park, Grand Canyon, Arizona.

SWCA, Inc. Environmental Consultants. 1999. Strategies for developing the Little Colorado River management plan. SWCA, Inc. Environmental Consultants, Flagstaff, Arizona.

SWCA, Inc. Environmental Consultants. 2005. Little Colorado River management plan. SWCA, Inc. Environmental Consultants, Flagstaff, Arizona.

SWCA, Inc. and Grand Canyon Wildlands Council (GCWC). 2007. A proposal to translocate humpback chub into Shinumo Creek, Grand Canyon. Draft Report to National Park Service, Grand Canyon, Arizona.

Szabo, B. J. 1990. Age of Travertine Deposits in Eastern Grand Canyon National Park, Arizona. *Quaternary Research* 34:24-32.

Tibbitts, T. J. and M. J. Johnson. 1999. Southwestern willow flycatcher inventory and monitoring along the Colorado River in Grand Canyon National Park. 1998 Summary Report. USGS Biological Resources Division, Colorado Plateau Field Station, Northern Arizona University, Flagstaff. 17 pp.

Tibbitts, T. J. and M. J. Johnson. 2000. Southwestern willow flycatcher inventory and monitoring along the Colorado River in Grand Canyon National Park. 1999 Summary Report. USGS Biological Resources Division, Colorado Plateau Field Station, Northern Arizona University, Flagstaff. 19 pp.

Toney, D. P. 1974. Observations on the propagation and rearing of two endangered fish species in a hatchery environment. Proceedings of the Annual Conference of the Western Association of State Game and Fish Commissions 54:252–259.

Topping, D. J., D. M. Rubin, J. C. Schmidt, J. E. Hazel, Jr., T. S. Melis, S. A. Wright, M. Kaplinski, A. E. Draut, and M. J. Breedlove. Comparison of Sediment-Transport and Bar-Response Results from the 1996 and 2004 Controlled-Flood Experiments on the Colorado River in Grand Canyon. Paper presented at the CD-ROM Proceedings of the 8th Federal Inter-Agency Sedimentation Conference, Reno, NV, April 2-6 2006.

Topping, D. J., D. M. Rubin, J. M. Nelson, P. J. Kinzel, III, and I. C. Corson. 2000b. Colorado River Sediment Transport 2. Systematic Bed-Elevation and Grain-Size Effects of Sand Supply Limitation. Water Resources Research 36:543-70.

Topping, D. J., D. M. Rubin, and L. E. Vierra, Jr. 2000a. Colorado River Sediment Transport 1. Natural Sediment Supply Limitation and the Influence of Glen Canyon Dam. Water Resources Research 36:515-42.

Trammell, M. A., D. W. Speas, and S. Meismer. 2004. Non-native cyprinid removal in the lower Green and Colorado rivers, Utah. Final report to the Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Trammell, M. A. and T. E. Chart. 1999.Colorado pikeminnow young-of-year habitat use, Green River, Utah, 1992-1996. Report C in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Trammell, M. A., R. A. Valdez, S. W. Carothers, and R. J. Ryel. 2002. Effects of a Low Steady Summer Flow Experiment in the Grand Canyon, Arizona. In Final report SWCA Consultants Inc. U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Topping, D. J., and T. S. Melis. 2007. Summary of water year 2007 sand supply below Glen Canyon Dam. Presentation to the GCDAMP Technical Working Group, October 2007.

Topping, D. J., T. S. Melis, D. M. Rubin, and S. A. Wright. 2004. High-Resolution Monitoring of Suspended-Sediment Concentration and Grain Size in the Colorado River in Grand Canyon Using a Laser-Acoustic System. In Proceedings of the Ninth International Symposium on River Sedimentation, edited by C. Hu, and Tan, Y, 2507-14. Yichang, China: People’s Republic of China, Tsinghua University Press.

Trammell, M. and R. Valdez. 2003. Native fish monitoring activities in the Colorado River within Grand Canyon during 2001. SWCA Environmental Consultants, Flagstaff, Arizona.

Trammell, M. A., R. A. Valdez, S. W. Carothers, and R. J. Ryel. 2002. Effects of a Low Steady Summer Flow Experiment in the Grand Canyon, Arizona. In Final report SWCA Consultants Inc. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Trammell, M. A. and T. E. Chart. 1999.Colorado pikeminnow young-of-year habitat use, Green River, Utah, 1992-1996. Report C in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City.

Turner, R. M. and M. M. Karpiscak. 1980. Recent Vegetation Changes Along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. In professional paper 1132. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey.

Tyus, H. M. 1998. Early records of the endangered fish *Gila cypha* Miller from the Yampa River of the Colorado with notes on its decline. Copeia 1998:190–193.

Tyus, H. M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979-1986. Transactions of the American Fisheries Society 116:111–116.

Tyus, H. M., and C. A. Karp. 1989. Habitat use and streamflow needs of rare and endangered fishes, Yampa River, Colorado and Utah. U.S. Fish and Wildlife Service Biological Report 89:1–27.

Tyus, H. M., and C. A. Karp. 1990. Spawning and movements of razorback sucker, *Xyrauchen texanus*, in the Green River Basin of Colorado and Utah. Southwestern Naturalist 35:427–433.

Unitt, P. "E*mpidonax traillii extimus*: An Endangered Subspecies." *Western Birds* 18, no. 3 (1987): 137-62.

U.S. Department of the Interior. 2002. Proposed experimental releases from Glen Canyon Dam and removal of non-native fish. Environmental Assessment. Prepared by Bureau of Reclamation, National Park Service, and US Geological Survey. Salt Lake City, UT. September 2002.

U.S. Department of the Interior. 2007. Record of Decision on Colorado River interim guidelines for Lower Basin shortages and the coordinated operations for Lake Powell and Lake Mead. U.S. Department of Interior, Bureau of Reclamation, Boulder City, NV. 59 pp.

USEPA (U.S. Environmental Protection Agency). 2000. Ecological Risk Assessment: Federal Guidelines. U.S. Environmental Protection Agency. Government Institutes, Washington, D.C.

USEPA (U.S. Environmental Protection Agency). 2005. Environmental Protection Agency Risk Assessment Values (RAVs) or Standards. Washington, D.C. http://www.scorecard.org/chemical-profiles/def/rav_us.html.

USEPA (U.S. Environmental Protection Agency). 2006. Integrated Risk Assessment (IRIS). Office of Research and Development, National Center for Environmental Assessment, U.S. Environmental Protection Agency. Washington, D.C. http://www.epa.gov/iris/intro.htm.

USFWS, U.S. Fish and Wildlife Service. 1990a. Humpback chub recovery plan, 2nd revision. Report of Colorado River Fishes Recovery Team to U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.

USFWS, U.S. Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants, final rule to list the Kanab ambersnail as endangered. Federal Register 57 (75): 13657-13661.

USFWS, U.S. Fish and Wildlife Service. 1995. Kanab ambersnail (*Oxyloma haydeni kanabensis*) recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 21 pp.

USFWS, U.S. Fish and Wildlife Service. 1998. Razorback sucker recovery plan. U.S. Fish and Wildlife Service, Region 6, Denver, Colorado.

USFWS, U.S. Fish and Wildlife Service. 2002a. Humpback chub (*Gila cypha*) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

USFWS, U.S. Fish and Wildlife Service. 2002b. Razorback sucker (*Xyrauchen texanus*) Recovery Goals: amendment and supplement to the Razorback Sucker Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

USFWS, U.S. Fish and Wildlife Service. 2002c. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico. i-ix + 210 pp., Appendices A-O.

USFWS, U.S. Fish and Wildlife Service. 2002d. Biological Opinion of Section 7 consultation of proposed experimental releases from Glen Canyon Dam and removal of non-native fish. Memorandum (Consultation # 02-21-03-F-016) to Regional Director, Bureau of Reclamation, Salt Lake City, UT; Superintendent, Grand Canyon National Park, Grand Canyon, AZ; Superintendent, Glen Canyon National Recreation Area, Page, AZ; Chief, Grand Canyon Monitoring and Research Center, USGS, Flagstaff, AZ. December 6, 2002.

USFWS, U.S. Fish and Wildlife Service. 2003a. Biological Opinion of Reinitiation of Section 7 consultation on proposed experimental releases from Glen Canyon Dam and removal of non-native fish. Memorandum (Consultation # 02-21-03-F-0016) to Regional Director, Bureau of Reclamation, Salt Lake City, UT; Superintendent, Grand Canyon National Park, Grand Canyon, AZ; Superintendent, Glen Canyon National Recreation Area, Page, AZ; Chief, Grand Canyon Monitoring and Research Center, USGS, Flagstaff, AZ. July 12, 2003.

USFWS, U.S. Fish and Wildlife Service. 2003b. Biological Opinion of Reinitiation of Section 7 consultation on proposed experimental releases from Glen Canyon Dam and removal of non-native fish. Memorandum (Consultation # 02-21-03-F-0016-R1) to Regional Director, Bureau of Reclamation, Salt Lake City, UT; Superintendent, Grand Canyon National Park, Grand Canyon, AZ; Superintendent, Glen Canyon National Recreation Area, Page, AZ; Chief, Grand Canyon Monitoring and Research Center, USGS, Flagstaff, AZ. August 12, 2003.

USFWS, U.S. Fish and Wildlife Service. 2005a. Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Southwestern Willow Flycatcher (e*mpidonax traillii extimus*); Final Rule. 50 cfr Part 17. In *Federal Register 70:60886-61009*: U.S. Department of the Interior, U.S. Fish and Wildlife Service.

USFWS, U.S. Fish and Wildlife Service. 2005b. Biological and Conference Opinion on the Lower Colorado River Multi-Species Conservation Program, Arizona, California, and Nevada. U.S. Fish and Wildlife Service, Phoenix, AZ. 214 pp.

USGS, United States Geological Survey. 2004. Climatic fluctuations, drought, and flow in the Colorado River Basin. United States Geological Survey fact sheet 2004-3062. 8 pp.

USGS, United States Geological Survey. 2006a. Grand Canyon humpback chub population stabilizing. United States Geological Survey fact sheet 2006-3109.

USGS, United States Geological Survey. 2006b. Status of Sand Supplies in the Colorado River Below GCD. Presentation to the GCDAMP Technical Work Group, November 2006. available at http://www.usbr.gov/uc/rm/amp/twg/mtgs/06nov08/Attach_14.pdf (accessed 12/07).

USGS, United States Geological Survey. 2006c. Assessment of the estimated effects of four experimental options on resources below Glen Canyon Dam. United States Geological Survey, Grand Canyon Research and Monitoring Center, Flagstaff, AZ. 210 pp.

USGS, United States Geological Survey. 2007. Grand Canyon humpback chub population improving. Fact Sheet 2007-3113. U.S. Geological Survey, Flagstaff, Arizona.

Valdez, R. A. 1990. The endangered fish of Cataract Canyon. Final Report of Bio/West, Inc., Logan, Utah, to U.S. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R. A. 1994. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase I, final report to Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R. A. 1996. Synopsis of the razorback sucker in Grand Canyon. Paper presented at the Razorback Sucker Workshop, January 11–12, 1996, Laughlin, Nevada. Sponsored by U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Flagstaff, Arizona.

Valdez, R. A. 1999. Possible responses by the fishes of the Colorado River in Grand Canyon to warmed releases from a multi-level intake structure on Glen Canyon Dam.

Valdez, R. A., B. R. Cowdell, and E. Pratts. 1995. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase II, final report to Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R. A., and B. R. Cowdell. 1996. Effect of Glen Canyon Dam beach/habitat-building flows on fish assemblages in Glen and Grand Canyons, Arizona. Project completion report submitted to Arizona Game and Fish Dept. and Glen Canyon Environmental Studies from Bio/West, Inc., Logan, UT.

Valdez, R. A., and D. W. Speas. 2007. A risk assessment model to evaluate risks and benefits to aquatic resources from a selective withdrawal structure on Glen Canyon Dam. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A., and E.J. Wick. 1983. Natural vs. manmade backwaters as native fish habitat. Pages 519–536 *in* V.D. Adams and V.A. Lamarra (eds.). Aquatic resources management of the Colorado River ecosystem. Ann Arbor Science, Ann Arbor, Michigan.

Valdez, R. A., and G. C. Clemmer. 1982. Life history and prospects for recovery of the humpback chub and bonytail chub. Pages 109–119 *in* W.H. Miller, H.M. Tyus, and C.A. Carlson (eds.). Fishes of the upper Colorado River system: present and future. Western Division, American Fisheries Society, Bethesda, Maryland.

Valdez, R. A., P. B. Holden, and T. B. Hardy. 1990. Habitat suitability index curves for humpback chub of the upper Colorado River Basin. Rivers 1(1):31-42.

Valdez, R. A., P. Mangan, R. Smith, B. Nilson. 1982. Upper Colorado River investigations (Rifle, Colorado to Lake Powell, Utah). Pages 100–279 *in* U.S. Fish and Wildlife Service. Colorado River Fishery Project, Final Report, Part 2: Field Investigations. U.S. Fish and Wildlife Service, Salt Lake City, Utah.

Valdez, R. A., and R. J. Ryel. 1995. Life history and ecology of the humpback chub (*gila cypha*), in the Colorado River, Grand Canyon, Arizona: final report. [online] http://www.gcmrc.gov/library/reports/biological/Fish_studies/gces/valdez1995f.pdf.

Valdez, R. A., and R. J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. Pages 3–31 *in* C. van Riper, III and E.T. Deshler (eds.). Proceedings of the Third Biennial Conference of Research on the Colorado Plateau. National Park Service Transactions and Proceedings Series 97/12.

Valdez, R. A. and S. W. Carothers. 1998. The aquatic ecosystem of the Colorado River in Grand Canyon. Final report to the Bureau of Reclamation, Salt Lake City

Valdez, R. A., S. W. Carothers, M. E. Douglas, M. Douglas, R .J. Ryel, K. R. Bestgen, and D. L. Wegner. 2000b. Research and Implementation Plan for Establishing a Second Population of Humpback Chub in Grand Canyon. In final report. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center.

Valdez, R. A., S. W. Carothers, D. A. House, M. E. Douglas, M. Douglas, R. J. Ryel, K. R. Bestgen, and D. L. Wegner. 2000a. A program of Experimental Flows for Endangered and Native Fishes of the Colorado River in Grand Canyon. Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, AZ.

Valdez, R. A., and T. L. Hoffnagle. 1999. Movement, habitat use, and diet of adult humpback chub. Pages 297–307 *in* R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez (eds.). The controlled flood in Grand Canyon. Geophysical Monograph 110. American Geophysical Union, San Francisco, California.

Valdez, R. A., T. L. Hoffnagle, C. C. McIvor, T. McKinney, and W. L. Leibfried. 2001. Effects of a Test Flood on Fishes of the Colorado River in Grand Canyon, Arizona. Ecological Applications 11(3):686-700.

Valdez, R. A., and T. L. Hoffnagle. 1999. Movement, Habitat Use, and Diet of Adult Humpback Chub. In The Controlled Flood in the Grand Canyon; Geophysical Monograph 110, American Geophysical Union.

Valdez, R. A., T. L. Hoffnagle, C. D. McIvor, T. McKinney, and W. C. Leibfried. 2001. Effects of a test flood on fishes of the Colorado River in Grand Canyon, Arizona. Ecological Applications 11:686–700.

Valdez, R. A., and W. J. Masslich. 1999. Evidence of reproduction by humpback chub in a warm spring of the Colorado River in Grand Canyon, Arizona. Southwestern Naturalist 44(3):384-387.

Van Haverbeke, D. 2003. Stock Assessment and Fisheries Monitoring Activities in the Little Colorado River within Grand Canyon During 2001. Final Report, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Van Haverbeke, D. R. 2003. Stock Assessment and Fisheries Monitoring Activities in the Little Colorado River within Grand Canyon During 2002. Final Report, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Van Haverbeke, D. R. 2004. Stock Assessment and Fisheries Monitoring Activities in the Little Colorado River within Grand Canyon During 2003. Final Report, Grand Canyon Monitoring and Research Center, Flagstaff, AZ.

Van Haverbeke, D. R., R. S. Rogers, M. V. Lauretta, and K. Christensen. 2007. 2005 Grand Canyon Long-Term Fish Monitoring Colorado River, Diamond Creek to Lake Mead.

2005 Annual Report to Grand Canyon Monitoring and Research Center from U.S. Fish and Wildlife Service, Hualapai Tribe, and SWCA Environmental Consultants, Flagstaff, AZ.

Vermeyen, T. C., DeMoyer, W. Delzer, and D. Kubly. 2003. A survey of selective withdrawal systems. Denver Technical Service Center Water Resource Services, Bureau of Reclamation, Denver, CO. 15 p. + 2 appendices.

Vernieu, W. 2003. Warming of the Colorado River under low steady flows. Abstract. Grand Canyon Monitoring and Research Center Science Symposium, Tucson, AZ. October 29, 2003.

Vernieu, W. S., S. J. Hueftle, and S. P. Gloss. 2005. Water Quality in Lake Powell and the Colorado River. pages 68-85 in The State of the Colorado River Ecosystem in Grand Canyon, Circular 1282, edited by J. E. Lovich S. P. Gloss, and T. S. Melis, Department of the Interior, U.S. Geological Survey. Reston, VA: U.S.

Walters, C., and J. Korman. 1999. Cross-Scale Modeling of Riparian Ecosystem Responses to Hydrologic Management. Ecosystems 5(2):411-421.

Walters, C., J. Korman, L. E. Stevens, and B. Gold. 2000. Ecosystem modeling for evaluation of adaptive management policies in the Grand Canyon. Conservation Ecology 4(2):1. [online] http://www.consecol.org/vol4/iss2/art1.

Ward, D. L 2001. Effects of reduced water temperature on swimming performance and predation vulnerability of age-0 flannelmouth sucker (*Catostomus latipinnis*). Thesis (M.S.), University of Arizona.

Ward, D. L, A. A. Schultz, and P. G. Matson. 2003. Differences in swimming ability and behavior in response to high water velocities among native and non-native fishes. Journal Environmental Biology of Fishes 68(1):1573-5133.

Ward. D. L., O. E. Maughan, S. A. Bonar, and W. J. Matter. 2002. Effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker. Transaction of the American Fisheries Society 131:492-497.

Ward, D.L, and S.A. Bonar. 2003. Effects of cold water on susceptibility of age-O flannelmouth sucker to predation by rainbow trout. The Southwestern Naturalist 48(1):43-46.

Webb, R. H. G. J. McAbe, R. Hereford, and C. Wilkowske. 2004. Climatic fluctuations, drought, and flow in the Colorado River Basin. U.S. Geological Survey Fact Sheet 2004-3062.4 pp.

Webb, R. H., J. C. Schmidt, G. R. Marzolf, and R. A. Valdez. 1999. The controlled flood in Grand Canyon. American Geophysical Union monograph 110. 367 p.

Webb, R. H., J. C. Schmidt, G. R. Marzolf, and R. A. Valdez (editors). 2000. The controlled flood in Grand Canyon. Geophysical monograph 110, American Geophysical Union, Washington, D.C.

Webb, M. A. and R. A. Fridell. 2000. Kanab Ambersnail Distribution Surveys in the East Fork of the Virgin River, Upper Parunuweap Canyon, Utah. In Publication No. 00-29. Salt Lake City, UT: Utah Division of Wildlife Resources.

Webb, R. H., J.C. Schmidt, G. R. Marzolf, and R. A. Valdez (editors). 2000. The controlled flood in Grand Canyon. Geophysical monograph 110, American Geophysical Union, Washington, D.C

Webb, R. H., P. G. Griffiths. 2001. Sediment Delivery by Ungaged Tributaries of the Colorado River in Grand Canyon, Arizona. U.S. Geological Survey Fact Sheet 018-01. 6 pp.

Webb, R. H., P. G. Griffiths, C. S. Magirl, and T. C. Hanks. 2005. Debris flows in Grand Canyon and the rapids of the Colorado River. Pages 139-152 in Gloss, S.P., J.E. Lovich, and T.S. Melis (editors). The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Webb, R. H., P. G. Griffiths, T. S. Melis, and D. R. Hartley. 2000. Sediment Delivery by Ungaged Tributaries of the Colorado River in Grand Canyon, Arizona. In Water Resources investigation report # 00-4055. Grand Canyon, AZ: U.S. Department of the Interior, U.S. Geological Survey. 67 pp.

Webb, R. H., P. T. Pringle, and G. R. Rink. 1989. Debris flows from tributaries of the Colorado River, Grand Canyon National Park, AZ. U.S. Geological Survey Professional Paper 1492. 39 p.

Webb, R. H., R. Hereford, and G. J. McCabe. 2005. Climatic fluctuations, drought, and flow in the Colorado River Basin. *In* S.P. Gloss, J.E. Lovich, and T.S. Melis, editors. The State of the Colorado River Ecosystem in Grand Canyon. US Geological Survey Circular 1282, pp. 59-69.

Wegner, D. 1996. Proceedings of Razorback Sucker Workshop, January 11–12, 1996, Laughlin, Nevada. Sponsored by U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Flagstaff, Arizona.

Weiss, S. J. 1993. Spawning, Movement and Population Structure of Flannelmouth Sucker in the Paria River. M.S. Thesis, Department of Biology, University of Arizona, Tucson, AZ.

Welker, T. L, and P. B. Holden. 2004. Razorback sucker studies on Lake Meade, Nevada and Arizona. 2003-2004 annual report. BIO/WEST report PR-578-8. Submitted to Department of Resources, Southern Nevada Water Authority, Las Vegas, NV.

Wick, E. J. 1997. Physical processes and habitat critical to the endangered razorback sucker on the Green River, Utah. Doctoral Dissertation. Colorado State University, Fort Collins.

Wiele, S. M. 1997. Modeling of flood-deposited sand distribution for a reach of the Colorado River below the Little Colorado River, Grand Canyon, AZ. U.S. Geological Survey Water Resources Investigation Report 97-4168.

Wiele, S. M., E. D. Andrews, and E. R. Griffin. 1999. The Effect of Sand Concentration on Depositional Rate, Magnitude, and Location in the Colorado River Below the Little Colorado River. pages 131-145 In The Controlled Flood in Grand Canyon, edited by J.C. Schmidt R.H. Webb, G.R. Marzolf, and R.A. Valdez. Geophysical Monograph 110.

Wiele, S. M., J. B. Graf, and J. D. Smith. 1996. Sand Deposition in the Colorado River in the Grand Canyon from Flooding of the Little Colorado River. Water Resources Research 32:3579-96.

Wiele, S. M., and M. Torizzo. 2005. Modeling of Sand Deposition in Archaeologically Significant Reaches of the Colorado River in Grand Canyon, USA. pages 357-94 In Computational Fluid Dynamics: Applications in Environmental Hydraulics, edited by S.N. Lane P.D. Bates, and R.I. Ferguson.

Woudhouse, C. A., S. T. Gray, and D. M. Meko. 2006. Updated streamflow reconstructions for the Upper Colorado River Basin. Water Resources Research 42:W05415.

Wright, S. A., T. S. Melis, D. J. Topping, and D. M. Rubin. 2005. Influence of Glen Canyon Dam Operations on Downstream Sand Resources of the Colorado River in Grand Canyon, Circular 1282. In The State of the Colorado River Ecosystem in Grand Canyon, edited by S.P. Gloss, Lovich, J.E., and Melis, T.S., pp. 17-31. Flagstaff, AZ: U.S. Department of the Interior, U.S. Geological Survey.

Wydoski, R. S., and E. J. Wick. 1998. Ecological value of floodplain habitats to razorback suckers in the Colorado River Basin. Final Report of U.S. Fish and Wildlife Service and National Park Service to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

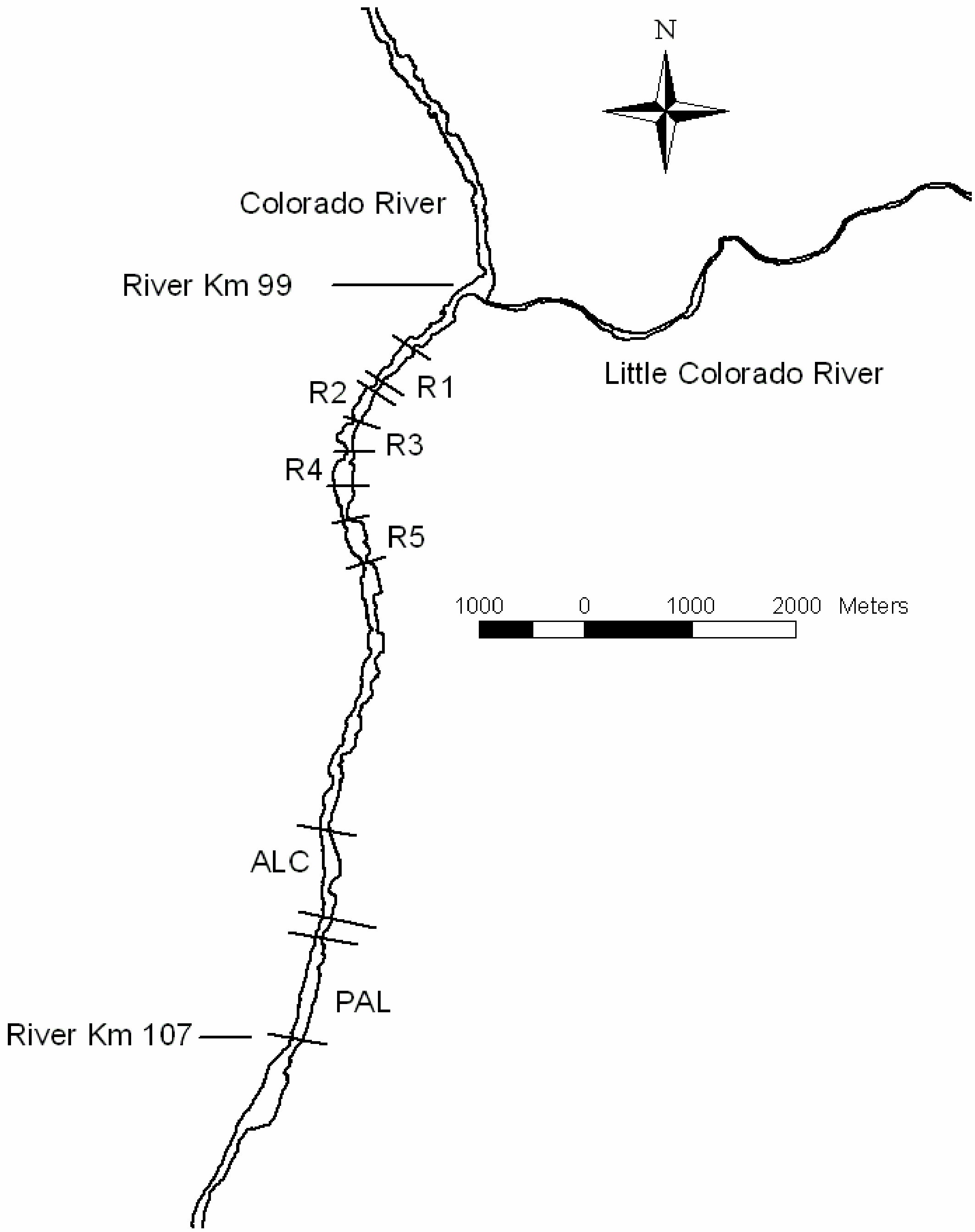
Yong, W. and D. M. Finch. 1997. Migration of the Willow Flycatcher Along the Middle Rio Grande. *Wilson Bulletin* 109:253-68.

Yu, Shyi-Liang and E. J. Peters. 2002. Diel and seasonal habitat use by red shiner (Cyprinella lutrensis). Zoological Studies 41(3):229-235.

Zimmerman, B., and W. Leibfried. 1999. Preliminary results of radio-telemetry of razorback suckers in the Colorado River, Western Grand Canyon. Page 74 in Hendrickson, D.A., and G.P. Garrett (editors). Proceedings of the Desert Fishes Council, Volume 29, 1997 Annual Symposium, Death Valley, California.

8 Appendix A

Figure A1. Transects used in 2-D hydrodynamic model (Korman et al. 2004).



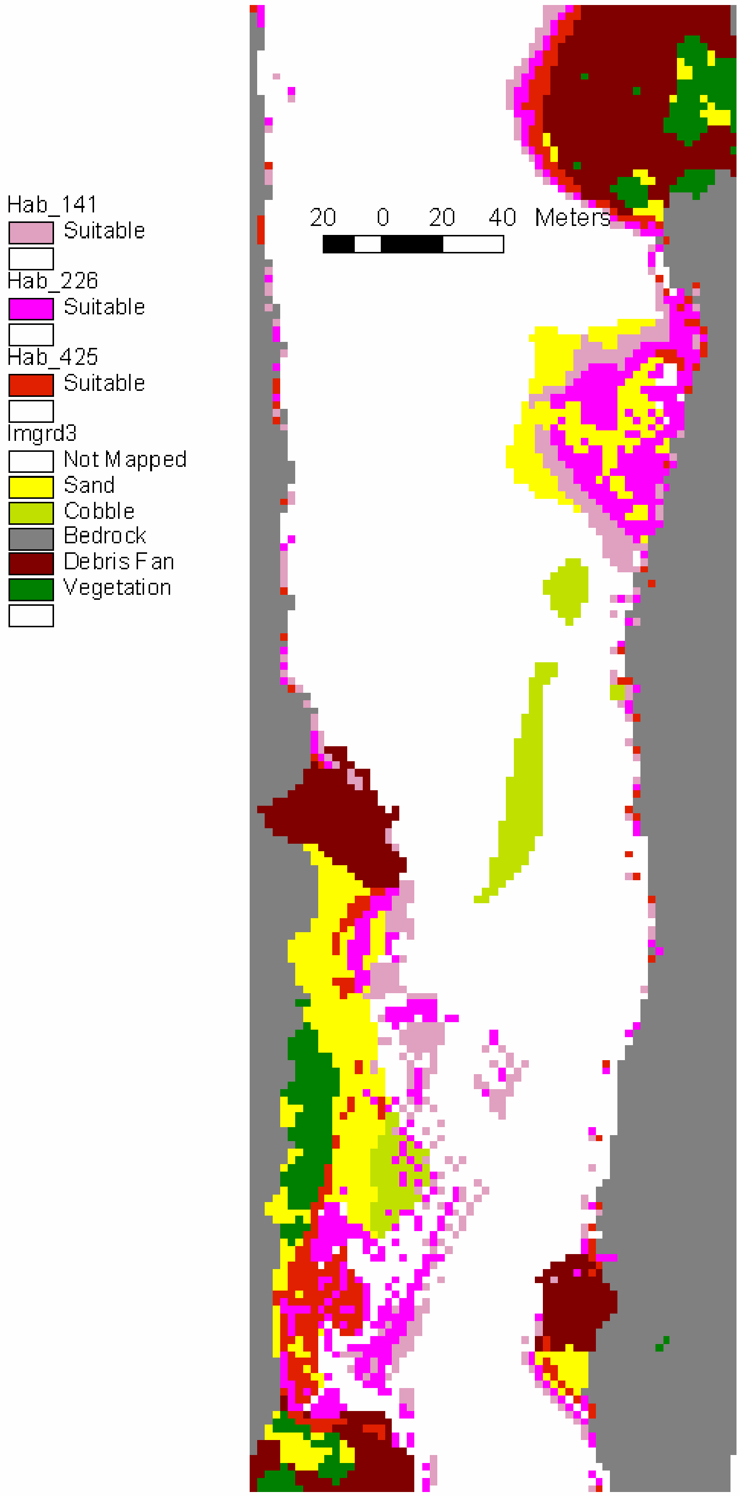


Figure A2. Transect R-1 from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

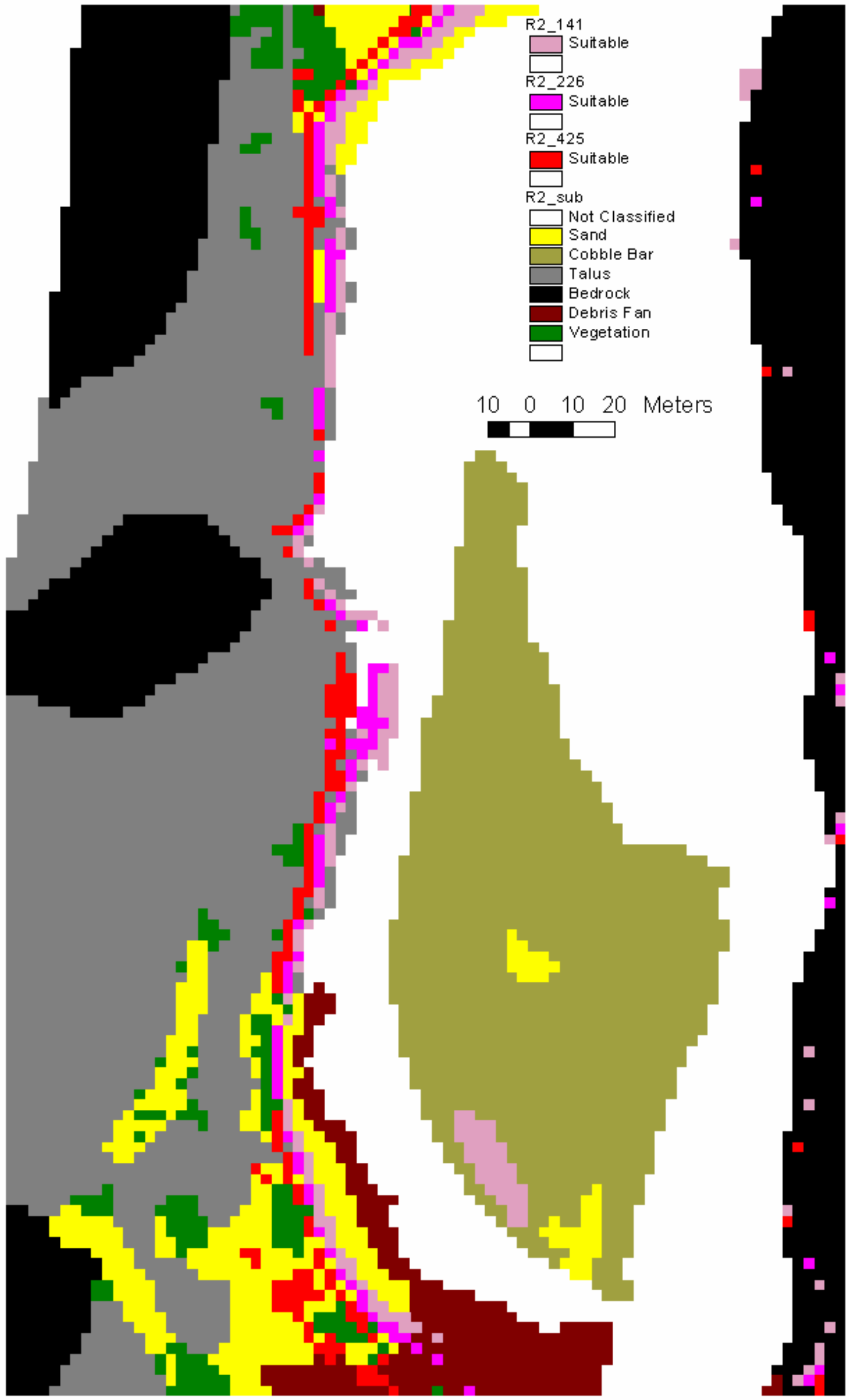


Figure A3. Transect R-2 from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

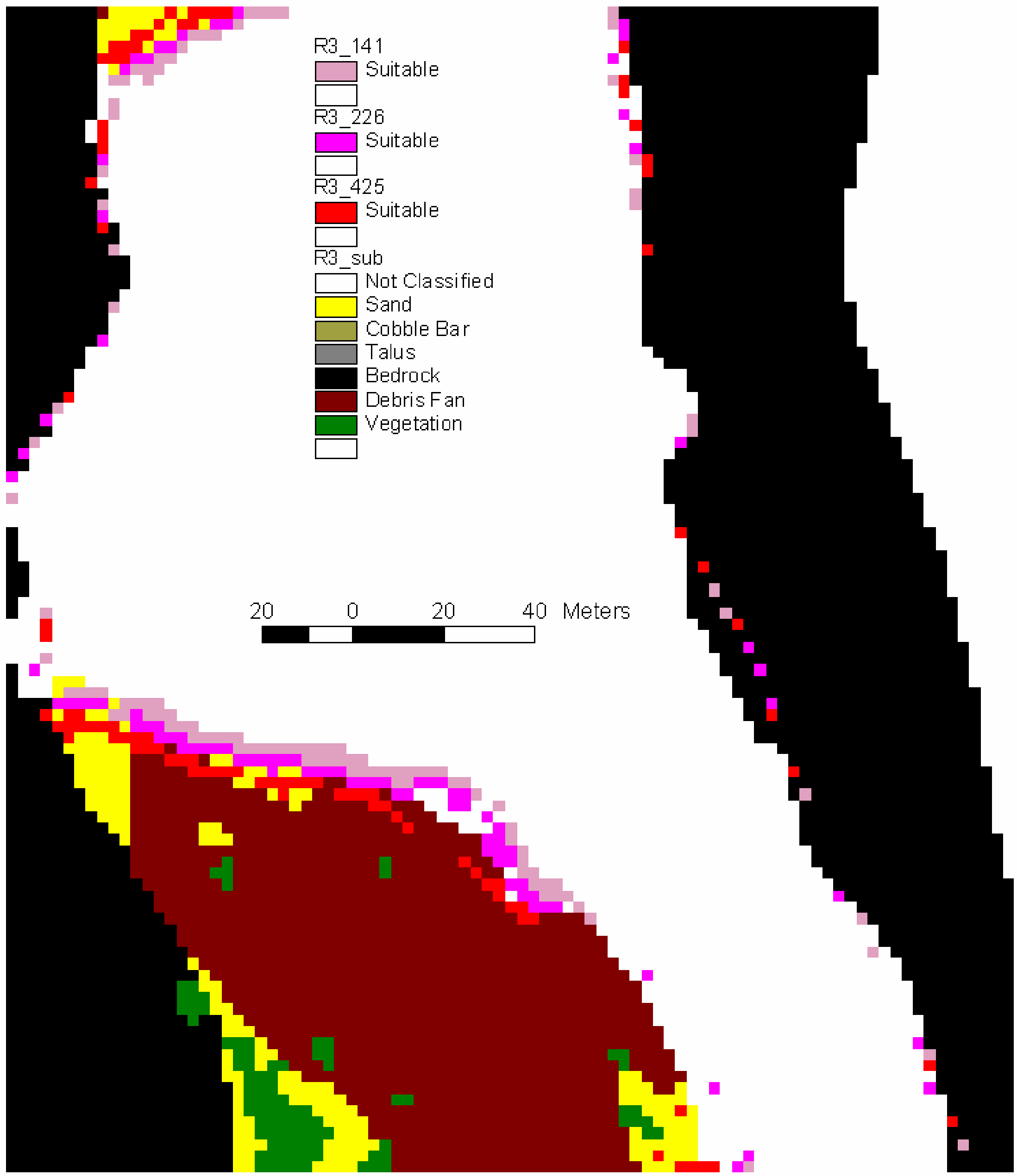


Figure A4. Transect R-3 from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

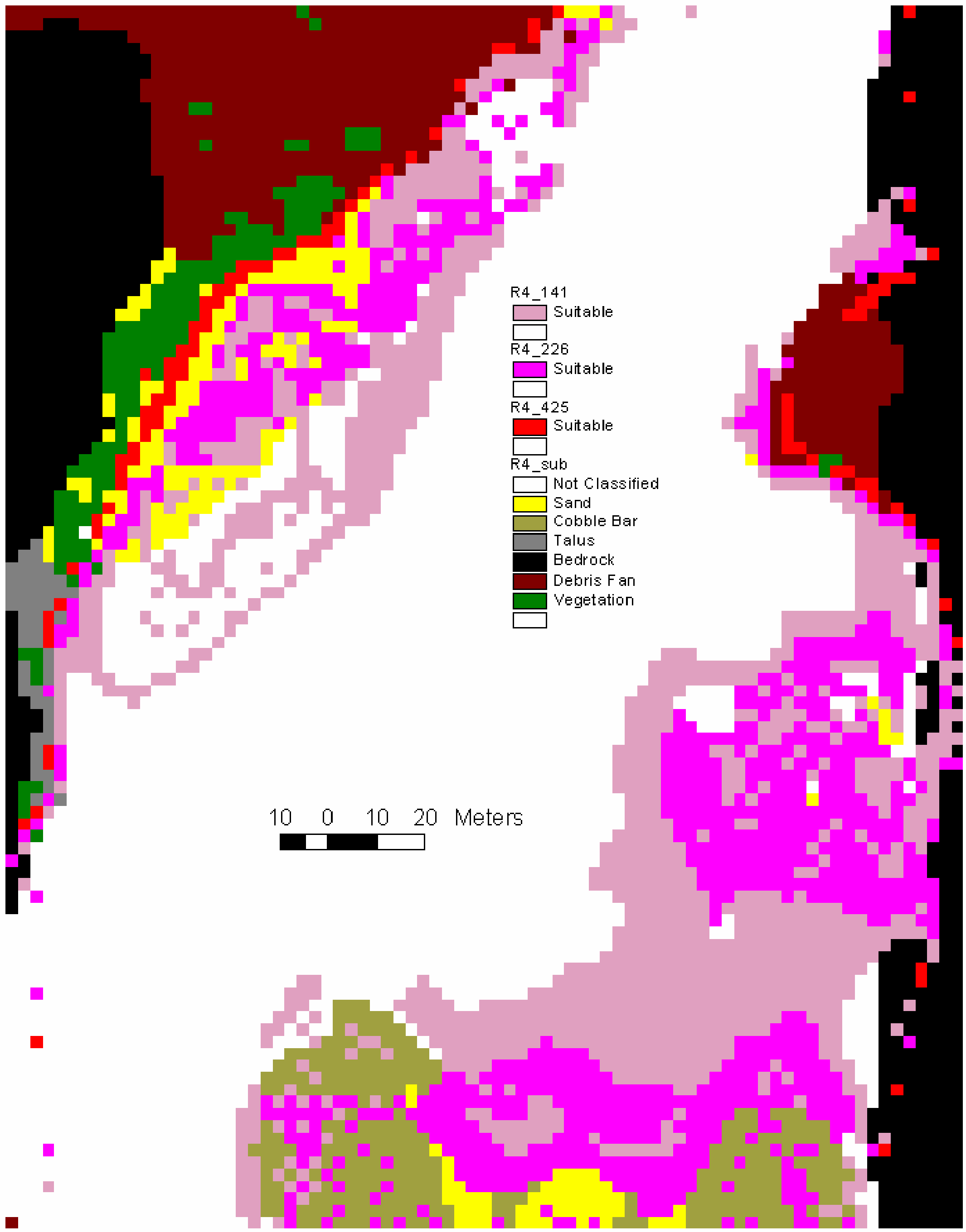


Figure A5. Transect R-4 from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

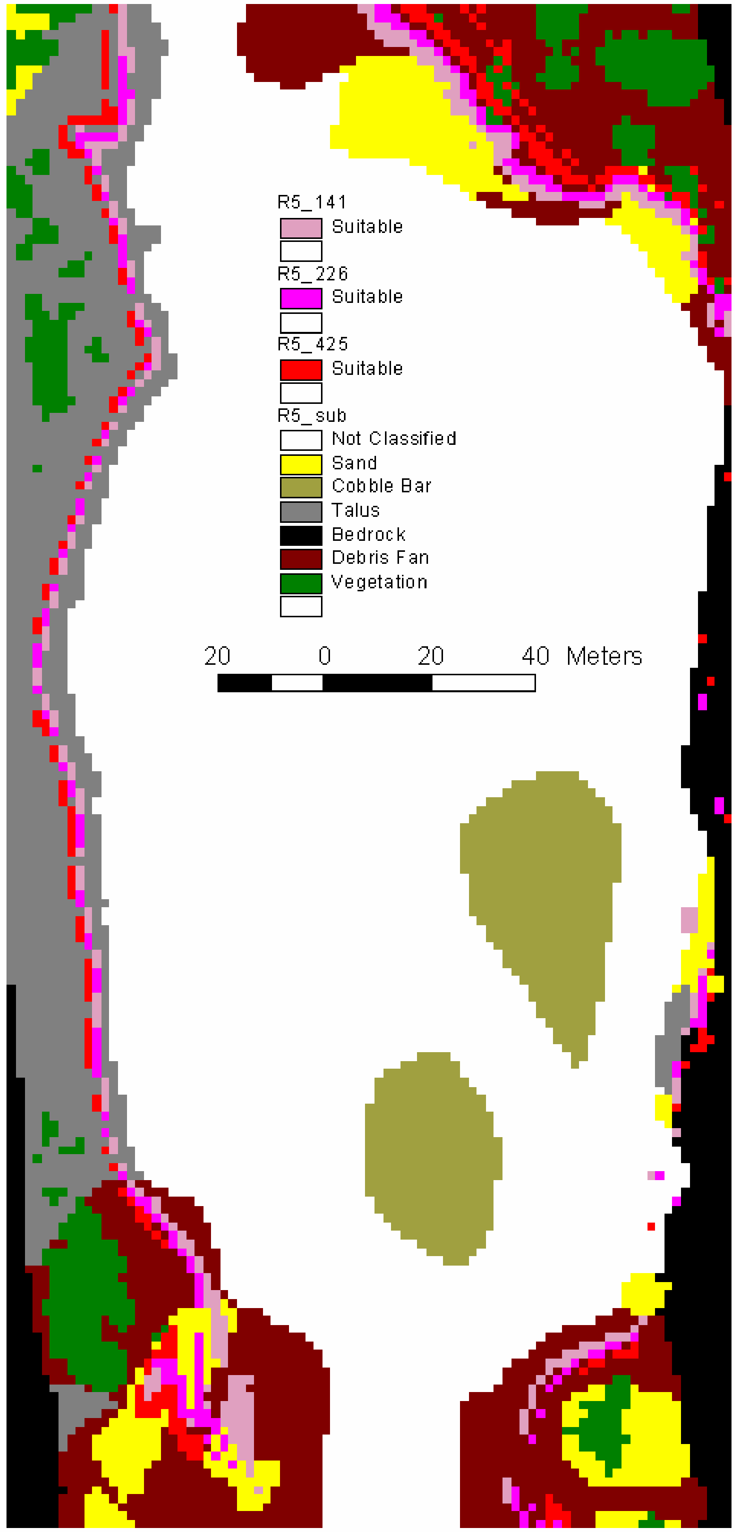


Figure A6. Transect R-5 from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

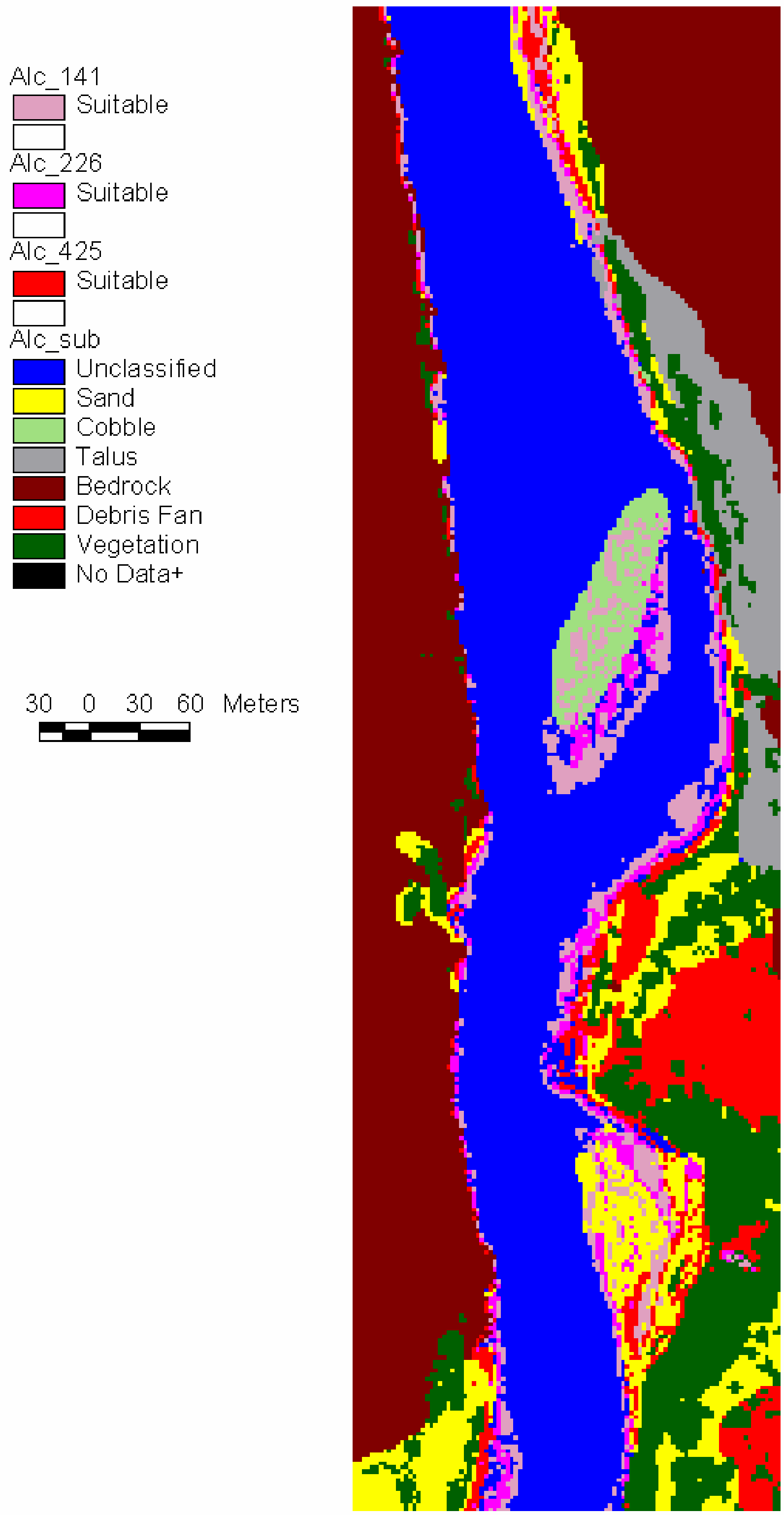


Figure A7. Transect ALC from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

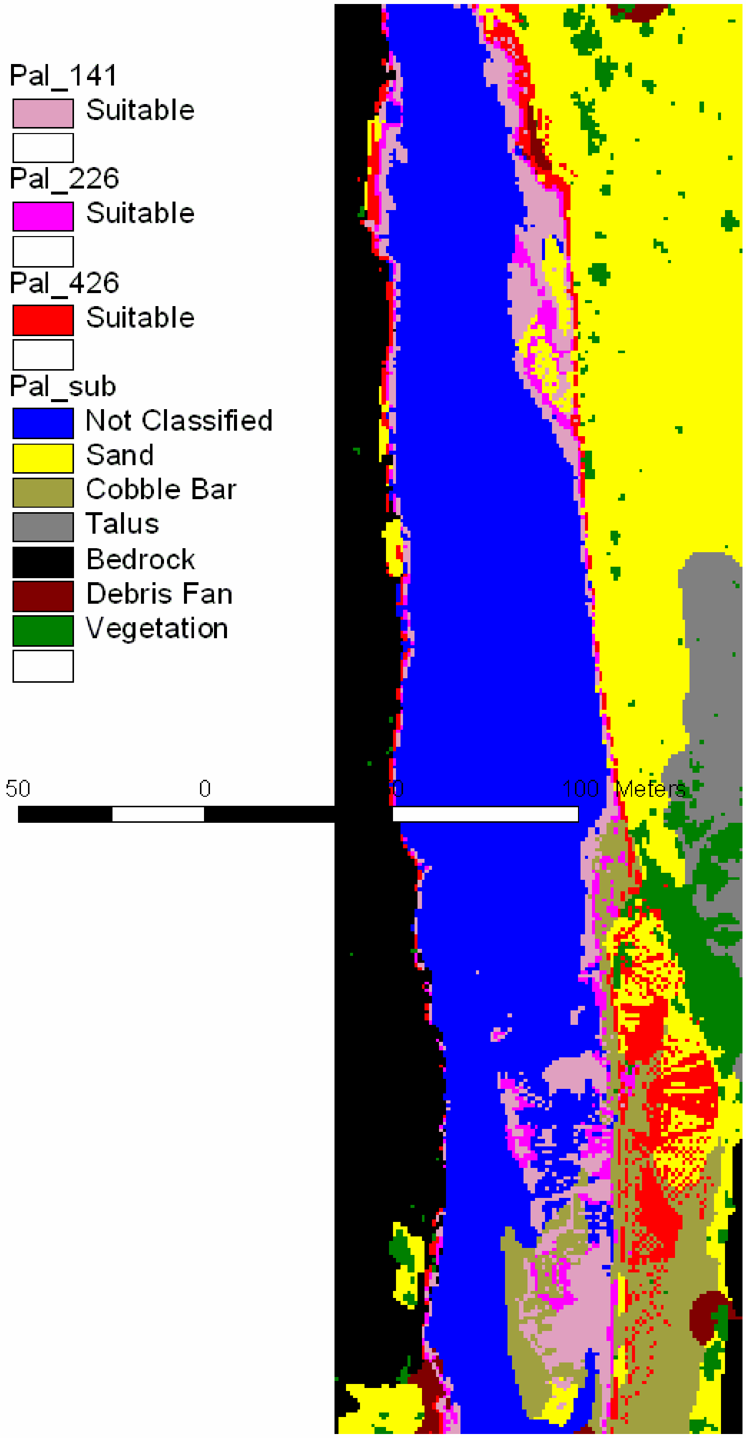


Figure A8. Transect PAL from Korman et al (2004; see Figure A-1). Upstream direction is toward the top of the figure. HAB_141 refers to suitable habitat at 5,000 cfs, HAB_226 refers to 8,000 cfs, HAB_425 refers to 15,000 cfs.

United States Department of the Interior

U.S. Fish and Wildlife Service
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Telephone: (602) 242-0210 FAX: (602) 242-2513

In Reply Refer To:

AESO/SE
22410-1993-F-167R1

February 27, 2008

Email Transmission
Memorandum

To: Deputy Regional Director, Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah

From: Field Supervisor

Subject: Final Biological Opinion for the Operation of Glen Canyon Dam

Thank you for your request for formal consultation with the U.S. Fish and Wildlife Service (FWS) pursuant to section 7 of the Endangered Species Act of 1973 (16 U.S.C. 1531-1544), as amended (Act). We received your request on November 13, 2007. At issue are impacts that may result from the proposed adoption of the experimental dam operations of Glen Canyon Dam in Coconino County, Arizona. The proposed action may affect humpback chub (*Gila cypha*) and its critical habitat, and the Kanab ambersnail (*Oxyloma haydeni kanabensis*).

You also requested our concurrence that the proposed action is not likely to adversely affect the razorback sucker (*Xyrauchen texanus*) and its critical habitat, the southwestern willow flycatcher (*Empidonax traillii extimus*) and its critical habitat, and the bald eagle (*Haliaeetus leucocephalus*). The bald eagle is no longer listed so section 7 consultation is not necessary. We concur with Reclamation's determinations for razorback sucker and southwestern willow flycatcher and their critical habitat and have provided our rationales in Appendix A of this biological opinion.

This biological opinion is based on information provided in your December 21, 2007, biological assessment (U.S. Bureau of Reclamation 2007a), subsequent exchanges of information with the Bureau of Reclamation (Reclamation), and other sources of information. Literature cited in this biological opinion is not a complete bibliography of all literature available on the species of concern, dam operations and its effects, or on other subjects considered in this opinion. A complete administrative record of this consultation is on file at our office.

We note that one of the purposes of the proposed action is to benefit the Grand Canyon population of humpback chub. Although the status of the Grand Canyon population of humpback chub has been improving, there is no clear indication for the cause of this improvement. Thus the proposed action takes a conservative approach to changes in dam releases in an attempt to capitalize on this trend in status without unduly risking these gains with more drastic changes in dam operations. However, there exists the possibility that the population could decline, despite the current trend and potential for beneficial effects from Reclamation's proposed action. Reclamation has agreed to reinitiate consultation if the trend in humpback chub status should reverse and the population decline, as described below in our biological opinion.

In keeping with our trust responsibilities to American Indian Tribes, we have provided for participation of the Bureau of Indian Affairs in this consultation and, by copy of this biological opinion, are notifying the following Tribes of its completion: the Chemehuevi Indian Tribe, Havasupai Tribe, Hopi Tribe, Hualapai Tribe, Kaibab Band of Paiute Indians, Navajo Nation, Pueblo of Zuni, and San Juan Southern Paiute Tribe.

Introduction

The proposed action for this biological opinion is a logical extension of a series of experiments conducted under the Glen Canyon Dam Adaptive Management Program (AMP), which include high flow tests, steady flows, removal of non-native fish, and non-native fish suppression flows. It consists of Reclamation's implementation of Modified Low Fluctuating Flows (MLFF) and experimental dam operations for the five-year experimental period (the remainder of water year 2008 through 2012). This biological opinion replaces the 1995 Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 1995, consultation number 2-21-93-F-167). At the end of the five-year period of the proposed action, it is expected that Reclamation will reconsult with FWS. Annual operations of Glen Canyon Dam (annual water volumes released) for this period will be defined by the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (Shortage Guidelines). Section 7 consultation for the Shortage Guidelines was completed on December 12, 2007 (U.S. Fish and Wildlife Service 2007, consultation number 22410-2006-F-0224), and a record of decision (ROD) implementing the Shortage Guidelines was signed by the Secretary of the Interior on December 13, 2007 (Shortage Guidelines ROD, U.S. Bureau of Reclamation 2007b).

Glen Canyon Dam will be operated in accordance with Reclamation's 1996 Record of Decision (U.S Bureau of Reclamation 1996). The proposed action is to continue Modified Low Fluctuating Flow releases as described in the 1996 ROD and associated 1995 Environmental Impact Statement (1995 EIS, U.S. Bureau of Reclamation 1995, 1996). As Reclamation implements the Shortage Guidelines, MLFF will be released as provided in the 1996 ROD, which places significant constraints on allowable fluctuations of powerplant releases (summarized in Table 1). Exception criteria as outlined in the 1997 Operating Criteria for Glen Canyon Dam (62 FR 9447) would also continue.

Reclamation's current operational approach has a minimum objective release of 8.23 million acre feet (maf) annually from Glen Canyon Dam. The proposed action would allow Reclamation to change these operations by allowing for potential annual releases less than the minimum objective release under certain, identified conditions as described in the Shortage Guidelines. However, even in years with an annual release less than 8.23 maf, daily and hourly releases would continue to be made according to the parameters of the 1996 ROD, which would not be affected by the proposed Federal action. Operations for the proposed experimental 5-year period would deviate from the 1996 ROD in only 2 ways: 1) a March 2008 experimental high flow test; and 2) stable flow releases in September and October from 2008-2012. These actions are further defined in the Proposed Action section below.

The 1996 ROD directed the formation and implementation of an adaptive management program to assist in monitoring and future recommendations regarding the impacts of Glen Canyon Dam operations. The AMP was formally established in 1997 to comply with the Grand Canyon Protection Act of 1992 (GCPA), the 1995 EIS, and the 1996 ROD, and provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management actions. This is accomplished through the Adaptive Management Work Group (AMWG), a Federal advisory committee. The AMWG consists of stakeholders that are Federal and State resource management agencies, representatives of the seven Basin States, Indian Tribes, hydroelectric power marketers, environmental and conservation organizations, and recreational and other interest groups. The duties of the AMWG are of an advisory capacity only, but recommendations of the AMWG are conveyed by the Secretary's Designee to the Secretary of the Interior and play an important role in the decisions of the Department of the Interior. Coupled with this advisory role are long-term monitoring and research activities that provide a continual record of resource conditions and new information to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions, including actions undertaken to conserve Act-listed species.

The AMP consists of the following major components:

- The AMWG, a Federal advisory committee that makes recommendations on how to adjust the operation of Glen Canyon Dam and other management actions to fulfill the obligations of the GCPA.

- The Secretary of the Interior's Designee that serves as the chair of the AMWG and provides a direct link between the AMWG and the Secretary of the Interior.

- The Technical Work Group (TWG) which translates AMWG policy into information needs, provides questions that serve as the basis for long-term monitoring and research activities, and conveys research results to AMWG members.

- The U.S. Geological Survey (USGS) Grand Canyon Monitoring and Research Center (GCMRC), which provides scientific information on the effects of the operation of Glen Canyon Dam and related factors on natural, cultural, and recreational resources along the Colorado River between Glen Canyon Dam and Lake Mead.

- The independent review panels (IRPs), which provide independent assessments of the program to ensure scientific validity. Academic experts in pertinent areas make up a group of Science Advisors (SAs).

Consultation History

Reclamation and the FWS have completed a number of consultations related to the AMP. Important consultations are summarized briefly here; additional information on past consultations is also provided in the Environmental Baseline.

- May 25, 1978 – We issued a jeopardy biological opinion to Reclamation on the operation of Glen Canyon Dam on humpback chub, and stated that operations were limiting the recovery of the Colorado pikeminnow (squawfish) (*Ptychocheilus lucius*). The suggested alternative to eliminate jeopardy consisted of recommending that Reclamation fund four long-term studies on: (1) the potential impact of warming downstream releases from Glen Canyon Dam; (2) the ecological needs of endangered species between Glen Canyon Dam and Lake Mead; (3) methods of reducing or eliminating factors that limit native fish habitat (flow fluctuations and low temperatures), and (4) the relationship between mainstem and tributary habitats and their utilization by endangered species.

- January 7, 1995 – We issued a biological opinion to Reclamation that the implementation of the MLFF alternative was likely to jeopardize the continued existence of the humpback chub and razorback sucker and was likely to destroy or adversely modify their critical habitat, but was not likely to jeopardize the bald eagle, Kanab ambersnail and peregrine falcon. The biological opinion identified one reasonable and prudent alternative (RPA) containing four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker: (1) development of an adaptive management program that implements studies and recommendations to increase the likelihood of both survival and recovery of listed species; (2) development of a management plan for the Little Colorado River; (3) sponsoring a workshop for developing a management plan for razorback sucker in Grand Canyon; and (4) establishing a second spawning aggregation of humpback chub below Glen Canyon Dam.

- February 16, 1996 – We issued a biological opinion to Reclamation that a proposed high flow test at Glen Canyon Dam in March 1996 was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail and southwestern willow flycatcher, and was not likely to destroy or adversely modify humpback chub critical habitat, and included a conference opinion that the test was not likely to destroy or adversely modify proposed southwestern willow flycatcher critical habitat.

- October 30, 1997 – We issued a biological opinion to Reclamation that a proposed fall test flow at Glen Canyon Dam in November 1997 was not likely to jeopardize the continued existence of the humpback chub or Kanab ambersnail and was not likely to destroy or adversely modify designated critical habitat for the humpback chub.

- December 6, 2002 – We issued a biological opinion on a proposal by Reclamation, the National Park Service (NPS), and the USGS for: (1) experimental releases from Glen Canyon Dam, (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish, and (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cubic feet per second (cfs) from Glen Canyon Dam during the period January 1-March 31. We concluded the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor (*Gymnogyps califorianus*), and southwestern willow flycatcher.

- June 12, 2003 – We issued a biological opinion to modify an aspect of the proposed action from the December 6, 2002, biological opinion, specifically to alter some aspects of a conservation measure from that opinion to translocate young humpback chub to the reach of the Little Colorado River above Chute Falls. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- August 12, 2003 – We issued a biological opinion to modify aspects of the proposed action from the December 6, 2002, biological opinion, including to extend the nonnative fish removal reach from 9 to 15 miles. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- November 17, 2004 – We issued a biological opinion to modify aspects of the proposed action from the December 6, 2002, biological opinion, primarily to modify the timing of a high experimental flow event to occur in the Fall as early as November 15. We concluded that this change in the proposed action was not likely to jeopardize the continued existence of the humpback chub, Kanab ambersnail, bald eagle, razorback sucker, California condor, and southwestern willow flycatcher.

- December 12, 2007 – We issued a biological opinion on the Shortage Guidelines which included actions within the geographic scope of the AMP, from Glen Canyon Dam to Lake Mead. The Shortage Guidelines specified a reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. We determined that implementation of the Shortage Guidelines was not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher.

Specific events related to this reinitiated consultation on Glen Canyon Dam operations for the five-year experimental period are presented below.

- Fall 2007 – We met with Reclamation several times and conducted numerous telephone conversations to discuss specific aspects of the proposed action as they relate to this consultation.

- November 13, 2007 – We received Reclamation's request for formal consultation; we also responded with a memorandum initiating formal consultation.

- December 4, 2008 – Reclamation informally requested a species list for the consultation. December 5, 2007 – We sent Reclamation, via memorandum, a species list for the consultation.

- December 20, 2008 – We received a memorandum from Brenda Burman, Deputy Assistant Secretary's Designee to the AMWG, summarizing the Department of the Interior's considerations for an experimental high flow test in 2008 and responses of AMWG members in this regard.

- December 27, 2007 – We received Reclamation's biological assessment for the proposed action.

- February 14, 2008 – We sent a draft biological opinion to Reclamation.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed action is to continue MLFF releases as described in the 1995 EIS (U.S. Bureau of Reclamation 1995, 1996). Nothing in this proposed action would modify the annual volume of water released from Glen Canyon Dam, a determination made pursuant to the Shortage Guidelines, which were adopted via a ROD, signed by the Secretary of the Interior on December 13, 2007 (U.S. Bureau of Reclamation 2007b). As Reclamation implements the Shortage Guidelines ROD, MLFF flows will be released as provided in the 1996 ROD, which places constraints on allowable fluctuations of powerplant releases (Table 1). Exception criteria as outlined in the 1997 Glen Canyon Dam Operating Criteria would also continue.

As part of this experimental action, Reclamation also proposes to incorporate experimental flows that have been designed to benefit endangered humpback chub and conservation of sediment resources in Grand Canyon. The experimental proposed action is: (1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours in March 2008 (only one high flow test is proposed for the 5-year period), and (2) fall (September and October) steady flows over the next five years (2008-2012). The high flow test hydrograph will duplicate the November 2004 high flow test hydrograph and consists of the following elements:

- On the evening of March 4, 2008 (or other approximate date in early March 2008) the MLFF release pattern will increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;

- Once powerplant capacity has been reached each of the four bypass tubes will be opened beginning on the morning of March 5, 2007, where once every three hours bypass releases will be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;

- An essentially constant flow of 41,500[1] cfs will be maintained for 60 hours, with flow changes less than 1,000 cfs/day;

- Discharge will then be decreased at a down-ramping rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached[2].

The steady releases during September and October of 2008 through 2012 will include the following constraints:

- The typical monthly dam release volumes will be maintained in all water years except water year 2008, where reallocation of water would occur for the high flow test in March;

- The dam releases for September and October will be steady[3], with a release rate determined to yield the appropriate monthly release volume;

- If possible, the monthly dam release volumes should be managed and determined to produce similar volumes in the months of September and October (Tables 2 and 4).

Monthly dam release volumes during the period of the proposed action could vary depending on the annual water release volume, as determined by the Shortage Guidelines ROD. After 2012, releases would be made according to the 1996 ROD unless Reclamation proposes alternative experimental release patterns.

Water year 2008 monthly water release volumes would be adjusted to provide water for a March high flow test (Table 2), but this would not cause the annual release from Glen Canyon Dam in water year 2008 to change. Maximum releases during March 2008 under the proposed action would be approximately 41,500 cfs during the peak high experimental flows. Tables 3 and 4 provide monthly release volumes and mean, minimum, and maximum daily releases for 10th, 50th, and 90th percentiles determined for the Shortage Guidelines ROD (U.S. Bureau of Reclamation 2007b). The 7.48 maf release pattern corresponds to the 10th percentile category (dry hydrology), the 8.23 maf release pattern corresponds to the 50th percentile, and the 12.3 maf monthly release pattern (wet hydrology) corresponds to the 90th percentile volume for the period of the proposed action (2008-2012). All monthly volumes are modeled volumes and subject to change based on actual hydrology and operations.

Releases greater than 9.5 maf generally occur during periods of equalization of reservoir storage contents between Lake Powell and Lake Mead. Implementation of equalization and balancing

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[1] Maximum capacity value calculated from the November 24-Month Study projected March 2008 Lake Powell reservoir elevation of 3586 feet and interpolated from the maximum full gate turbine capacity for seven units. One of the powerplant units will be off-line for repairs and unavailable for use in the experiment.

[2] If this element of the proposed action is undertaken, implementation of the high flow experiment will not affect the annual volume of water released from Glen Canyon Dam during water year 2008.

[3] Regulation release capacity of +/- 1,200 cfs will be available if needed for hydropower system regulation within each hour during the steady flow periods. Also, spinning reserves will be available if needed for emergency response purposes.

will follow the Shortage Guidelines ROD. When operating in the equalization tier, the upper elevation balancing tier, or the lower elevation balancing tier, scheduled water year releases from Lake Powell will be adjusted each month based on forecasted inflow and projected September active storage at Lake Powell and Lake Mead, as discussed in the Shortage Guidelines ROD.

The high flow test is intended to create and improve eddy complexes including backwater habitats and beaches. With respect to potential benefits for native fish, the hypothesis to be tested is that widespread beach building and sediment retention will result from controlled releases from the dam under sediment-enriched conditions in Grand Canyon. It is also hypothesized that high releases from the dam will increase sandbar crest height, while increasing return channel depth through scouring. If these geomorphic changes occur as a result of the high flow test, greater and more persistent backwaters could be created, which may benefit conservation of the humpback chub and other native fish species by providing more of these productive nearshore habitats utilized by young fish.

Steadying flows during September and October is intened to cause backwater and other nearshore habitat used by young native and endangered fish to become more hydraulically stable, with potentially warmer water temperatures than would exist under regular MLFF operations. These changes could improve conditions for survival and growth of young-of-year (<90 mm total length [TL, 3.54 in]) and juvenile (90-199 mm [3.54-7.83 in] TL) humpback chub, by providing more persistent suitable habitat (depth and velocity over preferred substrates), and increased productivity of algal and invertebrate prey items for use by humpback chub.

Reclamation considers the high flow test and the steady fall releases experimental actions to better understand benefits to humpback chub and native fish. Hence, the evaluation of the high flow test will focus on benefits to shaping humpback chub habitat, especially nursery backwaters, and the possible downstream transport of young-of-year and juvenile humpback chub. Evaluation of the steady fall flow is important to better understand the contrast between fluctuating flows and steady flows with respect to the extent of longitudinal warming, warming of shoreline habitats and nursery backwaters, stability of shoreline habitats, and the effect on humpback chub survival, growth, and bioenergetic expenditure. Full evaluation of this aspect of the proposed action is important to better understand how such test flows affect humpback chub and long-term species conservation. There is a high likelihood that dam releases during this proposed five-year experiment will be cool or cold. If so, this experiment also could provide the opportunity to contrast recent years of cool to warm release temperatures (2003-2005) with cool to cold release temperatures during the test period.

The purpose of the experimental high flow test is to take advantage of large amounts of sediment available in Marble and Grand canyons that currently exist, due to storm events and tributary inflow and sediment inputs in 2006 and 2007, in order to further analyze, through a high flow test, the effectiveness of such an approach to protect and improve downstream resources in Grand Canyon.

Following the proposed experimental high flow test, data collected during the test will be analyzed, as well as information collected during the previous 1996 and 2004 high flow experiments, along with other information, in order to develop predictive models and other analytical tools to better inform future decision making regarding dam operations and other related management actions, as described in the Science Plan for Potential 2008 Experimental

High Flow at Glen Canyon Dam (U.S. Geological Survey 2007a). The proposed action does not include any additional experimental high flow testing, and none will be implemented until the information from the 2008 high flow test is fully analyzed, presented to the Adaptive Management Work Group and the general public and can be integrated into an appropriate analytical framework based on predictive models and other analytical tools.

The experimental high flow test will build on extremely favorable sediment conditions afforded by recent high-volume 2006-2007 sediment inputs into Grand Canyon below Glen Canyon Dam. The high flow experiment will not modify, in any manner, the current long-term management approach to implementation of "beach-habitat building flows" as described in section 3 of the Operating Criteria for Glen Canyon Dam, published at 62 FR 9447 (March 3, 1997). As provided in section 3 of the Operating Criteria, in adopting the management approach for "beach-habitat building flows" the Secretary found that releases pursuant to such an approach "are consistent with the 1956 Colorado River Storage Project Act, the 1968 Colorado River Basin Project Act, and the 1992 Grand Canyon Protection Act." Id. While no modification is proposed or anticipated at this time, any future potential modification of the 1996 ROD or 1997 Glen Canyon Dam Operating Criteria would only occur after public review, comment and consultation, as well as any required environmental compliance efforts.

Conservation Measures

Reclamation has included the following conservation measures for listed species in the action area as part of its proposed action. As described above, the AMP provides a process for assessing the effects of current operations of Glen Canyon Dam on downstream resources and using the results to develop recommendations for modifying dam operations and other resource management and conservation actions. The AMP also provides for long-term monitoring and research activities to evaluate the effectiveness of the operational modifications to Glen Canyon Dam and other management actions. Many of the conservation measures listed below have already been occurring through the AMP at various levels. We believe conservation measures carried out through the AMP have resulted in significant conservation benefits to humpback chub and Kanab ambersnail. The existence of the AMP and the history of conservation of these species through the AMP serve to substantiate that the following conservation measures will be implemented as proposed by Reclamation. Implementation of some of these conservation measures may require additional compliance. FWS is currently investigating the feasibility of developing a recovery program for humpback chub in Grand Canyon. All of the conservation measures listed here could fall under such a program. Agreements would need to be developed to facilitate cost sharing with other agencies and organizations, both within and outside of the AMP, to fully implement a recovery program.

Humpback Chub

Humpback Chub Consultation Trigger – Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the FWS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and FWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval. FWS and Reclamation have agreed on this trigger based on the current estimated population size and past population trend, genetic considerations, and the capabilities of the ASMR model to estimate population size. This number was derived as a conservative approach to preventing the population from declining to the minimum viable population size for humpback chub, estimated to be 2,100 adult fish (U.S. Fish and Wildlife Service 2002a), with consideration for a buffer and acknowledging the variance inherent in the ASMR resulting from age estimation based on recent results from this model (Coggins 2007). This trigger provides additional protection against possible adverse affects to humpback chub from the proposed action. If the population of humpback chub declines to this level, Reclamation and FWS will consider appropriate actions through reinitiated section 7 consultation, for example, extending the period of steady releases to include July and August. Conversely, if the population of humpback chub expands significantly, FWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary.

Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon – Reclamation has been a primary contributor to the development of the AMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with AMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in this biological opinion, but will also consider funding and implementing other actions not identified here to implement the plan.

Humpback Chub Translocation – In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

Nonnative Fish Control – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

Humpback Chub Nearshore Ecology Study – In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fishes. This study will incorporate planned science activities for evaluating the high flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with FWS via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the FWS. This conservation measure is consistent with the *Sediment Research* conservation measure in the Shortage Guidelines biological opinion. This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth and survival of young humpback chub.

Monthly Flow Transition Study – Transitions between monthly flow volumes can often result in drastic changes to nearshore habitats. For example, past transitions from August to September in some years have consisted of a transition from a lower limit of 10,000 cfs in August to an upper limit of 10,000 cfs in September. Such a transition results in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fishes and food base for fish. Reclamation has committed to adjusting daily flows between months to attempt to attenuate these transitions such that they are more gradual, and to studying the biological effects of these transitions, in particular to humpback chub. If possible, Reclamation will work to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub, as acceptable to the FWS.

Humpback Chub Refuge – Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage Guidelines biological opinion), Reclamation will assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

Little Colorado River Watershed Planning – Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

Kanab Ambersnail

Habitat Protection – Reclamation will, through the AMP, temporarily remove and safe-guard all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent (17 m^2 [180 ft^2]) of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with GCMRC.

Action Area

The action area for this proposed action is the Colorado River corridor from Glen Canyon Dam in Coconino County, Arizona downstream to Separation Canyon, Mohave County, Arizona at and below the 41,500 cfs stage level of the Colorado River, as shown in Figure 1. Below Separation Canyon, ESA compliance is not addressed within the AMP but within the Lower Colorado River Multi-Species Conservation Program (MSCP; U.S. Fish and Wildlife Service 2005a). The MSCP addresses Section 7 and Section 9 responsibilities for areas up to and including the full-pool elevation of Lake Mead, and downstream areas along the Colorado River within the U.S.

STATUS OF THE SPECIES AND CRITICAL HABITAT

Humpback chub

The humpback chub was listed as endangered on March 11, 1967 (32 FR 4001). Critical habitat for humpback chub was designated in 1994. Seven reaches of the Colorado River system were designated as critical habitat for humpback chub for a total river length of 379 miles in the Yampa, Green, Colorado, and Little Colorado rivers in Arizona, Colorado and Utah. Known constituent elements include water, physical habitat, and biological environment as required for each life stage (59 FR 13374; U.S. Fish and Wildlife Service 1994). Water includes a quantity of sufficient quality (i.e., temperature, dissolved oxygen, lack of contaminants, nutrients, and turbidity) that is delivered to a specific location in accordance with a hydrologic regime that is required for the particular life stage. Physical habitat includes areas of the Colorado River for use in spawning, nursery, feeding, and rearing or corridors to these areas. The biological environment includes food supply and habitats with levels of nonnative predators and competitors that are low enough to allow for spawning, feeding, and rearing.

The humpback chub is a medium-sized freshwater fish (to about 20 inches) of the minnow family, Cyprinidae. The adults have a pronounced dorsal hump, a narrow flattened head, a fleshy snout with an inferior-subterminal mouth, and small eyes. It has silvery sides with a brown or olive-colored back. The humpback chub is endemic to the Colorado River Basin and is part of a native fish fauna traced to the Miocene epoch in fossil records (Miller 1955, Minckley et al. 1986). Humpback chub remains have been dated to about 4000 B.C., but the fish was not described as a species until the 1940s (Miller 1946), presumably because of its restricted distribution in remote whitewater canyons (U.S. Fish and Wildlife Service 1990). Because of this, its original distribution is not known.

Populations of this species occur in the Little Colorado and Colorado rivers in the Grand Canyon, Black Rocks area of the Colorado River, Westwater Canyon, Cataract Canyon, Desolation/Grey Canyon, and Yampa Canyon (Valdez and Clemmer 1982, U.S. Fish and Wildlife Service 1990, 2002a). The largest population in the upper basin is in Westwater Canyon, with an estimated population size of about 2,400 adult fish (age 4+; ≥ 200 mm [7.87 in] TL); humpback chub are currently rare in the Yampa River and in Cataract Canyon (Finney et al. 2004, McAda 2004, Jackson 2004a, 2004b, and Utah Division of Wildlife Resources 2004). In Grand Canyon, adult population estimates based on the ASMR model ranged from 10,000-11,000 in 1989 to 3,100-4,400 in 2001 (Coggins et al. 2006). However, between 2001 and 2006, numbers of adult fish, based on newer analyses using the ASMR model, appear to have increased from about 4,500-5,700 in 2001 to an estimated 5,300-6,700 in 2006 (Coggins 2007).

Adult humpback chub occupy swift, deep, canyon reaches of river (Valdez and Clemmer 1982, Archer et al. 1985, Valdez and Ryel 1995), with microhabitat use varying among age-groups (Valdez et al. 1990). Within Grand Canyon, adults demonstrate high microsite fidelity and occupy main channel eddies, while subadults use nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998, Stone and Gorman 2005). Young-of-year humpback chub use shoreline talus, vegetation, and backwaters typically formed by eddy return current channels (Arizona Game and Fish Department (AGFD) 1996). These habitats are usually warmer than the main channel especially if they persist for a long time and are not inundated or desiccated by fluctuating flows (Stevens and Hoffnagle 1999). Subadults also use shallow, sheltered shoreline habitats but with greater depth and velocity (Valdez and Ryel 1995, Childs et al. 1998).

Valdez and Ryel (1995, 1997) reported on adult humpback chub habitat use in the Colorado River in Grand Canyon. They found that adults used primarily large recirculating eddies, occupying areas of low velocity adjacent to high-velocity currents that deliver food items. Adults also congregated at tributary mouths and flooded side canyons during high flows. Adults were found primarily in large recirculating eddies disproportionate to their availability, with lesser numbers found in runs, pools, and backwaters. Hoffnagle et al. (1999) reported that juveniles in Grand Canyon used talus shorelines at all discharges and apparently were not displaced by a controlled high flow test of 45,000 cfs in late March and early April, 1996. Valdez et al. (1999) also reported no displacement of radiotagged adults, with local shifts in habitat use to remain in low-velocity polygons within large recirculating eddies.

As young humpback chub grow, they exhibit an ontogenic shift toward deeper and swifter offshore habitats that usually begins at age 1 (about 100 mm [3.94 in] TL) and ends with maturity at age 4 (≥200 mm [7.87 in] TL; Valdez and Ryel 1995, 1997, Stone and Gorman 2005). Valdez and Ryel (1995, 1997) found that young humpback chub (21–74 mm [0.83-2.91 in] TL) remain along shallow shoreline habitats throughout their first summer, at water velocities of 0.0, 0.06, and 0.30 m/s and at depths less than 1 m, and shift to more offshore habitats as they grow larger (75–259 mm [2.95-10.20 in] TL) by fall and winter, into deeper habitat with water velocities of 0.0, 0.18, and 0.79 m/s (0.0, 0.59, 2.6 ft/s), respectively, and at depths up to 1.5 m (4.9 ft). Stone and Gorman (2005) found similar results in the Little Colorado River, finding that humpback chub undergo an ontogenesis from diurnally active, vulnerable, nearshore-reliant young-of-year (30–90 mm [1.81-3.54 in] TL) into nocturnally active, large-bodied adults (180 mm [7.09 in] TL), that primarily reside in deep midchannel pools during the day, and move inshore at night.

Movement of adult humpback chub is substantially limited compared to other native Colorado River fishes (Valdez and Ryel 1995). Adults have a high fidelity for site-specific habitats in the Colorado River and generally remain within a 1-km (0.6 mi) area, except during spawning ascents of the Little Colorado River in spring. Adult radio-tagged humpback chub demonstrated a consistent pattern of greater near-surface activity during the spawning season and at night, and day-night differences decreased during moderate to high turbidity.

The humpback chub is an obligate warm-water species that requires relatively warm temperatures of about 16-22 °C (61-72 °F) for spawning, egg incubation, and survival of young. Spawning is usually initiated at about 16 °C (61 °F)(Hamman 1982). Highest hatching success is at 19–20 °C (66-68 °F) with incubation time of 3 days, and highest larval survival is slightly warmer at 21–22 °C (70-72 °F)(Marsh 1985). Hatching success under laboratory conditions was 12 percent, 62 percent, 84 percent, and 79 percent in 12–13 °C (54-54 °F), 16–17 °C (61-63 °F), 19–20 °C (66-68 °F), and 21–22 °C (70-72 °F), respectively, whereas survival of larvae was 15 percent, 91 percent, 95 percent, and 99 percent, at the same respective temperatures (Hamman 1982). Time from fertilization to hatching ranged from 465 hours at 10 °C (50 °F) to 72 hours at 26 °C (79 °F), and time from hatching to swim-up varied from 372 hours at 15 °C (59 °F) to 72 hours at 21–22 °C (70-72 °F). The proportion of abnormal fry varied with temperature and was highest at 15 °C (59 °F) (33 percent) and was 17 percent at 25 °C (77 °F). Marsh and Pisano (1982) also found total mortality of embryos at 5, 10, and 30 °C (41, 50, 86 °F). Bulkley et al. (1981) estimated a final thermal preference of 24ºC (75 °F) for humpback chub during their first year of life (80–120 mm [3.2-4.72 in]).

Humpback chub are broadcast spawners with a relatively low fecundity rate compared to cyprinids of similar size (Carlander 1969). Eight humpback chub (355–406 mm [14.0-16.0 in] TL), injected with carp (*Cyprinus carpio*) pituitary and stripped in a hatchery, produced an average of 2,523 eggs/female, or about 5,262 eggs/kg of body weight (Hamman 1982). Egg diameter ranged from 2.6 to 2.8 mm (0.10-0.11 in; mean, 2.7 mm [0.11 in]). Eleven humpback chub from the Little Colorado River (LCR) yielded 4,831 eggs/female following variable injections of carp pituitary and field stripping (Clarkson 1993).

Humpback chub in Grand Canyon spawn primarily during March–May in the lower 13 km of the Little Colorado River (Kaeding and Zimmerman 1983, Minckley 1996, Gorman and Stone 1999, Stone 1999) and during April–June in the upper basin (Kaeding et al. 1990, Valdez 1990, Karp and Tyus 1990). Most fish mature at about 4 years of age. Gonadal development is rapid between December and February to April, at which time somatic indices reached highest levels Kaeding and Zimmerman (1983). Adults stage for spawning runs in large eddies near the confluence of the Little Colorado River in February and March and move into the tributary from March through May, depending on temperature, flow, and turbidity (Valdez and Ryel 1995). Spawning has not been observed, but ripe males have been seen aggregating in areas of complex habitat structure (boulders, travertine masses, and other sources of angular variation) associated with deposits of clean gravel, and it is thought that ripe females move to these aggregations to spawn (Gorman and Stone 1999). Habitats where ripe humpback chub have been collected are typically deep, swift, and turbid. As a result, spawning in the wild has not been directly observed. Abrasions on anal and lower caudal fins of males and females in the LCR and in Cataract Canyon (Valdez 1990) suggest that spawning involves rigorous contact with gravel substrates.

At hatching, larvae have nonfunctional mouths and small yolk sacs (Muth 1990). Robinson et al. (1998) found larvae drifting in the LCR from April through June, and evidence suggesting that larvae actively disperse to find suitable nearshore habitats. Robinson et al. (1998) quantified numbers of larval humpback chub that are transported by LCR flows into the mainstem, and Robinson et al. (1998) and Stone and Gorman (2005) suggested that daily fluctuations in the mainstem river may reduce the quality of nearshore habitat for young-of-year and juvenile humpback chub, which may be particularly important during the monsoon period (July to November) when storms cause floods in the LCR, displacing large numbers of young humpback chub into the mainstem (GCMRC unpubl. data). Pre-dam annual peak Colorado River flows (April–July) ponded canyon-bound tributary mouths (Howard and Dolan 1981), including the LCR. Robinson et al. (1998) theorized that because ponding probably retained drifting larvae or slowed their passage, it probably allowed greater time for development in a warm, low-velocity environment. Without this ponding effect, presumably more young-of-year and juvenile humpback chub are likely transported into a now-harsher mainstem river while still at a size that is more vulnerable to thermal shock and predation.

Humpback chub attain a maximum size of about 480 mm (18.9 in) TL and 1.2 kg (2.6 lbs.) in weight (Valdez and Ryel 1997) and can live to be 20-30 years old (Hendrickson 1993). Humpback chub grow relatively quickly at warm temperatures until maturity at about 4 years of age, then growth rate slows substantially. Humpback chub larvae are approximately 7 mm (0.30 in) long at hatching (Muth 1990). In a laboratory, post-larvae grew at a rate of 10.63 mm (0.419 in)/30 days at 20 °C (68 °F), but only 2.30 mm (0.090 in)/30 days at 10 °C (50 °F)(Lupher and Clarkson 1994). Similar growth rates were reported from back-calculations of scale growth rings in wild juveniles at similar water temperatures from the Little Colorado River (10.30 mm (0.406 in)/30 days at 18–25 °C (64-77 °F)) and the mainstem Colorado River in Grand Canyon (3.50–4.00 mm (0.138-0.157 in)/30 days at 10–12 °C (50-54 °F); Valdez and Ryel 1995). Clarkson and Childs (2000) found that lengths, weights, and specific growth rates of humpback chub were significantly lower at 10 °C and 14 °C (50-57 °F; similar to hypolimnetic dam releases) than at 20 °C (68 °F; i.e., more characteristic of Little Colorado River temperatures during summer months).

Hendrickson (1993) aged humpback chub from the Little Colorado River and the mainstem Colorado River in Grand Canyon and showed a maximum of 23 annular rings. Based on polynomial regression of average number of annuli from otoliths (lapillus and asteriscus) and opercles, age-3 fish were 157 mm (6.18 in) TL and age-4 fish were 196 mm (7.72 in) TL. Valdez and Ryel (1995) recorded size at first observed maturity (based on expression of gametes, presence of spawning tubercles) of humpback chub in Grand Canyon at 202 mm (7.95 in) TL for males and 200 mm (7.87 in) TL for females; computed length of age-4 fish with a logarithmic growth curve was 201 mm (7.91 in) TL.

Humpback chub are typically omnivores with a diet consisting of insects, crustaceans, plants, seeds, and occasionally small fish and reptiles (Kaeding and Zimmerman 1982, Kubly 1990, Valdez and Ryel 1995). They appear to be opportunistic feeders, capable of switching diet according to available food sources, and ingesting food items from the water's surface, mid-water, and river bottom. Valdez and Ryel (1995) examined diets of humpback chub in Grand Canyon. Guts of 158 adults from the mainstem Colorado River, flushed with a nonlethal stomach pump, had 14 invertebrate taxa and nine terrestrial taxa, including simuliids (blackflies, in 77.8 percent of fish), chironomids (midges, 57.6 percent), Gammarus (freshwater shrimp, 50.6 percent), Cladophora (green alga, 23.4 percent), Hymenoptera (wasps, 20.9 percent), and cladocerans (water fleas, 19.6 percent). Seeds and human food remains were found in eight (5.1 percent) and seven (4.4 percent) fish respectively.

The decline of the humpback chub throughout its range and continued threats to its existence are due to habitat modification and streamflow regulation (including cold-water dam releases and habitat loss), competition with and predation by nonnative fish species, parasitism, hybridization with other native *Gila*, and pesticides and pollutants (U.S. Fish and Wildlife Service 2002a). Streamflow regulation, in general, eliminates flows and temperature needed for spawning and successful recruitment, which is exacerbated by predation and competition from nonnative fishes. In Grand Canyon, brown trout (*Salmo trutta*), channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), and rainbow trout (*Oncorhychus mykiss*) have been identified as principal predators of young humpback chub, with consumption estimates that suggest loss of complete year classes to predation (Marsh and Douglas 1997, Valdez and Ryel 1997). Valdez and Ryel (1997) also suggested that common carp could be a significant predator of incubating humpback chub eggs in the LCR. In the upper basin, channel catfish have been identified as the principal predator of humpback chub in Desolation/Gray Canyons (Chart and Lentsch 2000), and in Yampa Canyon (U.S. Fish and Wildlife Service 2002a). Smallmouth bass (*Micropterus dolomieu*) have also become a significant predator in the Yampa River (T. Chart, FWS, pers. comm., 2007). Parasitism, hybridization with other native *Gila*, and pesticides and pollutants are also factors in the decline (U.S. Fish and Wildlife Service 2002a).

Many section 7 consultations have occurred on the humpback chub in both the upper and lower basins of the Colorado River. Activities that continue to adversely affect the humpback chub and its habitat throughout its range include dam operations, recreation, land uses that impact water quality, and the presence of nonnative species. However many surveys, and numerous projects to improve the species status, such as translocation and nonnative species removal, have occurred for the species. Although the recovery goals for humpback chub that amend and supplement the 1990 Recovery Plan (U.S. Fish and Wildlife Service 2002a) are currently in revision, the document provides a complete discussion of the taxonomy, distribution, and life history of the species.

Kanab ambersnail

The Kanab ambersnail was listed as an endangered species without critical habitat in 1992 (57 FR 13657). The species is undergoing a 5-year review by the FWS, including a genetic evaluation of the species relatedness to other *Oxyloma*.

The genus *Oxyloma* has a broad distribution (North America, Europe and South Africa) with two species recognized in the southwestern United States: *O. retusa* in New Mexico and *O. haydeni* in Arizona and Utah. Within *O. haydeni* there are two subspecies, the Niobrara ambersnail (*O. h. haydeni*) and the Kanab ambersnail (*O. h. kanabensis*), both of which are found in Arizona and Utah. Populations of Kanab ambersnail presently occur from only four springs: two near

Three Lakes, near Kanab, Utah, and two in Grand Canyon National Park, Arizona, one at a spring and hanging garden at River Mile (RM, as defined in Stevens 1983) 31.5 known as Vaseys Paradise, and a translocated population at Upper Elves Chasm, at RM 116.6 (Sorensen 2005). A third population in the Kanab area, near "the Greens," a seep-fed marsh, was believed to be lost due to dewatering in the last decade (U.S. Fish and Wildlife Service 1995a). The remaining populations near Three Lakes are located on private lands at several small spring-fed ponds on cattail (*Typha* sp.).

The population at Elves Chasm was created via translocation of snails from Vaseys Paradise. In 1998, the AGFD in coordination with the NPS, translocated snails to three sites in Grand Canyon National Park: Elves Chasm, Keyhole Spring, and Deer Creek. Although Elves Chasm was the only successful translocation, it has shown success including recruitment, overwinter survival, and increased density of snails (Sorensen and Nelson 2002). Recently Kanab ambersnail has become rare at Elves Chasm, although the species remains abundant at Vaseys Paradise (J. Sorensen, AGFD, pers comm., 2007).

The Kanab ambersnail is dependent upon wetland vegetation for food and shelter, living in association with wetland plants including watercress (*Nasturtium*), monkeyflower (*Mimulus*), cattails, sedges (*Carex* spp.), and rushes (*Juncus* spp.). Stevens et al. (1997) found that Kanab ambersnail populations in the Grand Canyon region occur in areas where water sources originate from limestone or sandstone geologic strata. Kanab ambersnail at Vaseys Paradise predominantly use crimson monkeyflower and water-cress for food and shelter (Stevens et al. 1997a). The other Grand Canyon population, Upper Elves Chasm, is located above the 100,000 cfs stage of the river and is characterized by predominately crimson monkeyflower and maidenhair fern (*Adiantum capillus-veneris*), with lesser amounts of sedges, rushes, cattails, water-cress, helleborine orchids (*Epipactis gigantea*) and grasses (Poaceae)(Sorensen and Nelson 2002). From evidence collected in laboratory conditions, microclimatic conditions such as higher humidity and lower air temperatures relative to the surrounding environments and high vegetative cover may be important habitat features related to Kanab ambersnail survival (Sorenson and Nelson 2002).

Kanab ambersnails are hermaphroditic and capable of self-fertilization (Pilsbry 1948, Clarke 1991). Mature Kanab ambersnail mate and reproduce during the summer months (July and August), and deposit clear, gelatinous egg masses on undersides of moist to wet live stems, on the roots of water-cress, and on dead stems of crimson monkey-flower (Stevens et al. 1997a). In some years with relatively warm winters, more than one reproductive period can occur. Adult mortality increases in late summer and autumn leaving the overwintering population dominated by subadults. Young snails enter dormancy in October-November and typically become active again in March-April. Over-winter mortality of Kanab ambersnail can range between 25 and 80 percent (Stevens et al. 1997a & 1997b). Kanab ambersnail feed on plant tissue, bacteria, fungi and algae that are scraped off of dead plant tissue by means of a radula or rasp tongue. Stevens et al. (1997b) observed Kanab ambersnail feeding largely on crimson monkey-flower and water-cress.

Ongoing taxonomic studies indicate that although the population at Vaseys Paradise appears to be unique, the taxon itself may not be valid. Mitochondiral and cellular (microsatelite) DNA analysis indicates that the Kanab ambersnail may be part of a larger taxonomic group. However, these results are preliminary; the study is ongoing and should be completed in 2008 (M. Culver, University of Arizona, pers. comm. 2007).

Numerous biological opinions have been completed on the Kanab ambersnail. Most of these have been on the Grand Canyon population addressing the effects of experimental flows from Glen Canyon Dam. Activities that continue to adversely affect the Kanab ambersnail include water use, dam operations, and recreation-related trampling. However, many surveys, several research projects, and habitat salvage projects have occurred for the species. Stochastic events also continue to affect the distribution, quality, and extent of Kanab ambersnail habitat, predominantly drought.

ENVIRONMENTAL BASELINE

The environmental baseline includes past and present impacts of all Federal, State, or private actions in the action area, the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early section 7 consultation, and the impact of State and private actions which are contemporaneous with the consultation process. The environmental baseline defines the current status of the species and its habitat in the action area to provide a platform to assess the effects of the action now under consultation.

Status of the species and critical habitat within the action area

Humpback Chub and its Critical Habitat

Humpback chub in the lower Colorado River basin (below Glen Canyon Dam) occur in the Colorado River in Marble and Grand canyons, and in the lower 18 km (11 miles) of the LCR, constituting the Grand Canyon population, which also represents the lower basin recovery unit (U.S. Fish and Wildlife Service 2002a). Critical habitat in Arizona includes most of the habitat now used by the Grand Canyon population of humpback chub. Designated reaches are the lower 8 miles of the LCR and from RM 34 (Nautiloid Canyon) to RM 208 (Granite Park) along the Colorado River. This represents approximately 28 percent of the historical habitat for the species, and 48 percent of critical habitat. The dominant factors affecting critical habitat in Grand Canyon are habitat alteration due to the presence and operation of Glen Canyon Dam and the presence of nonnative fish that prey on and compete with native fishes. The known constituent elements are present and functional throughout designated critical habitat in the action area, primarily in the LCR; the mainstem Colorado River may provide all constituent elements, but at times appears too cold or has too many nonnative fishes to fully function.

Historically, humpback chub were likely distributed throughout Grand Canyon, with local concentrations, although there is little information to gauge historical abundance. Valdez and Ryel (1995) estimate that the range of humpback chub in Grand Canyon has declined by about 61 miles or 24 percent since Glen Canyon Dam was completed, based on historical captures of humpback chub from the dam site to Separation Canyon (RM 241), and current capture locations from South Canyon (RM 30.0) to Granite Spring Canyon (221.0).

The Grand Canyon population consists primarily of adults residing in and near the LCR, with much smaller aggregations of the species scattered throughout approximately 180 river miles of the mainstem Colorado River. Valdez and Ryel (1995) identified nine mainstem aggregations of humpback chub in Grand Canyon: 30 mile (RM 29.8 to 31.3); LCR Inflow (RM 57.0-65.4); Lava to Hance (RM 65.7-76.3); Bright Angel Creek Inflow (RM 83.8-93.2); Shinumo Creek Inflow (RM 108.1-108.6); Stephen Aisle (RM 114.9-120.1); Middle Granite Gorge (RM 126.1-129.0); Havasu Creek Inflow (RM 155.8-156.7); and Pumpkin Spring (RM 212.5-213.2). Monitoring continues to confirm the persistence of these aggregations (Trammell et al. 2002), although few or no humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Humpback chub have been caught infrequently downstream of Pumpkin Spring. One adult was captured downstream of Maxson Canyon (RM 244) in 1994 (Valdez 1994), and four humpback chub were caught at Separation Canyon (RM 239.5) in 2006 (AGFD 2006). The LCR Inflow is the largest aggregation, which is in the lower 13 km of the Little Colorado River and the adjoining 15 km of the Colorado River (RM 57.0-65.4). This aggregation has been expanded upstream of Chute Falls through mechanical translocation of fish (Stone 2007). The contribution of mainstem aggregations, other than the LCR Inflow aggregation, to the overall Grand Canyon population are not known, but is thought to be small.

The relationship between fish in the LCR inflow area and the LCR is uncertain; Douglas and Marsh (1996) suggested that two populations exist: one resident population in the LCR and one that migrates between the LCR and LCR inflow reach. However, Gorman and Stone (1999) suggested that the majority of adult humpback chub larger than 300 mm [11.81 in] TL live in the LCR inflow reach except during the spawning migration. Movement between the LCR, the LCR inflow, and other mainstem aggregations has been documented, although most movement is between the LCR and the LCR inflow, with less movement between the other mainstem aggregations (Paukert et al. 2006).

Douglas and Douglas (2007) concluded that genetic differences among the Marble and Grand canyon aggregations of humpback chub were difficult to distinguish at the microsatellite level. Aggregations appeared to be connected by geneflow, suggesting downstream drift of larvae and juveniles as a likely mechanism. The Little Colorado River population would be the primary source, but contribution from occasional local reproduction by mainstem aggregates cannot be excluded. The 30-mile aggregation in Marble Canyon was recorded as having two individuals with *G. elegans* haplotypes, and the microsatellite profile for this population was intermediate between genotypes found in Desolation Canyon (a hypothesized hybrid population) and Grand Canyon. Although reproduction has been documented for the 30-mile aggregation, it appears to have very low numbers of fish. As the only population in Grand Canyon that is upstream from the Little Colorado River it is least likely to receive migrants from downstream locations. Douglas and Douglas (2007) recommended further study of the 30-mile aggregation to evaluate the potential distinctiveness of these fish.

Coggins et al. (2006) summarized information on abundance and analyzed monitoring data collected since the late 1980s and found that data from all sources using various methods consistently indicated that the adult population had declined since monitoring began. Adult population estimates for an age-structured Jolly–Seber model ranged from about 14,500 in 1989 to about 2,400 in 2001; a similar model, the ASMR, estimated population size from 10,000-11,000 adults in 1989 to 3,100-4,400 in 2001 (Coggins et al. 2006). The main cause for the decline appears to be a decline in recruitment such that adult mortality exceeds recruitment. ASMR results suggest a peak in recruitment in the late 1970s to early 1980s of 13,500-18,500 age-2 fish. After that peak, an overall decline was evident to the early 1990s, when annual recruitment stabilized at about 2,000 age-2 fish (Coggins et al. 2006). Recent ASMR analyses indicate that the Grand Canyon population appears to have increased from about 4,500-5,700 in 2001 to an estimated 5,300-6,700 in 2006 (USGS 2007, Figure 2). While the recent increase in population size and stability has previously been attributed to increased recruitment resulting from warmer water temperatures, mechanical removal of nonnative piscivorous fish and/or experimental flows (high flow tests, steady flows in 2000), recent modeling suggests that initiation of increased recruitment predates each of these factors by at least four years (Coggins et al. 2007). No explanations for this recruitment increase have been proposed to date. The increase could have been due to factors associated with the Little Colorado River, the mainchannel Colorado River, or both parts of the system.

New information also shows greater numbers of young humpback chub in the mainstem than in previous years. Catch-rate indices indicate increases in numbers of sub-adult humpback chub (150-199 mm TL [5.91-7.83 in]; Coggins 2007, Figure 3). During 2002-2006, a total of 442 humpback chub <100 mm (3.94 in) TL were captured upstream of the Little Colorado River Inflow (RM 61.3) as far upstream as RM 30.7 (Ackmerman 2007). Of the 442 fish, 225 (13-66 mm [0.51-2.60 TL) were caught between RM 30 and RM 50. The 30-Mile aggregation is located 31 miles upstream of the Little Colorado River inflow and it is unlikely that the young humpback chub swam upstream that distance, especially given cool mainstem temperatures. Furthermore, the distribution of these fish, as well as average size above (mean = 38 mm [1.50 in] TL) and below the LCR (mean = 67 mm [2.64 in] TL), indicate that the natal source is upstream of RM 50 and not from the LCR. The causes for these recent increases in young humpback chub in the mainstem Colorado River are uncertain, but declines in nonnative trout over this same period as well as warmer river temperatures due to low reservoir levels in Lake Powell have been implicated.

Young-of-year and juvenile humpback chub observed outside the LCR aggregation were most abundant at RM 110-130 (Stephen Aisle and Middle Granite Gorge aggregations) during 2000 and 2004 and RM 160-200 during 2000 (Johnstone and Lauretta 2004, 2007, Trammell et al. 2002, AGFD 1996, Ackerman 2007). Seine catches of all young-of-year humpback chub outside the nine aggregations were at their highest in 21 years during 2004 (Johnstone and Lauretta 2007). Four humpback chub were also collected at Separation Canyon (RM 239.5) in 2005 (Ackerman et al. 2006). The Middle Granite Gorge aggregation (which includes adults) has been stable or increasing in size since 1993 (Trammell et al. 2002) and may be sustained via immigration from the LCR aggregation, as well as local reproduction. No humpback chub have been caught at the Havasu Inflow and Pumpkin Spring aggregations since 2000 (Ackerman 2007). Valdez and Ryel (1995) provided mark-recapture estimates for PIT-tagged humpback chub adults (≥200 mm [7.87 in] TL) in five of the remaining eight aggregations, including 30-Mile (estimate, n-hat = 52), Shinumo Inflow (n-hat = 57), Middle Granite Gorge (n-hat = 98), Havasu Inflow (n-hat = 13), and Pumpkin Spring (n-hat = 5). Population estimates have not been made for other mainstream aggregations since 1993 (Trammell et al. 2002).

The range and size of the LCR Inflow aggregation has also increased as a result of a conservation measure for humpback chub to minimize adverse effects of the 2002 proposal for experimental flows and nonnative fish suppression. In August 2003, nearly 300 young humpback chub were translocated above a natural barrier, Chute Falls, in the Little Colorado River approximately 16 km above the confluence. This translocation was followed by another translocation of 300 fish in July 2004, and 567 fish in July 2005 (Stone 2006). Results indicate that translocated fish had high survival and growth rates. Reproduction and downstream movement below Chute Falls has also been documented (Stone 2006). The Chute Falls aggregation now appears to be a source of recruitment to the lower portions of the Little Colorado River and the mainstem Colorado River (Stone 2007).

The decline of humpback chub in Grand Canyon has long been thought to be due primarily to emplacement of Glen Canyon Dam. The predam river was a highly variable ecosystem. Flow varied greatly between seasons, from peak flood flows in May or June with a median monthly discharge of about 50,000 cfs, to low flows in January with a median monthly discharge of about 5,000 cfs. Flood flows of over 120,000 cfs were relatively common, occurring about every six years, and low flows of 500-1,000 cfs were also common. Daily variation in discharge was relatively small, with a median of about 542 cfs (Topping et al. 2003). A turbid and sediment-laden stream much of the year, the river was nearly clear at low flows (Blinn and Cole 1990). Temperatures varied from 0 to 30 °C (32 to 86° F)(Korn and Vernieu 1998). Minckley (1991) suggested that food base for fishes was likely meager due to the high turbidities seasonally present and the scouring nature of the river, although allochthonous inputs, much reduced post dam, may have provided a significant source of macroinvertebrates as well as nutrients for autochthonous production (Minckley and Rinne 1985, Haden et al. 1999).

In contrast, the post-dam river is a more stable environment in all ways except for daily variation in discharge. The river now is limited by the 1996 ROD to discharges between 5,000 and 25,000 cfs, with the exception of high flow tests which may be up to 45,000 cfs (U.S. Bureau of Reclamation 1996). Necessary to maximize the value of hydropower generation, releases from Glen Canyon Dam are varied throughout the day to meet the demand for electricity. The post-dam median daily change in discharge (8,580 cfs) is now approximately 15 times greater than pre-dam (542 cfs) and actually exceeds the pre-dam median discharge (7,980 cfs; Topping et al. 2003). Post-dam changes in discharge create dramatic changes in diurnal river stage, 2 meters (m, 6.6 ft) or greater in some areas; pre-dam, diurnal stage change was seldom more than 0.3 m (1.0 ft) (GCMRC unpublished data). The river is now perennially cold; Glen Canyon Dam releases hypolimnetic water (the deeper layer of the reservoir) with a relatively constant temperature which ranges from 6-8 °C at high reservoir levels (43-46 °F), although releases from 2004-2006 were much warmer due to low Lake Powell reservoir levels. Post-dam productivity is much higher in terms of algal and invertebrate biomass, thus food availability for fishes is likely greater than pre-dam (Blinn and Cole 1990). More than 84-94 percent of the fine sediment input is now trapped behind the dam, and the post-dam median discharge of 12,600 cfs causes remaining fine sediment to be lost continually (Topping et al. 2000, Topping et al. 2003, Wright et al. 2005).

Much of the Grand Canyon population of humpback chub, and the majority of all spawning, occurs in the lower 10 miles of the LCR. The LCR appears to be little changed hydrologically from pre-Anglo settlement times, and is similar in some respects to the pre-dam Colorado River. Flow ranges from a median low discharge of about 200 cfs in June to a median high discharge in April of about 600 cfs. When at low or base flow, this travertine system is relatively clear and turquoise blue. During floods, the LCR carries large sediment loads and is extremely turbid. Water temperatures range from near freezing to about 25 °C (77° F). At low flow, the middle

LCR at Cameron is dry, with flow in the lower river supplied entirely by Blue Springs, about 12.5 miles upstream from the confluence.

Many of the physical changes in the post-dam Colorado River are believed to have contributed to eliminating spawning and recruitment of humpback chub in the mainstem river. Humpback chub require a minimum of about 16 °C (60 °F) for successful spawning, hatching and rearing of young fish (Hamman 1982, Marsh 1985, Clarkson and Childs 2000, Muth et al. 2000). Bulkley et al. (1982) found that young humpback chub 73-134 mm [2.9-5.28 in] TL forced to swim at a velocity of 0.51 m/sec fatigued after an average of 85 minutes at 20 °C, (68 °F) but fatigued after only 2 minutes at 14 °C (57 °F); a decrease of 6 °C (11 °F) reduced fatigue time by 98 percent. From the time that Lake Powell first filled in about 1980 until about 2000, cold hypolimnetic releases of 8-10 °C (46-50 °F) were characteristic of Glen Canyon Dam operations. These cold temperatures largely prevented mainstem reproduction by humpback chub, except perhaps in localized warm springs (Valdez and Masslich 1999). Throughout this post-dam period, low survival of larval and post-larval fish led to low recruitment to the adult population. This trend was attributed to effects of cold water temperatures (thermal shock, and poor swimming performance and predator avoidance) and nonnative fish predators and competitors (Lupher and Clarkson 1994, Valdez and Ryel 1995, Marsh and Douglas 1997, Clarkson and Childs 2000, Robinson and Childs 2001, Ward et al. 2002). Because cold temperatures can also cause larvae and juvenile fish to experience thermal shock (Berry 1988), and swimming ability is greatly reduced (Berry and Pimentel 1985, Ward and Bonar 2003), juvenile humpback chub exiting the warm LCR and entering the cold mainstem may be too lethargic to effectively avoid predation or swim to suitable nearshore habitats (Valdez and Ryel 1995, Robinson et al. 1998).

Although Glen Canyon Dam releases are relatively constant at 6-8 °C (43-46 °F), they are influenced by lake elevation, inflow hydrology, and to a lesser extent, release volumes and meteorological conditions. Release temperatures have varied from 7 to 16 °C (45-60 °F) through 2006. Between 1999 and 2005, Lake Powell elevations dropped more than 140 feet as a result of a basin-wide drought. While winter release temperatures remained cold, Glen Canyon Dam release temperatures increased to 16 °C (60 °F) in the fall of 2005. The drop in Lake Powell elevation resulted in warmer releases because the epilimnion was closer to the penstock withdrawal zone. Release temperatures from Glen Canyon Dam during 2004 and 2005 were the highest since August 1971 when the reservoir was filling. However, current reservoir level, though low, is high enough that releases are cold, and Reclamation predicts that reservoir levels will remain high and release temperatures cold for the next 5-10 years (i.e. there is a 75 percent chance that reservoir levels will remain above 3,600 ft and corresponding release temperatures will be <11 °C [51.8 °F] from 2009-2013)(U.S. Bureau of Reclamation 2007a).

Fluctuations also influence water temperatures in the mainstem river. Temperature differences between mainchannel and nearshore habitats can be especially pronounced in backwaters and other low velocity areas. But the amount of warming that occurs in backwaters is affected by daily fluctuations, which cause mixing with cold mainchannel waters (AGFD 1996). Hoffnagle (1996) found that mean, minimum, maximum and diel range of backwaters were higher under steady versus daily fluctuating flows, with mean daily temperatures (14.5 °C [58.1 °F]) under steady flows about 2.5 °C (4.5 °F) greater than those under fluctuating flows. Differences in the mainchannel temperatures during steady and fluctuating flows were also statistically significant, but mean temperatures differed by only 0.5 °C (0.9 °F). Similar results were documented by

Trammell et al. (2002), who found backwater temperatures during the 2000 low steady summer flow experiment to be 2-4 °C (3.6-7.2 °F) above those during 1991-1994 under fluctuating flows. Korman et al (2006) also found warmer backwater temperatures under steady flow conditions, concluding that backwaters were cooler during fluctuations because of the daily influx of cold main channel water.

Korman et al. (2006) also noted that nearshore areas affected by fluctuating flows (i.e., in the varial zone) warmed substantially for brief periods each day, which posits an ecological trade-off for fish utilizing these areas. On the one hand, fish may choose to exploit the warmer temperatures of the fluctuating zone on a daily basis and simply sustain any bioenergetic disadvantages of acclimating to rapidly changing discharge; or they may choose to remain in the permanently wetted zone which is always wetted, but colder than the immediate nearshore margin. In addition to increasing energy demands to fish that must move out of backwaters due to fluctuating flows, there is also an increased vulnerability to predation (Korman et al. 2004).

Reductions in sediment supply have likely reduced the number and quality of nearshore habitats such as backwaters that young humpback chub utilize as nursery habitats. Glen Canyon Dam and Lake Powell trap most of the sediment transported by the Colorado River. Tributaries downstream of the dam are now the only renewable sediment source to Glen, Marble, and Grand canyons. The dam and reservoir have also reduced annual flood peaks and increased moderate flows. The altered flow releases from the dam have less capacity to transport sand and coarser sized sediments than under pre-dam conditions with frequent floods.

The high flow tests of 1996 and 2004 were found effective at building or rebuilding sandbars, although persistence of the sandbars is variable. The 1996 beach/habitat-building flow deposited more sandbars and at a faster rate than predicted (Webb et al. 1999). Repeat topographic and hydrographic mapping of 33 sandbar-eddy complexes showed that the 1996 beach/habitat-building flow rebuilt previously eroded high-elevation sandbars, regardless of location, bar type, or canyon width (Hazel et al. 1999). More than half of the sand deposited at higher elevations was taken from the lower portions of the sandbars (Schmidt 1999) rather than being derived from tributary sand supplies accumulated on the channel bed, as originally hypothesized in the 1995 EIS (Wright et al. 2005). Over time, however, this resulted in a net decrease in total eddy-sandbar area and volume (Topping et al. 2004); many sandbars built during the 1996 high flow test eroded in as little as several days following the experiment.

In contrast to the 1996 high flow test, the 2004 high flow test was strategically timed to take advantage of highly sediment-enriched conditions (U.S. Geological Survey 2007a). Suspended sediment concentrations during the 2004 experiment were 60 to 240 percent of those measured during the 1996 experiment, although there was less sand in suspension below RM 42 (Topping et al. 2004). This resulted in creation of larger sandbars than those observed during the 1996 experiment in Marble Canyon, but area and volume of sandbars downstream of RM 42 actually decreased due to comparatively less sand in that area in 2004 than in 1996. Thus, it was clear from results of the 2004 high flow test that high flows conducted under sediment-depleted conditions (such as 1996) cannot be used to sustain sandbar area and volume (Topping et al. 2004); additionally, it became evident that more sand would be needed during future high flow tests to restore sandbars throughout Marble and upper Grand canyons.

In 2007, sand inputs from the Paria River were at least 2.5 million metric tons, or about 2.5 times the historical average (U.S. Geological Survey 2007a). Together with inputs from the Little Colorado River in 2006 and unexpected retention of sediment from both tributaries during 2006, sand inputs are currently at least 3 times the amount that triggered the 2004 high flow test, and greater than since at least 1998 (U.S. Geological Survey 2007a). This presents a unique opportunity to evaluate effects of a high flow test under sand-enriched conditions greater than ever tested before.

Backwaters are thought to be important rearing habitat for native fish due to low water velocity, warm water and high levels of biological productivity. They are created as water velocity in eddy return channels decline to near zero with falling river discharge, leaving an area of stagnant water surrounded on three sides by sand deposits and open to the mainchannel environment on the fourth side. Reattachment sandbars are the primary geomorphic feature which functions to isolate nearshore habitats from the cold, high velocity mainchannel environment.

Backwater numbers vary spatially among geomorphic reaches in Grand Canyon and tend to occur in greatest number in river reaches with the greatest active channel width, including the reach immediately downstream from the LCR (RM 61.5-77)(McGuinn-Robbins 1995). Numbers and size also vary temporally as a function of sediment availability and hydrology, and their size can vary within a year at a given site. Backwaters declined in number from 1990 to 1992 under experimental high fluctuating flows and MLFF, but a rapid but short lived increase in backwater numbers resulted from high inputs and flows from the LCR in 1993 as a result of high flood flows (Beus et al. 1994, McGuinn-Robbins 1995). Backwaters created in 1993 declined in 1994 under more average sediment and flow conditions (McGuinn-Robbins 1995). Backwater number can also vary tremendously depending on flow elevation during sampling and tend to be greatest at low flow elevations. Stevens and Hoffnagle (1999) noted that backwater numbers and area were reduced at flows greater than 10,000 cfs at any given point in time. McGuinn-Robbins found more backwaters during 1990 at the 5,000 cfs level than at the 8,000 cfs level, although area was greatest at the 8,000 cfs level.

Persistence of backwaters created during the 1996 high flow test appeared to be strongly influenced by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters, potentially available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Brouder et al. 1999, Hazel et al. 1999, Parnell et al. 1997, Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones had eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999).

Goeking et al. (2003) found no relationship between backwater number and flood frequency, although backwater size tends to be greatest following high flows and less in the absence of high flows due to infilling. Considering both area and number, however, no net positive or negative trend in backwater availability was noted during 1935 through 2000. At the decadal scale, several factors confound interpretation of high flow effects on backwaters bathymetry, including site-specific relationships between flow and backwater size, temporal variation within individual sites, and high spatial variation in reattachment bar topography (Goeking et al. 2003). Efficacy of high flow tests at creating or enlarging backwaters also depends on antecedent sediment load and distribution, hydrology of previous years (Rakowski and Schmidt 1999) and post-high flow river hydrology, which can shorten the longevity of backwaters to a few weeks depending on return channel deposition rates or erosion of reattachment bars (Brouder et al. 1999).

Biologically, the 1996 high flow caused an immediate reduction in benthic invertebrate numbers and fine particulate organic matter (FPOM) through scouring (Brouder et al. 1999, Parnell et al. 1999). Invertebrates had rebounded to pre-test levels by September 1996, but it is thought that the rate of recolonization was hindered by a lack of FPOM. Still, recovery of key benthic taxa such as chironomids and other Diptera was relatively rapid (3 months), certainly rapid enough for use as food by the following summer's cohort of young-of-year native fish (Brouder et al. 1999). Also during the 1996 high flow test, Parnell et al. (1999) documented burial of autochthonous vegetation during reattachment bar aggradation, which resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters. These nutrients are thus available for uptake by aquatic or emergent vegetation in the backwater.

In a study conducted in the upper Colorado River basin (middle Green River, Utah) Grand et al. (2006) found that the most important biological effect of fluctuating flows in backwaters is reduced availability of invertebrate prey caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the mainchannel and backwaters, and (to a lesser extent) reduced temperature. As the magnitude of within-day fluctuations increases, so does the proportion of backwater water volume influx, which results in a net reduction in as much as 30 percent of daily invertebrate production (Grand et al. 2006). Potential geomorphic differences between the Grand Canyon and the Upper Colorado River basin underline the need for additional research investigation.

An outstanding information need for management of Grand Canyon backwaters is the relationship between backwater bathymetry and suitability as fish habitat, specifically the relationship between depth, area, volume and thermal characteristics. Goeking et al. (2003) point out large backwaters may not incur as many benefits to young native fish as smaller backwaters because the latter will warm faster and thus remain warmer over time than larger backwaters; however, due to their depth, they may be more frequently available as fish habitat over a greater range of flows. In the Upper Colorado River basin, Colorado pikeminnow were found to utilize backwaters with average depths greater than 0.3 m (1.0 ft)(Trammell and Chart 1999) and average areas of 992 m^2 (0.245 acre)(Day et al. 1999). The issue of backwater depth is a research need from the standpoint that while greater depths afford more availability over a wide range of flows (Muth et al. 2000), the concurrent increase in volume with depth may slow warming rates.

Nonnative fish species have been present in the lower Colorado River, and likely in Grand Canyon, for over a century (Mueller and Marsh 2002). Since 1956, 24 nonnative fish species have been reported from Grand Canyon; 17 of which were present before the closure of Glen Canyon Dam (Valdez and Ryel 1995, Wieringa and Morton 1996). In Grand Canyon, brown trout, channel catfish, black bullhead, and rainbow trout have been identified as principal predators of young humpback chub (Marsh and Douglas 1997, Valdez and Ryel 1997). Valdez and Ryel (1997) also suggested that common carp could be a significant predator of incubating humpback chub eggs in the LCR.

Generally, the upper reaches of the mainstem river are dominated by coldwater nonnative species, such as rainbow trout, and the lower reaches by warmwater species such as channel catfish and common carp. Brown trout are captured in greatest numbers in and near Bright Angel Creek (Rogers and Makinster 2006, Johnstone and Lauretta 2007). Catfish appear to be the dominant species in the mainstem below Diamond Creek and above the Lake Mead delta area (Ackerman 2007). Other nonnative species such as bullhead (*Ameiurus* spp.), fathead minnow (*Pimephales promelas*), red shiner (*Cyprinella lutrensis*), and plains killifish (*Fundulus zebrinus*) are primarily tributary species, mostly in the LCR (Van Haverbeke 2006) but can occur in the mainstem, especially downstream of the confluence of the LCR (Johnstone and Lauretta 2007). These small-bodied species may be important predators and competitors of young humpback chub.

The Lee's Ferry Reach (dam to Paria River) supports a self-sustaining fishery of rainbow trout, whose population and food base are influenced by dam operations (McKinney et al. 1999, McKinney and Persons 1999, McKinney et al. 2001, Speas 2004, Speas et al. 2004, Korman et al. 2005). Brown trout occasionally move into the reach between the dam and the Paria River from downstream populations, but is not managed as part of the sport fishery and is not a desired species in this reach. Although their abundance has declined significantly over the last seven years, rainbow trout are still the dominant nonnative species between the Paria River and the Little Colorado River (Ackerman 2007, Johnstone and Lauretta 2007). Other nonnative species sporadically found in that reach include brown trout, common carp, channel catfish and fathead minnow. Invasion of nonnative fish from the upper LCR has recently been documented (Stone et al. 2007)

Below the Little Colorado River, rainbow trout numbers drop dramatically, although brown trout are common near Bright Angel Creek where they spawn and maintain a resident tributary population. Warm-water species such as common carp, channel catfish, and fathead minnow increase in numbers downstream of the Little Colorado River and are most abundant between Shinumo and Diamond creeks (Ackerman 2007). Red shiner and plains killifish are common in backwaters immediately below the Little Colorado River and occur sporadically downstream from that point (Lauretta and Serrato 2006, Johnstone and Lauretta 2007).

The Grand Canyon fish community has shifted over the past five years from one dominated by nonnative salmonids to one dominated by native species (Trammell et al. 2002, Johnstone et al. 2003, AGFD 2006, Lauretta and Serrato 2006, Ackerman 2007). Electrofishing catch rates of flannelmouth (*Catostomus latipinnis*) and bluehead suckers (*Pantosteus discobolus*) have increased four to six-fold in the past seven years, whereas trout catch rates have correspondingly declined (AGFD 2006); a similar trend is evident from trammel net data (Johnstone et al. 2003, Lauretta and Serrato 2006). Riverwide, young flannelmouth suckers were more abundant in 2004 than the previous 16 years (Johnstone and Lauretta 2007) and speckled dace are abundant in hoop net and seining samples, particularly in downstream reaches (Ackerman 2007). It is hypothesized that the recent shift from nonnative to native fish is due in part to warmer than average water temperatures, although the decline of coldwater salmonid competitors (due to mechanical removal or temperature increases) also has been implicated (USGS 2006, Ackerman 2007).

Recent declines in trout abundance in the Lees Ferry tailwater are attributed less to increased daily fluctuations during 2003-2005 and more to increased water temperatures and trout metabolic demands coupled with a static or declining food base, periodic oxygen deficiencies and nuisance aquatic invertebrates (New Zealand mudsnails; *Potamopyrgus antipodarum*). Whirling disease was discovered in the rainbow trout population below Glen Canyon Dam in June of 2007. Additionally, highly invasive quagga mussels (*Dreissena* sp.) were discovered in Lake Powell during the summer of 2007. Because of their high filtration and reproductive rates, quagga mussels frequently alter aquatic food webs and damage water supply infrastructure. Kennedy (2007) performed a risk assessment on establishment potential of quagga mussels in the Colorado River below Glen Canyon Dam, concluding that there is low risk of these mussels becoming established in high densities in the Colorado River or its tributaries below Lees Ferry. In contrast, conditions in the clear tailwater reach below the dam appear more suitable for establishment of this species.

The nonnative fish fauna of the Lees Ferry reach historically included less frequent taxa including common carp, largemouth bass (*Micropterus salmoides*), golden shiner (*Notemigonus crysoleucas*), redside shiner (*Richardsonius balteatus*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*) (GCMRC unpublished data). In more recent years, however, young-of-year green sunfish (*Lepomis cyanellus*), smallmouth bass, brown trout, and channel catfish have been collected in this reach; mature smallmouth bass and walleye (*Stizostedion vitreum*) have also been collected (GCMRC unpublished data). Sources of these fish are unknown, but the closest source containing green sunfish, catfish and smallmouth bass would be Lake Powell; means of introduction is unknown, but Reclamation is currently assessing risk potential for entrainment of Lake Powell fish through the dam penstocks.

Recently, a few smallmouth bass and striped bass were collected in the vicinity of the Little Colorado River (GCMRC unpublished data), but no population-level establishment has been documented to date. There are also recent records of green sunfish, black bullhead, yellow bullhead (*Ameiurus natalis*), red shiner, plains killifish and largemouth bass downstream of the Little Colorado River, usually associated with warm springs, tributaries, and backwaters (Johnstone and Lauretta 2007, GCMRC unpublished data). Striped bass are found in relatively low numbers below Lava Falls (Ackerman 2007).

Stone et al. (2007) reported common carp, fathead minnow and red shiner below Grand Falls (an ephemeral reach of the river), which indicates that the LCR is a viable conduit for introduction of nonnative fish from areas higher in the watershed. Other nonnative fish documented in the upstream reaches of the Little Colorado River basin include golden shiner, black bullhead, yellow bullhead, channel catfish, rock bass (*Ambloplites rupestris*), bluegill, green sunfish, smallmouth bass, and largemouth bass (Stone et al. 2007); thus these species could eventually occur in Grand Canyon.

Fish samples collected below Diamond Creek in 2005 (Ackerman et al. 2006) were comprised primarily of red shiner (28 percent), channel catfish (18 percent), common carp (12 percent), and striped bass (9 percent); smallmouth bass, mosquitofish (*Gambusia affinis*), and fathead minnow were also present in low numbers. Bridge Canyon Rapid impedes upstream movement of most fish species, except for the striped bass, walleye, and channel catfish (Valdez 1994, Valdez et al. 1995). Nonnative fish species increased from 11 above to 18 below the rapid (Valdez 1994, Valdez et al. 1995). Above Bridge Canyon Rapid, the red shiner was absent, but below the rapid it comprised 50 percent and 72 percent of all fish captured in tributaries and the mainstream, respectively (Valdez 1994, Valdez et al. 1995). Other common fish species found below Bridge

Canyon Rapid include the common carp, fathead minnow, and channel catfish; however, very little fish habitat exists in this reach due to declining elevations of Lake Mead and subsequent downcutting of accumulated deltaic sediments in inflow areas. Flannelmouth suckers comprised about 15 percent of the total catch from this reach during 2005 (Ackerman et al. 2006), several times greater than the 1.3 percent observed during 1992-1995 (Valdez et al. 1995). Percentage of speckled dace in the reach has not changed appreciably over the last decade, and no bluehead suckers were collected during 2005 (Valdez et al. 1995, Ackerman et al. 2006).

In an attempt to benefit native species, mechanical removal targeted at nonnative salmonid species in the mainchannel Colorado River and tributaries in Grand Canyon took place during 2003-2006 (Coggins and Yard 2003). Removal of salmonids and other nonnative fish (black bullhead, fathead minnow, common carp, brown trout) in the vicinity of the Little Colorado River by electrofishing contributed to a 90 percent reduction in rainbow trout over a four year period, although part of the decline is attributed to warmer main channel temperatures and higher daily flow fluctuations (GCMRC unpublished data). Main channel water temperatures during the removal period were as high as 6 °C (11 °F) above the 1990-2002 average. At the same time, electrofishing catch rates of young-of-year and age 1 flannelmouth sucker, bluehead sucker, and humpback increased by as much as a factor of ten; catch rates of speckled dace also increased.

Mechanical removal of spawning brown trout through weir operations in Bright Angel Creek yielded inconclusive results. During operations in 2002 (November—January), over 400 brown trout were removed from Bright Angel Creek and euthanized (Leibfried et al. 2005). When a similar removal effort was conducted in November—January of 2006, only 54 brown trout were removed, and rainbow trout catches were decreased by a similar proportion (Sponholtz and VanHaverbeke 2007). The decline cannot be attributed to weir operations alone, however, as both trout species experienced a considerable system-wide decline in abundance between the two removal periods.

Multi-pass backpack electrofishing was also evaluated as a mechanical control technique in Bright Angel and Shinumo creeks. In a 3.35 km reach of Bright Angel Creek, approximately 55 percent and 57 percent of the brown and rainbow trout populations, respectively, were removed through as many as 4 electrofishing passes. At Shinumo Creek, 35 to 85 percent of rainbow trout were removed through similar methods (Leibfried et al. 2006). In both creeks, however, recolonization rates from upstream and downstream have not been evaluated. Recently, GCMRC has proposed to implement a strategy to reduce warmwater nonnative fish (including crayfish) abundance and negative impacts to native fish found in the Colorado River in Grand Canyon (Hilwig et al., in review). This strategy would very likely be needed to offset potential undesirable positive responses of nonnative fish to artificial or natural increases in river temperatures. The draft plan consists of short-term (ca. 1-2 y) fulfillment of baseline information needs followed by implementation of longer-term (8+ y) nonnative fish control and management programs.

Asian fish tapeworm (*Bothriocephalus acheilognathi*), and anchor worm (*Lernaea cyprinacea*), may pose threats to native fish below Glen Canyon Dam. Asian tapeworm, first reported from Grand Canyon in 1990, is currently the most abundant fish parasite in the Little Colorado River, infecting 23-51 percent of all humpback chub (Clarkson et al. 1997, Choudhury et al. 2004) and also a variety of cyprinids. Main channel infestation rates are much lower and may be temperature-limited (4-22 percent) (Valdez and Ryel 1995). Optimal *B. acheilognathi* development occurs at 20-30 °C (68-86 °F) (Granath and Esch 1983). Choudhury et al. (2004) hypothesized that infection rates were positively related to both fish host and copepod density in the Little Colorado River and parasitic fauna found there have diversified through invasion of nonnative host fish species. *Lernaea cyprinacea* infects humpback chub at a higher rate than other species of fish in Grand Canyon (Hoffnagle 2000) and favors temperatures greater than 18 °C (64 °F)(Grabda 1963), with 23-30 °C (73-86 °F) being optimum (Bulow et al. 1979). Post-dam mainstream temperatures have prevented *L. cyprinacea* from completing its life cycle and limited its distribution to warmer backwaters. Infestation apparently does not increase fish mortality in the Upper Colorado Basin (Valdez and Ryel 1995).

A number of actions have been undertaken and are continuing under the auspices of the Glen Canyon Dam Adaptive Management Program to benefit the Grand Canyon population of humpback chub, including the AMP itself, its charter renewed in 2006. The AMP continues to provide a high level of monitoring and research on the Grand Canyon population of humpback chub, via the Grand Canyon Monitoring and Research Center. Annual mark-recapture monitoring of the species provides accurate estimates of population size of adult and sub-adult (150-199 mm TL [5.9-7.83 in]) humpback chub (Coggins 2007), important information for tracking progress on recovery (U.S. Fish and Wildlife Service 2002). Research and monitoring of native fishes in Grand Canyon, as well as their predators, competitors, diseases, and parasites is being carried out largely under the auspices of the GCMRC with funding provided by the AMP. Much of the research and monitoring work accomplished through GCMRC is accomplished through competitive proposals that are peer-reviewed by independent scientists. Results of this work are presented on a regular basis at TWG and AMWG meetings, and are published as reports and peer-reviewed articles in technical journals. Research on life history requirements, habitat needs, effects of dam operations, parasitism, predation, effects of handling stress, and numerous conservation actions described further below all continue (U.S. Geological Survey 2007b). Effects of these actions and experiments on fish populations and on the Grand Canyon ecosystem and are summarized in this section and in the Effects of the Action section.

In January 2003, the AMWG directed that an ad hoc committee be formed with the responsibility of developing a comprehensive plan for future research, monitoring, and management of the endangered fish. In August 2003, the humpback chub Ad Hoc Committee delivered the plan to the Science Advisors and then to AMWG, and the plan was used to fund projects in the 2004 and 2005 fiscal years. The plan, now referred to as the Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon, is presently being revised by the humpback chub Ad Hoc Committee and will be resubmitted to AMWG after projects are assessed by an AMWG ad hoc committee to determine which of them would be recommended for inclusion in the AMP.

Other aspects of the adaptive management planning process for humpback chub include development of a Strategic Science Plan, Core Monitoring Plan, several Beach Habitat Building Science Plans, and a study plan for the 2000 Low Steady Summer Flows and Nonnative Fish Mechanical Removal protocols. Many of these efforts are presently ongoing. In May and July of 2005, workshops to assess the knowledge gained through the AMP were conducted in Phoenix and Flagstaff, Arizona, respectively (Melis et al. 2005). At the workshops all aspects of the AMP were evaluated and assessed for the level of science and knowledge that had been gained to date. The workshops and resulting publications also helped to define and refine research questions and to prioritize research projects in the future on all aspects or resource management authority of the AMP including humpback chub. A science symposium was also conducted on October 25–27, 2005, (Gloss et al. 2005), providing a further synthesis of research and monitoring in the Colorado River ecosystem for the years 1991-2004.

Reclamation and the AMP conducted the first high flow experiment in March-April 1996, a week-long, 45,000 cfs beach habitat-building flow. Objectives were to rebuild high-elevation sandbars, restore backwater channels, retain fine silts and clays, restore the pre-dam disturbance regime, preserve and restore camping beaches, displace nonnative fishes, scour vegetation from camping beaches, and protect cultural resources, all without significant adverse impacts to endangered species, cultural resources, the Lees Ferry trout fishery, or hydropower production. Results of the 1996 experimental flood were documented by Webb et al. (1999), and are described in this section and in the Effects of the Action section.
In 1997, a fall flow test consisting of a powerplant release of 31,000 cfs for 48 hours was conducted.

In 1999, Reclamation funded a contractor to convene a panel of experts to develop a program of experimental flows for endangered and native fishes of the Colorado River in Grand Canyon (Valdez et al. 2000a). As part of this program, the third large experiment conducted by the AMP was an experimental flow for native fishes from March-September 2000. Flow components included: (1) short-term 8,000 cfs initiating the study for aerial photography; (2) stable, spring flows of 14,000-19,000 cfs to measure hydraulics and water temperatures at the mouth of the Little Colorado River; (3) spring and autumn powerplant capacity spike flows; (4) an extended period of 8,000 cfs during May, June, July, and August; and (5) a period of 8,000 cfs steady flows following the autumn spike flow to measure its effects and to conduct a second round of aerial photography. In October 2003 GCMRC convened a science symposium that was largely directed at presentation of results from the low summer steady flows (LSSF) research and monitoring. Effects of the experiment on fish populations were documented by Trammell et al. (2002), Rogers et al. (2003) and Speas et al. (2004), and are summarized in this section and in the Effects of the Action section.

In September 2002, Reclamation completed the Environmental Assessment on Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish (U.S. Bureau of Reclamation 2002), which proposed a program of experimental flows and nonnative fish removal. Mechanical removal of nonnative fish from the Colorado River above and below the LCR was started in January 2003 (Coggins and Yard 2003) and was continued through 2006. Rainbow trout and brown trout were removed from a 10-mile reach adjacent to the LCR. Nonnative suppression releases from Glen Canyon Dam were implemented from January to March 2003 to test the effectiveness of high fluctuating flows on limiting the recruitment of nonnative fish (Davis and Batham 2003). The high fluctuating flows for nonnative suppression were continued in 2004 and 2005.

In November 2004, a second high flow experiment was conducted. The duration of this release was reduced to 60 hours on peak and the magnitude was reduced to 41,500 cfs due to repairs being made on one of the dam turbines. Another important difference with the 1996 high flow experiment was that the 2004 release occurred only after sediment input triggers, based largely on antecedent input from the Paria River, had been met. The trigger required that at least 1 million metric tons of fine sediment had been received by the Colorado River prior to the high release.

In September and October of 2005, a series of two-week dam releases occurred that alternated between steady and fluctuating releases. The purpose of this short-term experiment was to examine the effects of daily fluctuations on water quality parameters and biotic constituents (phytoplankton, macroinvertebrates, and fishes) of associated shoreline habitats (Ralston et al. 2007).

In 2006, Reclamation initiated development of a long-term experimental plan which was proposed to include both dam releases and other management actions. This effort originated with a science planning group that produced four options which were recommended by the AMWG to the Secretary of the Interior. GCMRC provided an assessment of the effects of the four options (GCMRC 2006). Reclamation conducted public scoping meetings in December 2006 and January 2007 and identified the purpose and need for the Proposed Action as improving the understanding of the Colorado River ecosystem below Glen Canyon Dam and protection of key resources (humpback chub, sediment, and cultural resources). In April 2007, GCMRC convened a science workshop to evaluate the four options for their use in development of EIS alternatives. Workshop participants also developed a fifth alternative for consideration by Reclamation and its cooperating agencies.

In January 1999, Reclamation released a draft environmental assessment on a temperature control device (TCD) for Glen Canyon Dam. Such a device is also referred to as a selective withdrawal structure as its utility extends to other water quality issues as well as temperature control. The preferred alternative was a single inlet, fixed elevation design with an estimated cost of $15,000,000. Sufficient concern was evidenced in the review of the environmental assessment (Mueller et al. 1999) for unintended negative effects (i.e., nonnative fish proliferation) as a result of the operation of a TCD, as well as the lack of a detailed science plan to measure those effects, that the environmental assessment was withdrawn and not finalized. In 1999 and in 2001, Reclamation convened workshops to evaluate the feasibility of a temperature control device and to further develop research and monitoring for evaluating ecosystem responses to warmer temperatures.

In 2003, Reclamation completed a review of other selective withdrawal facilities, subsequently published in Vermeyen (2003). No major environmental complications were identified in the survey results. A risk assessment of the Glen Canyon Dam TCD proposal from the AMP Science Advisors (Garrett et al. 2003) recommended the installation of a TCD for Glen Canyon Dam as soon as possible and the construction of a pilot TCD in the interim. Reclamation continued to work on assessment of the TCD utilizing the U.S. Army Corps of Engineers' CE-QUAL-W2 model (Cole and Wells 2000) to model Glen Canyon Dam release temperatures, the 1-D Generalized Environmental Modeling System for Surface waters model (GEMSS; Kolluru and Fichera 2003) to model flow temperatures from Glen Canyon Dam to Separation Canyon, and the 3-D GEMSS model to model backwaters below the confluence of the LCR. The analysis showed an average increase in release temperature of about 3 °C (5 °F) with installation of a 2-unit TCD. Positive deviations with the 2-unit TCD begin in late April, peak in late summer to early autumn at about 7° C (13 °F), and remain positive until the end of November. The relationship between release temperature and downstream temperature is nonlinear and is limited by the ambient atmospheric conditions. During colder months release temperatures would cool as dam release waters moved downstream.

Reclamation also completed a risk assessment to help evaluate responses of aquatic resources in Grand Canyon to the construction and implementation of a TCD (Valdez and Speas 2007). The risk assessment utilized standard protocols and a mathematical model was used as a tool to quantify risks and benefits to fish, fish parasites, zooplankton, and macroinvertebrates from water temperature changes resulting from modification of 2 of the 8 generation units on the dam. All taxa present or with known potential to access the area were inventoried for each of six regions, including lower Lake Powell, Glen Canyon Dam to Paria River, Paria River to LCR, LCR to Bridge Canyon, and Bridge Canyon to Pearce Ferry. Results suggested benefits to all native fishes, but correspondingly higher benefits to many nonnative fish species that may compete with or prey upon native species. Fish species carrying the highest risk for benefiting from warmer water were rainbow trout, brown trout, common carp, fathead minnow, red shiner, channel catfish, and smallmouth bass. Preliminary results also show more suitable conditions for warmwater fish parasites, including anchor worm and Asian fish tapeworm. Results also predicted an increase in periphyton biomass and diversity with warmer water, which could lead to increased food and/or substrate for epiphytes, aquatic invertebrates, fish, and waterfowl. Warm water impacts to macroinvertebrates include minor shifts in relative abundance of existing taxa with the possibility of increased taxa richness, which could be beneficial if limited to insect taxa. However, increased potential for invasion by crayfish and other nuisance species is significant.

Reclamation has concluded that a TCD designed to allow only warmer water to be released downstream is technically feasible, but that the risks in terms of increases in nonnative species and their effects to humpback chub are significant. In light of these concerns and with the recommendation of an independent scientist panel convened in April 2007 to discuss long-term experimental planning, Reclamation also briefly investigated whether construction of a TCD with both warm- and cold-water release capability is possible and under what circumstances cold water would be available for release. Due to the high cost of design investigation, no specific design work or feasibility analysis was completed, thus feasibility of a TCD with both warm- and cold-water release capability remains a question and an information need. Since dam release temperatures during the experimental period are likely to be cold, new information on temperature effects during the experimental period will inform a potential future decision on construction of the TCD.

Reclamation has worked to help develop watershed planning efforts in the Little Colorado River. A Little Colorado River Management Plan was prepared in 1999 (SWCA 1999, SWCA 2005), but not finalized. Reclamation has had numerous meetings with representatives from various stakeholders that have constituted Little Colorado River watershed groups. Currently, there is a Statewide Water Resources Advisory Group that provides technical assistance and advice to interested parties. The Little Colorado River Plateau Resources Conservation and Development (RC&D) is focused on implementing a strategic plan developed by sponsors and Council Members with the priority goal of formulating and publishing an all inclusive watershed management plan. There are 32 participants in the RC&D. The Little Colorado River Watershed Coordinating Council operates under the umbrella of the RC&D and is developing the Little Colorado River Watershed Management Plan. The Bureau of Reclamation Lower Colorado Region has committed to fund 50 percent of the estimated $600,000 to develop the plan with the other 50 percent coming from the non-federal stakeholders. Reclamation will continue to work with these organizations to better understand how to affect land and water management in the LCR watershed in a manner that conserves water quantity and quality to benefit the endangered humpback chub. Reclamation will also continue to assist in developing a watershed management plan, emphasizing actions that could be accomplished to address the threats to the endangered humpback chub arising in the Little Colorado River Basin and the potential roles to be taken by various participants and watershed organizations as a conservation measure in this biological opinion.

Reclamation has also contributed to a better understanding of the genetic relatedness among populations of humpback chub in the Colorado River basin and aggregations of humpback chub in Grand Canyon by funding research and planning efforts. Valdez and Ryel (1995) established the presence of nine aggregations of humpback chub, including the individuals in the LCR. Genetic evaluations by Colorado State University (Douglas and Douglas 2007) on the entire taxon and by the FWS on humpback chub collected in the LCR and held at Willow Beach National Fish Hatchery have provided important information in making these determinations. Reclamation also funded, through the AMP, development of a genetics management plan for humpback chub in Grand Canyon, which is currently being developed (Keeler-Foster in prep.).

In 2003, as a conservation measure to the biological opinion on the 2002 experimental flows and nonnative fish removal proposal, the FWS began a translocation program funded by Reclamation for humpback chub above Chute Falls in the LCR. From 2003-05, a total of 1,150 young-of-year humpback chub were translocated from the lower LCR to the LCR above Chute Falls. Preliminary results indicate that translocated fish survival and growth rates are high; limited reproduction and downstream movement to below Chute Falls has also been documented (Sponholtz et al. 2005, Stone 2006, 2007). Reclamation has also investigated the feasibility of developing a second spawning population of humpback chub in Grand Canyon, utilizing translocation and actions to improve mainstem habitat (Valdez et al. 2000b). In 2002, 2003 and 2006 NPS funded nonnative rainbow trout and brown trout removal from Bright Angel Creek with backpack electrofishers and a fish weir (SWCA 2006, Sponholtz and VanHaverbeke 2007), to help control nonnative trout in the mainstem Colorado River and evaluate the potential for translocation of humpback chub into Bright Angel Creek.

Other actions in Grand Canyon that affect humpback chub include actions under the authority of the NPS under various management plans at Glen Canyon National Recreation Area and Grand Canyon National Park. These plans include activities such as commercial and noncommercial river trip permits, research permits, regulations on recreational use, and monitoring and management actions of the NPS. NPS recently completed its Colorado River Management Plan for management of recreation in Grand Canyon National Park, and completed consultation on the plan with FWS (U.S. Fish and Wildlife Service 2006). The plan includes implementing research on determining the possible effects of recreation on humpback chub; currently there is little available information on this subject. Actions undertaken within Grand Canyon National Park by NPS and other entities overlap with actions under the AMP; there is a need for improved coordination between these actions to better understand the overall effects to humpback chub.

The AGFD regulates recreational fishing for trout in Glen and Grand canyons. As previously discussed, nonnative trout are a predator and competitor of humpback chub. AGFD prohibits angling at the confluence area of the LCR and mainstem. Available information indicates that few rainbow trout in the Lees Ferry reach emigrate downstream (Maddux et al. 1987), although the lack of evidence of spawning and recruitment between Lees Ferry and the LCR suggests rainbow trout must emigrate from either upstream or downstream areas (GCMRC unpubl. data).

AGFD also conducts a variety of monitoring activities, in conjunction with FWS and GCMRC, on humpback chub in Grand Canyon. Despite the essential need to monitor humpback chub status, netting and electrofishing can cause mortality (Ruppert and Muth 1997, Paukert et al. 2005).

Although the timeframe of the proposed action is relatively short, 5 years, the effects of climate change should be considered. The ongoing drought and corresponding low reservoir levels and warm water releases in 2004-2006 illustrate the potential for climate change to impact humpback chub. The Fourth Assessment Report (Summary for Policymakers) of the Intergovernmental Panel on Climate Change (IPCC 2007) presented a selection of key findings regarding projected changes in precipitation and other climate variables as a result of a range of unmitigated climate changes projected over the next century. Although annual average river runoff and water availability are projected to decrease by 10-30 percent over some dry regions at mid-latitudes, information with regard to potential impacts on specific river basins is not included. Recently published projections of potential reductions in natural flow on the Colorado River Basin by the mid-21st century range from approximately 45 percent by Hoerling and Eischeid (2006), to approximately 6 percent by Christensen and Lettenmaier (2006), but, as documented in the Shortage Guidelines EIS (U.S. Bureau of Reclamation 2007c; Appendix N), these projections are not at the spatial scale needed for Colorado River Simulation System (CRSS), the model used to project future flows.

The CRSS hydrologic model, used as the primary basis of Reclamation's effects analysis, does not project future flows or take into consideration projections such as those cited above, but rather relies on the historic record of the Colorado River Basin to analyze a range of possible future flows. Using CRSS, projections of future Lake Powell reservoir elevations are probabilistic, based on the 100-year historic record. This record includes periods of drought and periods with above average flow. However, studies of proxy records, in particular analyses of tree-rings throughout the upper Colorado River Basin indicate that droughts lasting 15-20 years are not uncommon in the late Holocene. Such findings, when coupled with today's understanding of decadal cycles brought on by El Niño-Southern Oscillation and Pacific Decadal Oscillation (and upstream consumptive use), suggest that the current drought could continue for several more years, or the current dry conditions could shift to wetter conditions at any time (Webb et al. 2005). Thus, the period of the proposed action may include wetter or drier conditions than today.

Although precise estimates of the future impacts of climate change throughout the Colorado River Basin at appropriate spatial scales are not currently available, these impacts may include decreased mean annual inflow to Lake Powell, including more frequent and more severe droughts. Such droughts may decrease the average storage level of Lake Powell, which could correspondingly increase the temperature of dam releases. Increased release temperatures have been cited as one potential factor in the recent increase of young-of-year and juvenile humpback chub (USGS 2006) but concerns also exist that warmer aquatic habitat will also increase the risk of warm-water nonnative fish predation. To allay this risk if such warming occurs, in the Shortage Guidelines biological opinion Reclamation has committed to the monitoring and control of nonnative fish as necessary, in coordination with other Department of the Interior agencies and working through the AMP (U.S. Fish and Wildlife Service 2007).

Previous consultations on humpback chub in Grand Canyon have included the recently completed Shortage Guidelines biological opinion mentioned above, as well as consultations on the preferred alternative on the operations of Glen Canyon Dam, above powerplant-release experimental flows, nonnative trout removal, and various NPS management plans. Recent consultations are further summarized below.

Operation of Glen Canyon Dam

In January 1995, FWS concluded that the preferred alternative, the modified low fluctuating flow (MLFF) alternative, was likely to jeopardize the continued existence of the humpback chub and was likely to destroy or adversely modify their critical habitat. The 1995 biological opinion on the operation of Glen Canyon Dam identified a reasonable and prudent alternative (RPA) that was necessary to avoid jeopardizing the continued existence of the humpback chub. The RPA contained four elements that were necessary to avoid jeopardizing the continued existence of the humpback chub and razorback sucker: (1) development of an adaptive management program that implements studies and recommendations to increase the likelihood of both survival and recovery of listed species; (2) development of a management plan for the Little Colorado River; (3) sponsoring a workshop for developing a management plan for razorback sucker in Grand Canyon; and (4) establishing a second spawning aggregation of humpback chub below Glen Canyon Dam. The biological opinion also anticipated take in the form of displacement of juvenile fish downstream during beach habitat building flow (BHBF) tests. BHBF releases are scheduled high releases of short duration that are in excess of power plant capacity in accordance with hydrologic triggering criteria, designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system.

Spring 1996 Beach Habitat Building Flow from Glen Canyon Dam

The first test of a BHBF was conducted in spring of 1996. BHBF tests were included as part of the proposed action of the FWS January 1995 biological opinion on the preferred alternative for the Operation of Glen Canyon Dam. Consultation with the FWS was re-initiated on the preferred alternative from the 1995 EIS because a new species was listed since the original consultation, the southwestern willow flycatcher with proposed critical habitat. The FWS concluded that the proposed test flow was not likely to jeopardize the continued existence of the humpback chub, and determined take from the proposed action in the form of 25 humpback chub due to harm, harassment, and mortality due to displacement from the BHBF.

Fall 1997 Test Flow from Glen Canyon Dam

In November 1997 Reclamation conducted a fall test flow as a test of a powerplant release of 31,000 cfs for 48 hours. These smaller powerplant capacity flows, called Habitat Maintenance Flows (HMFs), were designed to help maintain results achieved from BHBF events. Because such a test in the fall was not addressed in prior consultations, consultation was reinitiated. FWS concluded that the test flow was not likely to jeopardize the continued existence of the humpback chub and was not likely to destroy or adversely modify designated critical habitat for the humpback chub. Take of humpback chub was anticipated from harm, harassment and mortality from displacement of juvenile humpback chub downstream.

2002 Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish

The FWS 2002 biological opinion covered the following actions: (1) experimental releases from Glen Canyon Dam (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish and; (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31.

FWS concluded that the proposed action was not likely to jeopardize the continued existence of the humpback chub, nor adversely affect its critical habitat. The December 2002 biological opinion included the incidental take of up to 20 humpback chub during the nonnative fish removal efforts. The action included, as a conservation measure, translocation of 300 humpback chub above Chute Falls, to increase the survivorship of young humpback chub by providing habitats with reduced predation and improved conditions for growth via temperature and food base. This consultation was reinitiated twice in 2003, to modify the number and size of humpback chub that could be translocated, and to alter the geographic extent of nonnative fish removal.

2004 Fall BHBF Test

Consultation was conducted in 2004 to conduct a BHBF test in the fall because existing compliance only allowed for a full BHBF test in the spring. FWS concluded that the action was not likely to jeopardize the continued existence of the humpback chub nor adversely modify its critical habitat. Reclamation included several conservation measures for humpback chub including the continuation of humpback chub translocation in the Little Colorado River, and further study and monitoring of the results and study of effects on humpback chub from dam operations including BHBF tests and stable and fluctuating flows. No additional take of humpback chub was anticipated beyond that provided in the 2002 biological opinion.

Grand Canyon National Park Colorado River Management Plan

On January 3, 2006, FWS completed its biological opinion on the NPS Colorado River Management Plan, a visitor-use management plan which specifies actions to preserve park resources and the visitor experience while enhancing recreational opportunities. FWS concluded that the action was not likely to jeopardize the continued existence of the humpback chub nor adversely modify its critical habitat. Conservation measures for humpback chub included restricting recreational use in the Little Colorado River, and implementing research to better determine the effect of recreational use on the species, as available funding permits. FWS anticipated incidental take in the form of harassment of humpback chub at the confluence of the Little Colorado River, from recreation-related disturbance, up to an amount that results in physical injury or morality; reasonable and prudent measures and terms and conditions included implementing research to determine the effect of recreation on humpback chub.

2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead

FWS completed a biological opinion on the Shortage Guidelines on December 12, 2007.
The Shortage ROD specified reduction of consumptive water uses below Lake Powell during

times of low reservoir conditions and modification of the annual release volumes from Lake Powell. Adverse effects to humpback chub were determined to come primarily from the potential for beneficial effects to nonnative fish, resulting in subsequent competition with or predation on humpback chub, and beneficial effects to Asian tapeworm that could cause increased parasitism. FWS concluded that the Shortage Guidelines were not likely to jeopardize the continued existence of the humpback chub, the southwestern willow flycatcher, or the Kanab ambersnail, and not likely to destroy or adversely modify designated critical habitat for the humpback chub or the southwestern willow flycatcher. FWS anticipated incidental take of humpback chub in the form of harm and mortality, and was determined to be exceeded if the proposed action results in an increase in nonnative species and subsequent decrease in the status of the humpback chub, despite efforts by Reclamation through the AMP to control nonnative fish species; specifically: (1) a 50 percent increase in nonnative fish species abundance in the mainstem Colorado River at the confluence of the LCR from 2007 levels; and (2) efforts to control nonnative fish species by Reclamation in collaboration with GCMRC and other DOI agencies and AMP participants are ineffective such that the increase persists over a consecutive 5-year period; and (3) during this consecutive 5-year period, monitoring indicates a significant decline in humpback chub recruitment or survivorship that is solely attributable to the proposed action.

The Shortage Guidelines included conservation measures to offset the adverse affects of the proposed action. There is broad overlap in the proposed action being investigated in this biological opinion and the Shortage Guidelines, and the AMP will be Reclamation's vehicle and authority to carry out conservation actions with regard to both actions. The conservation measures from the Shortage Guidelines biological opinion will therefore largely be implemented concurrently with those of this biological opinion, and consist of the following:

Nonnative Fish Control – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue efforts to control both cold- and warm-water nonnative fish species in the mainstem of Marble and Grand canyons, including determining and implementing levels of nonnative fish control as necessary. Control of these species using mechanical removal and other methods will help to reduce this threat.

Humpback Chub Refuge – Reclamation will assist FWS in development and funding of a broodstock management plan and creation and maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing expedited advancement of $200,000 in funding to the FWS during CY 2008; this amount shall be funded from, and within, the amount identified in the MSCP BO (U.S. Fish and Wildlife Service 2005a; page 26). Creation of a humpback chub refuge will reduce or eliminate the potential for a catastrophic loss of the Grand Canyon population of humpback chub by providing a permanent source of genetically representative stock for repatriating the species.

Genetic Biocontrol Symposium – Reclamation will transfer up to $20,000 in fiscal year 2008 to FWS to help fund an international symposium on the use and development of genetic biocontrol of nonnative invasive aquatic species which is tentatively scheduled for October 2009. Although only in its infancy, genetic biocontrol of nonnative species is attracting worldwide attention as a potential method of controlling aquatic invasive species. Helping fund an effort to bring researchers together will further awareness of this potential method of control and help mobilize efforts for its research and development.

Sediment Research – In coordination with other DOI AMP participants and through the AMP, Reclamation will monitor the effect of sediment transport on humpback chub habitat and will work with the GCMRC to develop and implement a scientific monitoring plan acceptable to FWS. Although the effects of dam operation-related changes in sediment transport on humpback chub habitat are not well understood, humpback chub are known to utilize backwaters and other habitat features that require fine sediment for their formation and maintenance. Additional research will help clarify this relationship.

Parasite Monitoring – In coordination with other DOI AMP participants and through the AMP, Reclamation will continue to support research on the effects of Asian tapeworm on humpback chub and potential methods to control this parasite. Continuing research will help better understand the degree of this threat and the potential for management actions to minimize it.

Kanab Ambersnail

In the action area, the Kanab ambersnail occurs in the vegetation at the spring-fed Vaseys Paradise. Vaseys Paradise is a popular water source and attraction site for Colorado River boat trips; however, access is limited by a dense cover of poison ivy (*Toxicodendron rydbergii*). The habitat and population size of Kanab ambersnail is influenced by interseasonal and interannual conditions, including drought-induced variation in spring flow, die-back of vegetation, killing frosts, monsoon-related scour, browsing by ungulates (primarily bighorn sheep [*Ovis canadensis*]) and other factors. The population size may vary 10-fold between the end of the winter season and the peak of summer reproduction.

Historically, the Grand Canyon experienced annual floods of 100,000+ cfs and Kanab ambersnail were likely swept downstream and drowned (Stevens et al. 1997a). Today, Glen Canyon Dam limits such flood events, although several high flows above power plant capacity, such as BHBFs, have resulted in discharges of up to 45,000 cfs. Flows of this magnitude will inundate and scour the occupied habitat of the Kanab ambersnail at Vaseys Paradise. Most, if not all, snails in the vegetation would be washed down river or covered with sediment. Based on estimates calculated in August 2004, a flow of 45,000 cfs would scour approximately 1,285.2 ft^2 of habitat, approximately 17 percent of available habitat. During the 2004 BHBF, AGFD and GCMRC removed portions of ambersnail habitat in the potential inundation zone prior to the flood and later replaced these habitat pieces after flooding subsided. The conservation measure was deemed successful, as these lower habitat areas had recovered completely in 6 months. Recovery of this habitat from previous high flow tests that did not include habitat mitigation efforts required 3 years for ambersnail habitat to recover completely from scouring (Sorensen 2005).

Trampling by recreationists and flash floods from the talus slope above Vaseys Paradise also contribute to habitat loss and can results in direct Kanab ambersnail mortality. However, impacts from recreationists are likely minimal due to steep slopes and a dense cover of poison ivy. Additionally, plateau-origin flash floods are rare in the region (Stevens et al. 1997a).

Evidence exists that a small number of Kanab ambersnails at Vaseys Paradise were parasitized by a trematode, tentatively identified as *Leucochloridium* sp. (Stevens et al. 1997b). Potential vertebrate predators include rainbow trout (in submerged areas), summer breeding Say's and black phoebe (*Savornis savi* and *S. niaricans*), canyon wren (*Catherpes mexicanus*), winter resident American dipper (*Cinclus mexicanus*), and canyon mice (*Peromyscus crinitus*) (Stevens et al. 1997b, U.S. Fish and Wildlife Service 1995a). Predation rates by birds and mice are not available, but analysis of mice feces indicates that snails are not regularly eaten by rodents (Meretsky and Wegner 1999).

Water sedge, a plant with patchy distribution in Kanab ambersnail habitat, is a source of forage for bighorn sheep, especially during a drought. Vaseys Paradise is now regularly used by bighorn sheep, resulting in vegetation used by the snails being trampled (Gloss et al. 2005). Drought conditions from 2001-2003 caused one of the two prominent spring caves to go completely dry in 2004. The drought conditions and increased grazing by bighorn sheep in the snail's habitat at Vaseys Paradise caused a shift in vegetation resulting in more mixed plots with less watercress and apparently reduced the amount and quality of ambersnail habitat; as a result, numbers of ambersnails declined. Wetter conditions since then have resulted in both spring caves flowing again; habitat appears to have improved, although numbers of ambersnails detected in plot sampling are still relatively low (Sorensen 2005).

Reproduction has been documented in the population introduced at Elves Chasm, and the population is self-sustaining, although recently the ambersnail has become rare at this location. In 1999, an expert panel was convened to evaluate the status of this species and related mollusk species. Ongoing questions about taxonomic status remain, although ongoing mitochondiral and cellular (microsatelite) DNA analysis should clarify this issue (M. Culver, University of Arizona, pers. comm. 2007). An "Interim Conservation Plan of *Oxyloma (haydeni) kanabensis* complex and Related Ambersnails in Arizona and Utah" has been developed by AGFD (Sorensen and Nelson 2002) and guides current management.

Previous consultations for this species in Grand Canyon have included the preferred alternative on the operations of Glen Canyon Dam, above powerplant release experimental flows, and other actions; these consultations are summarized below.

Operation of Glen Canyon Dam

In January 1995, FWS concluded that the preferred alternative on operations of Glen Canyon Dam, the MLFF alternative, was not likely to jeopardize the continued existence of the Kanab ambersnail. Take of Kanab ambersnail was anticipated in the form of harm, harassment and mortality from the scouring loss of habitat during BHBF tests in the amount of 10 percent of occupied habitat at Vaseys Paradise.

Spring 1996 Beach Habitat Building Flow from Glen Canyon Dam

Consultation was reinitiated on the proposed action of the January 1995 biological opinion to allow for a proposed test of a BHBF from Glen Canyon Dam in the spring of 1996, because a new species had been listed (southwestern willow flycatcher), and in part because new information revealed that incidental take for the Kanab ambersnail would be exceeded. FWS concluded that the action was not likely to jeopardize Kanab ambersnail, and anticipated take in the form of harm, harassment, and mortality from the scouring loss of habitat during the BHBF would be in the amount of 17 percent of the Kanab ambersnail habitat at Vaseys Paradise. Reasonable and prudent measures and terms and conditions included monitoring of effects of the test on the Vaseys Paradise population, and translocating snails out of the inundated zone into higher elevation habitat.

Fall 1997 Test Flow from Glen Canyon Dam

In November 1997, Reclamation conducted a fall test flow as a test of a powerplant release of 31,000 cfs for 48 hours, an HMF. Because such a test in the fall was not addressed in prior consultations, consultation was reinitiated. FWS concluded that the action was not likely to jeopardize Kanab ambersnail, and anticipated take in the form of harm and mortality from the scouring loss of habitat during the HMF in the amount of 1 percent of the Kanab ambersnail habitat at Vaseys Paradise. Reasonable and prudent measures and terms and conditions included monitoring of effects of the flow on the Vaseys Paradise population, and establishing a refuge population and a second wild population.

2002 Proposed Experimental Releases from Glen Canyon Dam and Removal of Nonnative Fish

The December 2002 biological opinion included the following actions: (1) experimental releases from Glen Canyon Dam; (2) mechanical removal of nonnative fish from the Colorado River in an approximately 9-mile reach in the vicinity of the mouth of the Little Colorado River to potentially benefit native fish and; (3) release of nonnative fish suppression flows having daily fluctuations of 5,000-20,000 cfs from Glen Canyon Dam during the period January 1-March 31.

FWS concluded that the action was not likely to jeopardize Kanab ambersnail. The proposed action included a conservation measure consisting of temporary removal and safeguard of approximately 25 to 40 percent of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat would be replaced once the high flow was complete to facilitate re-establishment of vegetation. Take was anticipated in the form of harm and mortality from the scouring loss of 117 m^2 (1,259.4 ft^2) of habitat during a BHBF.

2004 Fall BHBF Test

Consultation was re-initiated in 2004 to conduct a BHBF test in the fall because existing compliance only allowed for a test in the spring. FWS concluded that the action was not likely to jeopardize the continued existence of the Kanab ambersnail. The proposed action included a conservation measure consisting of temporary removal and safeguard of approximately 25 to 40 percent of Kanab ambersnail habitat that would be flooded by the experimental release. The relocated habitat would be replaced once the high flow was complete to facilitate re-establishment of vegetation. Take was anticipated in the form of harm and mortality from the scouring loss of 119.4 m^2 (1,285.2 ft^2) of habitat during a BHBF.

Grand Canyon National Park Colorado River Management Plan

On January 3, 2006, FWS completed its biological opinion on the NPS Colorado River Management Plan, a visitor-use management plan which specifies actions to preserve park resources and the visitor experience while enhancing recreational opportunities. FWS concluded that the action was not likely to jeopardize the continued existence of the Kanab ambersnail. Conservation measures included educating river guides about the presence of the species and potential for recreation-induced impacts, monitoring, and, as available funding permits, implementing research to assess the effects of recreation on Kanab ambersnails. Take was anticipated in the form of harm and mortality in the amount of 10 m^2 (107.6 ft^2) of Kanab ambersnail habitat at Vaseys Paradise from recreational use.

2007 Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead

FWS completed a biological opinion on the Shortage Guidelines on December 12, 2007. The Shortage ROD specified reduction of consumptive uses below Lake Powell during times of low reservoir conditions and modification of the annual release volumes from Lake Powell. Adverse effects to Kanab ambersnail were anticipated due to scouring of habitat during high flows following periods of low flow and new habitat establishment compared to no action conditions. Take was anticipated in the form of harm and mortality due habitat scouring, and was determined to be exceeded if the proposed action results in a long-term decrease in the amount of Kanab ambersnail habitat; specifically: (1) ongoing monitoring by Reclamation, in collaboration with GCMRC and other DOI agencies and AMP participants, reveals that there is a reduction of the amount of Kanab ambersnail habitat present at Vaseys Paradise of more than 20 percent from 2007 that is solely attributable to the proposed action; and (2) efforts to prevent habitat loss by Reclamation, in collaboration with other AMP participants, prove ineffective such that this reduction in Kanab ambersnail habitat at Vaseys Paradise continues over a 5-year period. Reclamation included the following conservation measure:

Monitoring and Research – Through the AMP, Reclamation will continue to monitor Kanab ambersnail and its habitat in Grand Canyon and the effect of dam releases on the species, and Reclamation will also assist FWS in funding morphometric and genetic research to better determine the taxonomic status of the subspecies.

EFFECTS OF THE ACTION

Effects of the action refer to the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated and interdependent with that action that will be added to the environmental baseline. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration. Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur.

Humpback Chub and Its Critical Habitat

The proposed action consists of five years of MLFF flows (U.S. Bureau of Reclamation 1995, 1996) with a one-time high flow test in March of 2008 of approximately 41,000 cubic feet per second and stable flows in September and October in all five years. Reclamation intends this action to assist in the conservation of endangered species as well as providing benefits to sediment conservation, increasing scientific understanding, and to collect data for use in determining future dam operations. Overall, the proposed action should have a positive benefit to humpback chub and its critical habitat compared to current conditions by improving nearshore habitat important for young humpback chub, although there may be some short-term minor impacts to the species, primarily via temporary downstream displacement of humpback chub during experimental high flow releases designed to enhance areas of backwater habitat and the potential to benefit nonnative species with steady flow releases.

Small-bodied humpback chub may be vulnerable to displacement by high flows (above 30,000 cfs) conducted during periods of cold dam releases (8-10 °C [46.4-50.0 ºF]) when their swimming performance is reduced (Bulkley et al. 1982). The high flow test proposed for 2008 would not occur until March, which historically has been viewed as the timeframe posing the least amount of risk to a number of species, including humpback chub (Hoffnagle et al. 1999, U.S. Bureau of Reclamation 1995), the young of which are generally thought to utilize deeper eddies and shoreline cover in the fall and winter months (Valdez and Ryel 1995). However, as in 2004, the Colorado River currently supports high numbers of young-of-year and juvenile humpback chub (Ackerman 2007) that would theoretically be vulnerable to displacement by high flow tests.

Reclamation evaluated effects of high flows by comparing retention rates (i.e. percentage of fish able to maintain their position in a given reach) expected during a high flow test to those predicted for the median monthly flow in March under MLFF (U.S. Bureau of Reclamation 2007a). Retention rates over a range of flows were modeled using a particle-tracking algorithm in conjunction with velocity predictions from a 2-D hydrodynamic model developed by Korman et al. (2004). This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5, below the LCR confluence. The model contains four assumptions of fish swimming behavior: 1) passive, no swimming behavior; 2) rheotactic, in which particles (or "fish") swim toward lower velocity currents at 0.1 to 0.2 m/s (0.33 to 0.66 ft/s); 3) geotactic, in which particles swim toward the closest bank at 0.2 m/s (0.66 ft/s); and 4) upstream, in which the particle attempts to move upstream at 0.2 m/s (0.66 ft/s). Temperature of the Colorado River in the LCR inflow reach during the proposed time period for high flow tests (early March) typically ranges from 8 to 10 °C (46-50 ºF, AGFD 1996). At these levels, young-of-year and juveniles may fatigue rapidly and may be unable to withstand swift currents, forage efficiently, or escape predators. Bulkley et al. (1982) reported that swimming ability of young-of-year and juvenile humpback chub (73–134 mm [2.87-5.28 in] TL) in a laboratory swimming tunnel was positively and significantly related to temperature. Humpback chub forced to swim at a velocity of 0.51 m/sec (1.67 ft/sec) fatigued after an average of 85 minutes at 20 °C (68 ºF), but fatigued after only 2 minutes at 14 °C, a reduction in time to fatigue by 98 percent. Time to fatigue is presumably further reduced below 14 °C (57 ºF), especially for the smallest individuals. For these reasons, and also to identify the "worst case scenario" of fish displacement, Reclamation focused primarily on results for passive swimming behavior in their analysis.

Adult humpback chub will likely be little affected by high flows (Hoffnagle et al. 1999, Valdez and Hoffnagle 1999), although high flows would occur at a time of the year prior to the historical spring run-off that would result in the rise of the pre-dam hydrograph. Little is known about the extent to which humpback chub rely on changes in flow as a reproductive cue. Valdez and Ryel (1995) held that neither water quantity or quality serve as cues for gonadal development or staging behavior in humpback chub; rather they hypothesized that climatic factors, such as photoperiod, were important. Humpback chub typically begin to spawn on the receding hydrograph as water temperatures start to rise (Kaeding and Zimmerman 1983, Tyus and Karp 1989, Kaeding et al. 1990, Valdez and Ryel 1995), but the LCR population also spawns in years with little appreciable runoff.

Korman et al. (2004) predicted that retention rates of small-bodied fish in the Colorado River immediately below the LCR will decrease with increased discharge, but that this pattern tended to vary considerably with reach geomorphology and assumptions on swimming behavior of the fish. Passively drifting fish were the most susceptible to displacement, but also the least sensitive to the effects of variable discharge magnitude. Assuming that passively drifting fish can be used to represent the poor swimming ability of humpback chub at low temperatures, then we would expect that about 21 percent of these fish would be able to maintain their position within a given river reach during high flow tests of 41,500 (Korman et al. 2004). The retention rate at mean monthly flows for March under MLFF (about 9,400 cfs), by contrast, is predicted to be about 36 percent. Therefore we would expect retention to decrease by 15 percentage points during the proposed action; absolute numbers of fish swept downstream would be dependent on young-of-year and juvenile population size at the time of the high flow test in March 2008.

Total suitable habitat would also be at a low level across the continuum of flow elevations during the high flow test. However, available habitat over talus and debris fan substrates is not expected to change during high flows as compared to regular MLFF releases (about 9,700 cfs), and area of vegetated shorelines would actually be near its maximum predicted values. Thus if the fish could exploit these unchanged or improved habitats as refuge from high flows, displacement could be minimized (see also Converse et al. 1998).

A reasonable, although very approximate, estimate of numbers of young-of-year and juvenile humpback chub that could be present during the high flow test, based on catch rates and hoop net catch data, is about 6,000 (L. Coggins, U.S. Geological Survey, pers. com. 2007). Thus, based on Korman et al. (2004), approximately 900 young-of-year and juvenile humpback chub could be displaced. Conducting a high flow test during the month of March nevertheless appears to pose the fewest risks to young-of-year and juvenile humpback chub. During this period, occurrence of larval humpback chub in the Colorado River should be minimal or nonexistent. In contrast to the November 2004 high flow test, humpback chub would be about 10 months old in March (as opposed to five months), and presumably stronger and better able to adjust position with varying flows. Depending on habitat use and growth rate assumptions, humpback chub should be from five to 20 mm (0.79 in) larger in March than in November at 8-12 °C (46-54 °F) (Lupher and Clarkson 1994, Valdez and Ryel 1995, Gorman and VanHoosen 2000, Petersen and Paukert 2005). Hoffnagle et al. (1999) reported no statistically significant change in catch rates of young humpback chub along shorelines before and after the March-April 1996 controlled flood of 45,000 cfs. Catch rate of humpback chub did significantly decline in 2004 after the high flow test, although this may also have been caused by increased turbidity, confounding these results (GCMRC, unpublished).

Nonnative fish are also likely to experience negative impacts of the high flow tests, perhaps more so than humpback chub due to their preferences for lower water velocities (Minckley and Meffe 1987). Hoffnagle et al. (1999) noted that the 1996 test had few discernable effects on native fish, but reduced numbers of fathead minnow and plains killifish, presumably by downstream displacement. Trammell et al. (2002) found similar results for fathead minnow during the September 2000 habitat maintenance flow. Similar results involving other native and nonnative species have also been found in other streams in the southwest (Minckley and Meffe 1987, Schultz et al. 2003).

Although results of the 2004 high flow test support predictions made in Korman et al. (2004), no attempt has been made to validate the assumptions of the model with empirical data, so displacement rates of young-of-year and juvenile humpback chub over a range of operational and experimental flows remain uncertain and should be evaluated. The fate of displaced humpback chub in downstream reaches is also unknown; the exact river reaches and habitat conditions they are likely to arrive at are not known. Also, the exact number of fish displaced by high flows will vary markedly by the distribution of fish among discrete shoreline types, as certain shoreline types afford more refuge from high flow velocities than others (e.g., talus slopes provide better cover as compared to sandbars). Downstream displacement could provide positive effects for some humpback chub if they are carried to downstream aggregations, survive, and increase the size of these groups.

The high flow test may also create or improve backwater habitats. Impacts of high flow tests on backwater habitats occur at both short-term (i.e., weeks to months following high flow tests) and long-term (i.e. months to years) time scales. Information is available on short-term effects to backwater habitats following high flow tests (Parnell et al. 1997, Brouder et al. 1999, Wiele et al. 1999), but long-term effects are not well documented, and likely vary depending on sediment availability prior to the test and differences in post-test flow regimes.

Reclamation assumed in its biological assessment that backwaters in Grand Canyon are mostly inundated, but non-flowing, eddy return current channels, and as such, sandbars are a requisite condition for their occurrence. The elevation of sandbars and depth of recirculation channels are significant correlates reflecting the availability of backwaters over a range of flows. The higher the sandbar elevation, the more likely the separation of the backwater from mainchannel currents would occur over a range of flows. The depth of the recirculation channel serves the same function as the height of the sandbar, with the greatest depths creating more frequent availability of backwaters over the greatest range of flows. High flow tests tend to increase the elevation of the sandbar and deepen the return current channel (Andrews 1999, Goeking et al. 2003), although there are exceptions to this general pattern (Parnell et al. 1997).

Immediate physical impacts of high flow tests on backwater habitats include increased relief of bed topography, increased elevation of reattachment bars and deepened return current channels (Andrews et al. 1999). Biologically, the 1996 test significantly reduced backwater macroinvertebrate standing stocks due to scouring of the return current channel, but key taxa (i.e., chironomids) recovered to pre-flood levels within three months (Brouder et al. 1999). Nutrient enrichment due to burial and decomposition of organic matter during the high flow test (Parnell et al. 1999) probably enhanced recovery of benthic macroinvertebrates. As a result, reductions of invertebrate prey had little or no impact on food availability to fish (McKinney et al. 1999, Valdez and Hoffnagle 1999). Further, since humpback chub probably do not commonly utilize backwaters in March (Valdez and Ryel 1995) (proposed time frame for the 2008 high flow test), negative effects due to reduced food availability in backwaters at this time of year is less likely to have an adverse effect to humpback chub.

One goal of test flows conducted during 1996 and 2004 was redistribution of channel bottom sediment to the channel margins to establish and maintain habitats for young life stages of humpback chub in the mainstream. The chief difference between the proposed 2008 high flow test and previous experiments is that the amount of fine sediment in the system is about three times greater than that which triggered the 2004 high flow test. This greater sediment availability during 2008 should lead to more widespread construction of sandbars (Schmidt 1999, U.S. Geological Survey 2007a), which should increase the likelihood of backwater formation and more nursery habitat for humpback chub. This assumption is an uncertainty and will be considered in this test using comparisons of before and after habitat mapping.

The relationship between backwater bathymetry and suitability as fish habitat in Grand Canyon, specifically the relationship between dam operations, depth, area, volume and thermal characteristics, is a longstanding information need. Goeking et al. (2003) point out that large backwaters may not incur as many benefits to young native fish as smaller backwaters because the latter will warm faster and thus remain warmer over time than larger backwaters; however, due to their depth, they may be more frequently available as fish habitat over a greater range of flows. In the Upper Colorado River basin, Colorado pikeminnow were found to utilize backwaters with average depths greater than 0.3 m (1.0 ft)(Trammell and Chart 1999). While greater depths afford more availability over a wide range of flows (Muth et al. 2000), the concurrent increase in volume with depth may slow warming rates.

Persistence of backwaters created during 1996 appeared to be strongly governed by post-high flow dam operations. Whereas the 1996 test resulted in creation of 26 percent more backwaters available as rearing areas for Grand Canyon fishes, most of these newly created habitats disappeared within two weeks due to reattachment bar erosion (Parnell et al. 1997, Brouder et al. 1999, Hazel et al. 1999, Schmidt et al. 2004). Nearly half of the total sediment aggradation in recirculation zones had eroded away during the 10 months following the experiment and was associated in part with relatively high fluctuating flows of 15,000-20,000 cfs (Hazel et al. 1999). Similarly, following the 2004 test, high flows of 5,000-25,000 in January to early April of 2005 appeared to contribute to the rapid degradation of newly created backwaters utilized by humpback chub (R. VanHaverbeke, FWS, pers. com. 2006).

Because sediment erosion and transport increases with discharge volume and range of fluctuation (U.S. Geological Survey 2008), post-high flow test flows will determine in part the long-term persistence of created habitats. Post-test flow regimes to minimize erosion have yet to be developed and tested, and are not part of the proposed action. However, MLFF flows in the months following the March 2008 test flow will consist of moderately low fluctuating flows (Tables 3 and 4), with a maximum flow and range of fluctuations of 9,300-17,300 cfs occurring in July and August of 2008. Thus if the high flow test is successful in creating backwaters they should persist over a longer period than previous tests.

Reclamation used a 2-D hydrodynamic model to predict two-dimensional fields of depth and velocity over a range of daily flow fluctuations and monthly volumes (Korman et al. 2004) to determine how changes in flow from the proposed action to current conditions would affect fish habitat. Specifically, the model evaluated young-of-year fish habitat availability and suitable habitat persistence in Grand Canyon under MLFF and the proposed action. Depth and velocity at seven transects in the first 10 km (6.2 mi) below the LCR were modeled over the range of flows proposed in the alternative. This model was developed using channel bathymetry from seven transects located from RM 61.5 to 66.5 (Wiele et al. 1996, 1999). Transects ranged from 253 to 993 m (830 to 3259 ft) in length and represented the full range of shoreline types typically utilized by young-of-year humpback chub: talus slopes, debris fans, vegetated shorelines, cobble bars, bedrock and sandbars. Descriptions of these shoreline types can be found in Converse et al. (1998). The hydrodynamic model was used successfully to predict patterns of sand deposition following the 1993 flood from the Little Colorado River and during and after the 1996 high flow test (Wiele et al. 1996, 1999), illustrating the accuracy of the model.

The amount of total suitable habitat at a given flow elevation was computed by summing the total wetted area of each reach where velocity was less than or equal to critical values. Two criteria were evaluated for suitable water velocity: < 0.25 m/s (0.82 ft/s) and <0.10 m/s (0.33 ft/s). The first criterion was a composite of several field and laboratory studies published previously, including Bulkley et al. (1982), Valdez et al. (1990) and Converse et al. (1998). The second criterion was selected to be more representative of a suite of nonnative species currently found in the Little Colorado River or the adjacent main channel Colorado River (Minckley and Meffe 1987). Depths of <1 m (3.3 ft, maximum depth of most humpback chub habitats sampled in Converse et al. 1998) were used to further restrict predictions on suitable humpback chub and nonnative fish habitat. To further simulate young-of-year and juvenile humpback chub habitat availability, habitat predictions were limited to areas that intersected the streambed and computed habitat over shoreline types. Persistent suitable habitat was used to determine the area of suitable habitat that is stable across daily ranges in discharge (Bowen et al. 1998, Freeman et al. 2001, Korman et al. 2004). The suitable habitat areas at 5,000 cfs, 8,000 cfs, and 15,000 cfs were calculated for each transect. The total area of habitat common to flow elevations is referred to as the amount of "persistent suitable habitat."

Reclamation also presented absolute values for suitable habitat specific to discrete shoreline types to show habitat availability over a range of discharge found in the proposed action and MLFF, and considered the three shoreline types most commonly utilized by humpback chub (talus, vegetated shorelines, debris fans) as well as the total habitat area (<0.25 m/s [0.82 ft/s], <1 m [3.3 ft] depth) intersecting all shoreline types. Reclamation examined the relationship of flows on fish habitat across a range of flows using previously published predictions for flows to approximate effects of the proposed action (Korman et al. 2004). The assumption is that predictions for habitat persistence at a steady release of 8,000 cfs would approximate September and October steady releases in the proposed action (8,000 or 9,000 to 10,000 cfs per day), and that daily ranges between 5,000 cfs and 8,000 cfs would approximate MLFF conditions for the same period (5,000 to 12,000 cfs/day). Higher fluctuations of 8,000 cfs to 20,000 cfs were used to approximate fluctuations at higher flow elevations such as those in July and August.

The net effect of steady flows during September and October on habitat persistence is most likely to be positive. Depending on river location, the amount of persistent habitat increases by 63 to 400 percent when flows are held steady at 8,000 cfs as compared to fluctuations between 5,000 and 8,000 cfs (Korman et al. 2004) (Figure 15). The increase is even more dramatic when compared to higher fluctuations (8,000 to 20,000 cfs). So predictions for persistence of fish habitat for flows of the proposed action (i.e., relatively steady flows of 9,000-10,000 cfs as compared to fluctuations between 5,000 to 12,000 cfs per day) should be similar, that is that stable flows will dramatically increase the amount and persistence of suitable habitat.

The same benefits of a more stabilized nearshore environment would be accrued for nonnative fish; however, their general preference for slightly lower water velocities restricts them to a smaller area than for humpback chub and perhaps other native fish, which tend to be more tolerant of higher velocities (Meffe and Minckley 1987, Minckley and Meffe 1987). Reclamation found that, depending on the transect, humpback chub have available for their use at any given point under steady flows 16 to 34 percent more habitat than nonnative fish, which presumably translates into a competitive advantage for humpback chub and other native fish (U.S. Bureau of Reclamation 2007a).

One consequence of allocating volumes of water released by Glen Canyon Dam throughout the year by month is that, during wet years and years of high reservoir elevation, flow volumes during the transition from September to October could diminish by over 50 percent depending on real-time dam operations decisions; similar transitions could occur, and have occurred in the past, between August and September. With that change comes a dramatic decrease in daily minimum flows, which is expected to increase available habitat for humpback chub. However, the rate at which this shift from one month to another is a very rapid change in flow regime. This may entail bioenergetic costs to humpback chub as they are forced to relocate to favorable habitat as habitats under the preceding month become dewatered or flooded as new habitats are created. This effect could be exacerbated, for example, if chub are using the vegetated portion of the channel inundated at high flows but then need to move to talus or debris fans habitat at the lower elevations. The risk of stranding is also a concern. So more gradual transitions from one water year or one monthly allocation to the next, especially during wet years, may have important benefits to humpback chub; as a conservation measure, Reclamation has committed to researching this issue to minimize potential impacts to humpback chub.

Humpback chub growth rates vary as a function of water temperatures (Lupher and Clarkson 1995, Clarkson and Childs 2000). Flow regime (monthly volume and degree of flow fluctuation) can have a profound effect on water temperatures in the Colorado River in Grand Canyon (Trammel et al. 2002, Korman et al. 2006) (monthly volume, steady and fluctuating flows during September and October). Flow regimes in the proposed action will be the same as MLFF, with the exception of steady flows in September and October.

To analyze effects of steady and fluctuating flows on temperature-influenced growth of humpback chub, Reclamation (2007a) used models and empirical backwater and main channel temperatures (from Trammell et al. 2002) and information on young-of-year and juvenile humpback chub growth rates at different temperatures from observations from laboratory and field studies (Lupher and Clarkson 1995, Valdez and Ryel 1995, Clarkson and Childs 2000, Gorman and VanHoosen 2000, Peterson and Paukert 2005).

Reclamation (2007a) found that, based on historic data (Trammell et al. 2002), main channel water temperatures in September are predicted to be 1-2 °C (1.8-3.6 °F) warmer under steady flow conditions than under fluctuating flows, and backwater temperatures are predicted to be 0.9-1.8 °C (1.6-3.2 °F) warmer than the mainchannel. Depending on river reach, humpback chub growth rates during the month of September are predicted to increase by 12 to 36 percent in the mainchannel environment and nine to 19 percent more in backwaters. This increase in growth is due solely to changes in temperature; additional increases in growth could also accrue from bioenergetic benefits via increased habitat stability and increased abundance in prey. No assessment was possible for October due to a lack of information, although Korman et al. (2005) found backwaters to be about 1 °C (1.8 °F) cooler than the main channel during that period. Modeling results predicted much smaller increases in temperature under steady flows than under fluctuating flows, but this may have been due to the coarseness of river units in the model. Additional monitoring and model validation will help clarify this relationship.

The steady flows in September and October should also increase the productivity of backwaters, both as a result of temperature increases, but perhaps more because of a reduction in water exchanged with the main channel. In the Upper Colorado River basin (in the Green River in Utah), Grand et al. (2006) found that fluctuating flows significantly reduced the availability of invertebrate prey, an important food source for young fish. This reduction was caused by dewatered substrates (see also Blinn et al. 1995), exchange of water (and invertebrates) between the main channel and backwaters, and reduced temperature. Grand et al. (2005) found that as the magnitude of within-day fluctuations increase, so does the proportion of backwater water volume exchanged, resulting in a net export of as much as 30 percent of daily invertebrate production.

Prey availability may be further enhanced simply by the creation of new backwaters and improvement of existing backwaters from the proposed high flow test in March 2008. AGFD (1996) hypothesized that the 1993 Little Colorado River flood expanded the availability of stable backwater habitats, which coincided with increases of benthic invertebrate standing stocks the following year. Also, following the 1996 high flow test, burial of autochthonous vegetation resulted in increased levels of dissolved organic carbon, nitrogen and phosphorus in sandbar ground water and in adjacent backwaters, making these nutrients available for uptake by aquatic or emergent vegetation in the backwater (Parnell et al. 1999). Increases in benthic standing stocks caused by stable flows in September and October (and perhaps greater availability of backwaters) would benefit humpback chub via potential for added growth prior to the onset of winter, when invertebrate standing stocks are much reduced.

The same benefits of increased temperature and invertebrate prey availability that benefit humpback chub, will also likely benefit nonnative fish, primarily small-bodied cyprinids that utilize the same backwater habitats. Reclamation has been aggressive in developing nonnative control methods in Grand Canyon through the AMP, and has committed, as a conservation measure of the proposed action to continue to develop and implement, with GCMRC and other AMP participants, a nonnative fish control plan for both coldwater and warmwater nonnative fish.

The AMP has thus far not attempted removal of nonnative fish from backwaters. In the Upper Colorado Basin, Trammell et al. (2004) found that the feasibility of using mechanical removal to reduce nonnative cyprinid fish species in backwater habitats was limited to short-lived, site-specific reductions in abundance. However, they concluded that such programs could be beneficial to native fish if efficiency was improved and reductions were timed to be most beneficial to listed fish species. Because backwaters in Grand Canyon tend to have much higher densities of fish relative to the mainstem than in the Upper Basin (AGFD 1996, Parnell et al. 1997), removal of small-bodied nonnative fishes from backwaters in Grand Canyon could be more effective, as recolonization of backwaters from the mainstem may be much lower (Reclamation 2007).

Humpback Chub Critical Habitat

The known constituent elements of water and physical habitat will not be affected in the lower eight miles of the LCR. However, because the proposed action could result in an increase in the presence of nonnative fish species that could invade the LCR, the proposed action could reduce the quality of critical habitat in the LCR in terms of the biological constituent element. Critical habitat from RM 34 (Nautiloid Canyon) to RM 208 (Granite Park) along the Colorado River will be affected in the ways described above. The constituent element of physical habitat in the mainstem will be most affected, likely from an increase in the number of backwaters. The quality of nearshore habitats, especially during September and October should also improve, becoming warmer and more productive relative to current conditions. This could have some adverse affects to humpback chub, by potentially increasing numbers of nonnative fish. The biological environment includes food supply and habitats with levels of nonnative predators and competitors that are low enough to allow for spawning, feeding, and rearing. Increases in the quality of nearshore habitats, particularly backwaters, should benefit the food base for young humpback chub, although levels of nonnative predators and competitors could increase in response to these changes.

Summary of Effects to Humpback Chub and Its Critical Habitat

The proposed action is likely to result in some adverse effects to humpback chub, mostly from displacement of young fish during the high flow test. However, these effects are expected to be short term, and outweighed by other beneficial aspects of the proposed action. The long-term effects on humpback chub and its critical habitat are expected to be positive, due to creation and improvement of rearing habitats for humpback chub in the mainstem. Effects of the fall steady flows are expected to be positive via improved growth and survival of young-of-year and juvenile humpback chub prior to the onset of winter. Beneficial effects of steady flows in fall months should be especially pronounced during the first few years following the 2008 high flow test. Creation and improvement of backwater rearing habitats expected from the high flow test would expand habitat spatial extent, and steady flow would improve overall habitat stability (persistence) and quality (temperature, prey availability), improving the physical and biological constituent elements of critical habitat, especially for young humpback chub.

In addition, Reclamation has committed to implementing a suite of conservation measures as part of its proposed action to reduce the adverse affects of the proposed action and promote long-term species conservation. As described under "Conservation Measures" in the Description of the Proposed Action section, these include a humpback chub consultation trigger, a comprehensive plan for the management and conservation of humpback chub in Grand Canyon, humpback chub translocation, nonnative fish control, a humpback chub nearshore ecology study, a monthly flow transition study, creation and maintenance of humpback chub refuges, and Little Colorado River watershed planning. As described in the conservation measures, some of these conservation measures will entail additional planning documents and compliance that will be developed by Reclamation in conjunction with the AMP and FWS. For a description of currently planned efforts to evaluate the proposed high flow test, see the Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam (U.S. Geological Survey 2007a).

A confounding aspect to the attempts of the AMP to conserve humpback chub has been, and will continue to be, nonnative species. Many actions designed to benefit humpback chub, such as steady flows, will likely also benefit nonnative fish species. Reclamation will directly address this issue by continuing to develop and implement, with GCMRC and the AMP, a control plan for nonnative cold- and warm-water species in Grand Canyon. Reclamation's commitment to continue translocation of humpback chub, both in the Little Colorado River and into other tributaries in Grand Canyon should also serve in this regard by creating humpback chub populations in habitats free from high densities of nonnative species.

A number of research needs were identified by Reclamation and others in developing this proposed action. In particular, the effect of various flow regimes on mainstem nearshore habitats and the concomitant impact to the survival and recruitment of young humpback chub continues to raise many questions. These include: the efficacy of high flows to create backwaters; the suitability of backwaters as humpback chub rearing habitat; the persistence of backwaters created by a high flow test in relation to the post-test flows; response of young-of-year and juvenile humpback chub to steady and fluctuating flows in terms of growth, bioenergetics, survival, behavior and habitat use; differences in temperatures of mainchannel and nearshore habitats under steady and fluctuating flows and response of native and nonnative fishes; and changes in primary and secondary production under steady and fluctuating flows. Although the high flow test and stable flows that are the key components of Reclamation's proposed action are expected to provide a conservation benefit to humpback chub, this is not known with any certainty. Reclamations proposed action and conservation measures, specifically the nearshore ecology and flow transition studies, should provide much needed insight into these questions.

Although the status of the Grand Canyon population of humpback chub has been improving, there is no clear indication for the cause of this improvement. Thus the proposed action takes a conservative approach to changes in dam releases in an attempt to capitalize on this trend in status without unduly risking these gains with more drastic changes in dam operations. However, there exists the possibility that the population could decline, despite the current trend and potential for beneficial effects from Reclamation's proposed action. Reclamation has agreed to reinitiate consultation if the trend in humpback chub status should reverse and the population decline to a level of 3,500 adult fish. Reclamation will also help create and maintain humpback chub refuge populations at offsite facilities to protect the genetic diversity of the population, and to assist with watershed planning in the Little Colorado River watershed to help address potential threats that could arise from elsewhere in the watershed. These conservation measures will serve as insurance against unforeseen adverse effects, both from the proposed action and from elsewhere.

Kanab Ambersnail

The proposed action will have no effect on the water flow from the side canyon spring that maintains wetland and aquatic habitat at Vasey's paradise. Kanab ambersnail habitat can be adversely affected by scouring at Colorado River flows exceeding 17,000 cfs. The high flow test will increase flows to 41,500 cfs. These flows will inundate Kanab ambersnail habitat and likely scour the vegetation and carry the snails downstream. During the March 1996 high flow test (45,000 cfs), all Kanab ambersnail habitat at Vaseys Paradise below the 45,000 cfs flow level was scoured away. It is likely that several hundred snails were lost, and it took 2.5 years for the habitat to recover to pre-flood conditions (IKAMT 1998; Stevens et al. 1997b). In 2004 during the high flow test, approximately 25 – 40 percent ($29m^2$ to $47m^2$; 312 ft^2 to 506 ft^2) of habitat that would normally be lost due to scour effects from the high flow test was temporarily removed prior to the test flow and replaced afterwards; 55 live Kanab ambersnails were also found and moved above the 41,500 cfs flow line. This conservation measure was successful, with essentially full recovery of the scoured snail habitat six months later, as opposed to 2.5 years to recover following the 1996 event when this conservation measure was not employed (Sorensen 2005). Reclamation will carry out this habitat-safeguarding conservation measure again for the 2008 experimental high flow test which will greatly reduce adverse effects to the snail and its habitat from the proposed action.

Steady flows in September and October will have little effect on snails and snail habitat. Snails are becoming dormant at that time of year as winter approaches, and the time period, two months, is brief. Thus, should steady flows result in lowering the elevation of the varial zone, little if any new habitat should become established at the new lower steady flow level which could be scoured when flows and fluctuations increase in November and December.

CUMULATIVE EFFECTS

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Native American use of the Colorado River in Grand Canyon includes cultural, religious, and recreational purposes, as well as land management of tribal lands (e.g. recreational use including rafting, hunting and fishing). Non-Federal actions on the Paria River and Kanab Creek are limited to small developments, private water diversions and recreation. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. Since a significant portion of the project area is on Federal lands, all legal actions likely to occur would be considered Federal actions, and would be subject to additional section 7 consultation.

CONCLUSION

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat[4]. After reviewing the current status of the humpback chub and its critical habitat, the current status of the Kanab ambersnail, the environmental baseline for the action area, the effects of implementation of the proposed action, and the cumulative effects, it is our biological opinion that implementation of the March 2008 high flow test and the five-year implementation of MLFF with steady releases in September and October, as proposed, is not likely to jeopardize the continued existence of the humpback chub or the Kanab ambersnail, and is not likely to destroy or adversely modify designated critical habitat for the humpback chub.

We present this conclusion for the humpback chub and its critical habitat for the following reasons:

- In 1995, in a consultation on the operations of Glen Canyon Dam, specifically on the MLFF, we anticipated that operation of Glen Canyon Dam (the monthly, daily, and hourly operation as defined in the MLFF and the 1996 ROD) would jeopardize the continued existence of the species. Populations in the upper Colorado River basin have declined as of January 2008. The Grand Canyon population, which was the population analyzed in the 1995 biological opinion, appears to have recently improved to around 6,000 adult fish. This is less than the number of adult fish thought to be present in Grand Canyon in 1995, and indeed the status of the species is reduced overall from what it was in 1995. Much of the scope of dam operations for the next five years under the proposed action will contain elements of the 1996 (MLFF) and 2007 (Shortage Guidelines) RODs,

[4] See the December 27, 2004, memo from Acting Director, Fish and Wildlife Service.

such as the range of daily flow fluctuation and seasonal variations in monthly volume. However, the most recent and best available estimates of humpback chub population trend (Coggins 2007) indicate that there has been increased recruitment into the population from some year classes starting in the mid- to late-1990s, during the period of MLFF operations, causing the decline in humpback chub to stabilize and begin to reverse. This improvement in the population trend has been attributed in part to the results of nonnative fish mechanical removal, increases in temperature due to lower reservoir elevations and inflow events, the 2000 low steady summer flow experiment, and other experimental flows and actions (USGS 2006a). Considering though that the most recent population modeling indicates the increase was due to increased recruitment as early as 1996 but no later than 1999 (Coggins 2007), the increase in recruitment began at least four and as many as nine years prior to implementation of nonnative fish control, incidence of warmer water temperatures, the 2000 low steady summer flow experiment, and the 2004 high flow test. The exact causes of the increase in recruitment, and whether it is attributable to conditions in the mainstem or in the Little Colorado River are unclear. Nevertheless, removal of nonnative fish, increased temperature due to drought, and habitat conditions resulting from natural and experimental actions will likely be beneficial to humpback chub, and further increases in recruitment are likely based on recent catch rates of sub-adult humpback chub (Coggins 2007). These results indicate that some combination of conditions under MLFF has benefited humpback chub, and that more recent conservation actions likely have as well, and are likely to continue to.

- The proposed action will have some adverse effects from the displacement of young-of-year and juvenile humpback chub by the high flow test; however, these effects should be outweighed by the expected beneficial effects of the high flow test and fall steady flow components: creation or improvement of backwater habitats, the creation of more persistent suitable habitat conditions, the creation of warmer nearshore habitats, and the creation of more productive nearshore habitats. These effects will most benefit young-of-year and juvenile humpback chub, and should improve their survivorship, increasing total recruitment, thought to be the key factor in improving the status of this species.

- Reclamation is committed to implementing a suite of conservation measures, through the AMP. These conservation measures further increase our confidence in our opinion that all adverse affects of the proposed action are reduced to the point that the action will not jeopardize the species or result in adverse modification of critical habitat:

    - *Humpback Chub Consultation Trigger* – Pursuant to 50 CFR § 402.16 (c), reinitiation of formal consultation is required and shall be requested by the Federal agency or by the FWS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered. Reclamation and FWS agree to specifically define this reinitiation trigger relative to humpback chub, in part, as being exceeded if the population of adult humpback chub (≥200 mm [7.87 in] TL) in Grand Canyon declines significantly, or, if in any single year, based on the age-structured mark recapture model (ASMR; Coggins 2007), the population drops below 3,500 adult fish within the 95 percent confidence interval. FWS and Reclamation have agreed on this trigger based on the current estimated population size and past population trend, genetic considerations, and the capabilities of the ASMR model to estimate population size. This number was derived as a conservative approach to preventing the population from declining to the minimum viable population size for humpback chub, estimated to be 2,100 adult fish (U.S. Fish and Wildlife Service 2002a), with consideration for a buffer and acknowledging the variance inherent in the ASMR resulting from age estimation based on recent results from this model (Coggins 2007). This trigger provides additional protection against possible adverse affects to humpback chub from the proposed action. If the population of humpback chub declines to this level, Reclamation and FWS will consider appropriate actions through reinitiated section 7 consultation, for example, extending the period of steady releases to include July and August. Conversely, if the population of humpback chub expands significantly, FWS and Reclamation will consider the potential for reinitiation of consultation to determine if steady flows continue to be necessary.

- *Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon* – Reclamation has been a primary contributor to the development of the AMP's Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon. Reclamation will continue to work with AMP cooperators to develop a comprehensive approach to management of humpback chub. Reclamation has committed to specific conservation measures in this biological opinion, but will also consider funding and implementing other actions not identified here to implement the plan.

- *Humpback Chub Translocation* – In coordination with other Department of the Interior (DOI) AMP participants and through the AMP, Reclamation will assist NPS and the AMP in funding and implementation of translocation of humpback chub into tributaries of the Colorado River in Marble and Grand canyons. Nonnative control in these tributaries will be an essential precursor to translocation, so Reclamation will help fund control of both cold and warm-water nonnative fish in tributaries, as well as efforts to translocate humpback chub into these tributaries. Havasu, Shinumo and Bright Angel creeks will initially be targeted for translocation, although other tributaries may be considered. Reclamation will work with FWS, NPS and other cooperators to develop translocation plans for each of these streams, utilizing existing information available such as SWCA and Grand Canyon Wildlands (2007) and Valdez et al. (2000a). These plans will consider and utilize genetic assessments (Douglas and Douglas 2007, Keeler-Foster in prep.), identify legal requirements and jurisdictional issues, methods, and assess needs for nonnative control, monitoring and other logistics, as well as an implementation schedule, funding sources, and permitting. Reclamation and the AMP will also fund and implement translocation of up to 500 young humpback chub from the lower Little Colorado River to above Chute Falls in 2008 if FWS determines that a translocation is warranted. Reclamation and the AMP will continue to monitor humpback chub in the reach of the Little Colorado River above Chute Falls for the 5-year period of the proposed action, and will undertake additional translocations above Chute Falls as deemed necessary by FWS.

- *Nonnative Fish Control* – As first presented in the biological opinion on the Shortage Guidelines, Reclamation will, in coordination with other DOI AMP participants and through the AMP, continue efforts to assist NPS and the AMP in control of both cold- and warm-water nonnative fish species in both the mainstem of Marble and Grand canyons and in their tributaries, including determining and implementing levels of nonnative fish control as necessary. Because Reclamation predicts that dam releases will be cool to cold during the period of the proposed action, control of nonnative trout may be particularly important. Control of these species will utilize mechanical removal, similar to recent efforts by the AMP, and may utilize other methods, to help to reduce this threat. GCMRC is preparing a nonnative fish control plan through the AMP process that addresses both cold and warm-water species that will further guide implementation of this conservation measure.

- *Humpback Chub Nearshore Ecology Study* – In coordination with other DOI AMP participants and through the AMP, Reclamation will implement a nearshore ecology study that will relate river flow variables to ecological attributes of nearshore habitats (velocity, depth, temperature, productivity, etc.) and the relative importance of such habitat conditions to important life stages of native and nonnative fishes. This study will incorporate planned science activities for evaluating the high flow test on nearshore habitats as well as the 5-year period of steady flow releases in September and October. A research plan will be developed with FWS via the AMP for this study by August 1, 2008, and a 5-year review report will be completed by 2013. The plan will include monitoring of sufficient intensity to ensure significant relationships can be established, as acceptable to the FWS. This conservation measure is consistent with the *Sediment Research* conservation measure in the Shortage Guidelines biological opinion. This study will help clarify the relationship between flows and mainstem habitat characteristics and availability for young-of-year and juvenile humpback chub, other native fish, and competitive or predaceous nonnative fish, and support continued management to sustain mainstem aggregations. The feasibility and effectiveness of marking small humpback chub (<150 and <100 mm TL [5.91 and 3.93 in]) will also be evaluated as part of the study, and if effective, marking young fish will be utilized in the study. Marking young humpback chub, if feasible and effective, could greatly aid in developing information on the early life history, growth and survival of young humpback chub.

- *Monthly Flow Transition Study* – Transitions between monthly flow volumes can often result in drastic changes to nearshore habitats. For example, past transitions from August to September in some years have consisted of a transition from a lower limit of 10,000 cfs in August to an upper limit of 10,000 cfs in September. Such a transition results in a river stage level that is below the varial zone of the previous month's flow, and may be detrimental to fishes and food base for fish. Reclamation has committed to adjusting daily flows between months to attempt to attenuate these transitions such that they are more gradual, and to studying the biological effects of these transitions, in particular to humpback chub. If possible, Reclamation will work to adjust September and October monthly flow volumes to achieve improved conditions for young-of-year, juvenile, and adult humpback chub, as acceptable to the FWS.

- *Humpback Chub Refuge* – Once appropriate planning documents are in place, and refuge populations of humpback chub are created (as a conservation measure of the Shortage Guidelines biological opinion), Reclamation will assist FWS in maintenance of a humpback chub refuge population at a Federal hatchery or other appropriate facility by providing funding to assist in annual maintenance. In case of a catastrophic loss of the Grand Canyon population of humpback chub, a humpback chub refuge will provide a permanent source of sufficient numbers of genetically representative stock for repatriating the species. This action would also be an important step toward attaining recovery.

- *Little Colorado River Watershed Planning* – Reclamation will continue its efforts to help other stakeholders in the Little Colorado River watershed develop watershed planning efforts, with consideration for watershed level effects to the humpback chub in Grand Canyon.

- We believe critical habitat will remain functional and continue to serve the intended conservation role for the humpback chub, and that elements of critical habitat will be improved by the proposed action (improved quantity and quality of nearshore habitats for young humpback chub) and that the suite of conservation measures implemented by Reclamation will serve to further benefit humpback chub critical habitat.

We present this conclusion for the Kanab ambersnail for the following reasons:

- Although implementation of the proposed action will result in some loss of Kanab ambersnails and their habitat, we anticipate this loss will be small and not impair the long-term stability of the population because Reclamation has agreed to implement the following conservation measure:

  - *Habitat Protection* – Reclamation will, through the AMP, temporarily remove and safe-guard all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent (17 m^2 [180 ft^2]) of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with GCMRC.

The conclusions of this biological opinion are based on full implementation of the project as described in the <u>Description of the Proposed Action</u> section of this document, including any Conservation Measures that were incorporated into the project design.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulations pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is defined (50 CFR 17.3) to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. "Harass" is defined (50 CFR 17.3) as intentional or negligent actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns that include, but are not limited to, breeding, feeding or sheltering. "Incidental take" is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act, provided that such taking is in compliance with the terms and conditions of this Incidental Take Statement.

The measures described below are non-discretionary and must be undertaken by Reclamation so that they become binding conditions of any grant or permit issued, as appropriate, for the exemption in section 7(o)(2) to apply. Reclamation has a continuing duty to regulate the activity covered by this incidental take statement. If Reclamation (1) fails to assume and implement the terms and conditions or (2) fails to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Reclamation must report the progress of the action and its impact on the species to the FWS as specified in the incidental take statement [50 CFR § 402.14(i)(3)].

AMOUNT OR EXTENT OF TAKE

Humpback chub

The level of take that could occur from the proposed action would be in the form of harm or mortality, resulting primarily from the displacement of young-of-year and juvenile humpback chub during the experimental high flow test, stranding due to monthly flow transitions, and possibly from an increase in nonnative species via effects of the September and October steady releases. Reclamation estimates that displacement of juvenile humpback chub, based on Korman et al. (2004), will increase by about 15 percent as a result of the high flow test. In 2007, population size of sub-adult humpback chub in the mainstem could not be estimated because of low numbers captured. A past attempt to monitor this effect, during the 2004 high flow test, was confounded by the high turbidity that accompanies a high flow test; although catch of juvenile humpback chub decreased after the high flow test, catch rate is known to also decline with increased turbidity. A reasonable, although very approximate, estimate of numbers of young-of-year and juvenile humpback chub that could be present during the high flow test, based on catch rates and hoop net catch data, is about 6,000 (L. Coggins, U.S. Geological Survey, pers. com. 2007). Thus, based on Korman et al. (2004), approximately 900 young-of-year and juvenile humpback chub could be displaced. Humpback chub mortalities resulting from the high flow test will be difficult to detect, due to the small size of individuals transported downstream and the size and remoteness of the action area. And juvenile humpback chub that are displaced downstream are not necessarily killed, and could survive and even recruit into other aggregations. Given all of these factors, although take of juvenile humpback chub is reasonably certain to occur, in the form of harm and mortality as a result of the high flow test, the anticipated level of take of humpback chub is unquantifiable. Similarly, stable flows should benefit humpback chub, but the possibility exists that these flows may benefit nonnative species, which could result in take of humpback chub through harm or mortality. Again, due to logistical constraints and the difficulty in detecting take in this remote action area, we are unable to estimate the number of humpback chub that could be taken from this element of the proposed action. We anticipate, however, that because the proposed action will also have beneficial effects to humpback chub, and Reclamation is implementing a suite of conservation measures to help conserve the species, take of humpback chub from the proposed action is not anticipated to result in a decline in the overall Grand Canyon population. Reclamation's conservation measure to help develop a nearshore ecology study will provide important information in this regard. As a surrogate measure of take, we will consider anticipated take to be exceeded if the proposed action results in detection of more than 20 humpback chub mortalities during the high flow test, attributable to the high flow test.

Kanab Ambersnail

The level of take that could occur from the proposed action would be in the form of harm or mortality, resulting from scouring of habitat during the high flow test. Although the conservation measure to safe-guard habitat should offset much of the take to the species from the proposed action, and the actual level of take will be difficult to detect, as a surrogate measure of take, we will consider anticipated take to be exceeded if the proposed action results in more than 117 m^2 (1259 ft^2) of Kanab ambersnail habitat being removed at Vaseys Paradise and this loss is attributable to the high flow test.

EFFECT OF THE TAKE

In this biological opinion, we determine that this level of anticipated take is not likely to result in jeopardy to the humpback chub or Kanab ambersnail. The implementation of the proposed action will ensure that, while incidental take may still occur, it is minimized to the extent that habitat quality and quantity will be maintained in the planning area, and the species will be conserved.

REASONABLE AND PRUDENT MEASURES AND TERMS AND CONDITIONS

In order to be exempt from the prohibitions of section 9 of the Act, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are nondiscretionary.

Humpback Chub

The following reasonable and prudent measure is necessary and appropriate to minimize take of humpback chub:

> Monitor the effects of the proposed action on humpback chub and its habitat to document levels of incidental take and report the findings to the FWS. Reclamation shall work in

collaboration with the AMP participants including GCMRC and other cooperators to complete this monitoring.

The following term and condition will implement this reasonable and prudent measure:

Reclamation, in collaboration with the AMP participants including the GCMRC and other cooperators, shall submit a written report to the FWS annually documenting activities of the proposed action for the year, and any documented take. The report will include a discussion of the progress of the implementation of Reclamation's conservation measures included in the proposed action.

Kanab Ambersnail

The following reasonable and prudent measure is necessary and appropriate to minimize take of Kanab ambersnail:

Monitor the effects of the proposed action on Kanab ambersnail and its habitat to document levels of incidental take and report the findings to the FWS. Reclamation shall work in collaboration with the AMP participants including GCMRC and other cooperators to complete this monitoring.

The following term and condition will implement this reasonable and prudent measure:

Reclamation, in collaboration with the AMP participants including GCMRC and other cooperators, shall submit a written report to the FWS annually documenting activities of the proposed action for the year that resulted in documented take. The report will include a discussion of the progress of the implementation of Reclamation's conservation measure included in the proposed action.

Review requirement: The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take is exceeded, such incidental take would represent new information requiring review of the reasonable and prudent measures provided. Reclamation must immediately provide an explanation of the causes of the taking and review with FWS the need for possible modification of the reasonable and prudent measures.

Disposition of Dead or Injured Listed Species

Upon locating a dead, injured, or sick listed species, initial notification must be made to the FWS's Law Enforcement Office (2450 West Broadway Road, Suite 113, Mesa, Arizona, 85202, telephone: 480/967-7900) within three working days of its finding. Written notification must be made within five calendar days and include the date, time, and location of the animal, a photograph if possible, and any other pertinent information. The notification shall be sent to the Law Enforcement Office with a copy to this office. Care must be taken in handling sick or injured animals to ensure effective treatment and care and in handling dead specimens to preserve the biological material in the best possible state.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans or to develop information.

Humpback Chub

FWS recommends that Reclamation continue working with FWS to implement activities that will achieve the revised recovery goals for humpback chub when they become available in 2008. We also recommend that Reclamation utilize the Comprehensive Plan for the Management and Conservation of Humpback Chub in Grand Canyon and work with FWS to determine what actions will remain to be accomplished, and find additional funding sources that would be provided by other willing partners to help achieve recovery.

Kanab Ambersnail

FWS recommends that Reclamation continue to work with FWS to implement the "Interim Conservation Plan for the *Oxyloma (haydeni) kanabensis* Complex and Related Ambersnails in Arizona and Utah" (AGFD 2002).

In order for the FWS to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the FWS requests notification of the implementation of any conservation recommendations.

REINITIATION NOTICE

This concludes formal consultation on the action outlined in your request. As provided in 50 CFR 402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease, pending reinitiation.

We appreciate your continued efforts to conserve listed species. For further information, please contact Glen Knowles (602) 242-0210 or (x233) or Lesley Fitzpatrick (602) 242-0210 (x236). Please refer to consultation number (22410-1993-F-167R1) in future correspondence concerning this project.

Steven L. Spangle

cc: Regional Director, Fish and Wildlife Service, Albuquerque, NM
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Chief, Habitat Branch, Arizona Game and Fish Department, Phoenix, AZ
Director, Environmental Programs, Bureau of Indian Affairs, Phoenix, AZ
Chemehuevi Indian Tribe, Chemehuevi Valley, CA
Havasupai Tribe, Supai, AZ
Hopi Tribe, Kykotsmovi, AZ
Hualapai Tribe, Peach Springs, AZ
Kaibab Band of Paiute Indians, Pipe Springs, AZ
Navajo Nation, Window Rock, AZ
Pueblo of Zuni, Zuni, NM
San Juan Southern Paiute Tribe, Tuba City, AZ

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LITERATURE CITED

Ackerman, M.W. 2007. 2006 Native fish monitoring activities in the Colorado River, Grand Canyon. Cooperative Agreement (04WRAG0030) Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 79 p.

Ackerman, M.W., D. Ward, T. Hunt, R.S. Rogers, D.R. VanHaverbeke, A. Morgan, and C. Cannon. 2006. 2006 Grand Canyon long-term fish monitoring in the Colorado River, Diamond Creek to Lake Mead. Annual report to the U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Albrecht, B., T. Sanderson and P.B. Holden. 2007. Razorback sucker studies on Lake Mead, Nevada and Arizona 2006-2007. BIO-WEST, Inc., Annual Report to U.S. Bureau of Reclamation, Boulder City, Nevada, PR-1093-1. 60 p

Andrews, E. D., C.E. Johnston, J.C. Schmidt, and M. Gonzales. 1999. Topographic evolution of sandbars. Pages 117-130 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Archer, D.L., L.R. Kaeding, B.D. Burdick, and C.W. McAda. 1985. A study of the endangered fishes of the upper Colorado River. Final Report of U.S. Fish and Wildlife Service, Grand Junction, Colorado, to Northern Colorado Water Conservancy District.

Arizona Game and Fish Department. 1996. The ecology of Grand Canyon backwaters. Cooperative Agreement Report (9-FC-40-07940) to Glen Canyon Environmental Studies, Flagstaff, Arizona. 165 p.

Berry, C.R. 1988. Effects of cold shock on Colorado River Squawfish larvae. Southwestern Naturalist 33(2):193-197.

Berry, C.R., and R. Pimentel. 1985. Swimming performances of three rare Colorado River fishes. Transactions of the American Fisheries Society 114:397-402.

Beus, S.S., M.A. Kaplinksi, J.E. Hazel, and L. Kearsley. 1994. Monitoring the effects of interim flows from Glen Canyon Dam on sand bar dynamics and campsite size in the Colorado River corridor, Grand Canyon National Park, Arizona. Draft final report submitted to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Blinn, D.W., and G.A. Cole. 1991. Algal and Invertebrate Biota in the Colorado River: Comparison of Pre-and Post-Dam Conditions. Pages 102-123 in Colorado River Ecology and Dam Management, Proceedings of a symposium, May 24-25, 1990. National Academy Press, Washington, DC.

Blinn, W.J. P. Shannon, L.E. Stevens and J.P. Carder. 1995. Consequences of fluctuating discharge for lotic communities. Journal of the North American Benthological Society 14(2):233-248.

Bowen, Z.K., M.C. Freeman, and K.D. Bovee. 1998. Evaluation of generalized habitat criteria for assessing impacts of altered flow regimes on warmwater fishes. Transactions of the American Fisheries Society 127:455-468.

Brouder, M.J., and T.L. Hoffnagle. 1997. Distribution and prevalence of the Asian tapeworm, Bothriocephalus acheilognathi, in the Colorado River and tributaries, Grand Canyon, Arizona, including two new host records. Journal of Helminthological Society of Washington 64:219–226.

Brouder, M.J., D.W. Speas and T.L. Hoffnagle. 1999. Changes in number, sediment composition and benthic invertebrates of backwaters. Pages 241-248 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Bulkley, R.V., C.R. Berry, R. Pimental, T. Black. 1982. Tolerance and preferences of Colorado River endangered fishes to selected habitat parameters. Colorado River Fishery Project Final Report Part 3. Bureau of Reclamation, Salt Lake City, Utah.

Bulow, F. J., J. R. Winningham, and R. C. Hooper. 1979. Occurrence of copepod parasite Lernaea cyprinacea in a stream fish population. Transactions of the American Fisheries Society 108:100–102.

Carlander, K.D. 1969. Handbook of Freshwater fishery biology. Vol.1. The Iowa State University Press, Ames, Iowa. 752 p.

Chart, T.E., and L. Lentsch. 2000. Reproduction and recruitment of Gila spp. and Colorado pikeminnow (*Ptychocheilus lucius*) in the middle Green River; 1992–1996. Utah Division of Wildlife Resources, publication number 00-18. Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Childs, M.R., R.W. Clarkson, and A.T. Robinson. 1998. Resource use by larval and early juvenile native fishes in the Little Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 127:620–629.

Choudhury, A., T.L. Hoffnagle, and R.A. Cole. 2004. Parasites of Native and Nonnative Fishes of the Little Colorado River, Grand Canyon, Arizona. Journal of Parasitology 90:1042-53.

Christensen, K. 2007. Southwestern willow flycatcher surveys in lower Grand Canyon, Fiscal Year 2007. Department of Natural Resources, Hualapai Tribe. Final Report to U.S. Bureau of Reclamation, Boulder City, Nevada.

Christensen, N. and D.P. Lettenmaier. 2006. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River basin. Hydrology and Earth System Sciences Discussion 3:1-44.

Clarke, A.H. 1991. Status survey of selected land and freshwater gastropods in Utah. U.S. Fish and Wildlife Service Report, Denver, Colorado.

Clarkson, R.W. 1993. Unpublished data on fecundity of humpback chub in the Little Colorado River, Grand Canyon, Arizona. Arizona Game and Fish Department, Phoenix, Arizona.

Clarkson, R.W., and M.R. Childs. 2000. Temperature effects of hypolimnial-release dams on early life stages of Colorado River Basin big-river fishes. Copeia 2000:402–412.

Clarkson, R.W., A.T. Robinson, and T.L. Hoffnagle. 1997. Asian tapeworm (*Bothriocephalus acheilognathi*), in native fishes from the Little Colorado River, Grand Canyon, Arizona. Great Basin Naturalist 57:66–69.

Coggins, L.G. 2007. Abundance trends and status of the Little Colorado River population of humpback chub: an update considering 1989-2006 data. United States Geological Survey open file report 2007-1402.

Coggins, L.G., Pine, W.E., III, Walters, C.J., Van Haverbeke, D.R., Ward, D., Johnstone, H.C. 2006. Abundance trends and status of the Little Colorado River population of humpback chub. North American Journal of Fisheries Management (26):233–245.

Coggins, L. and M. Yard. 2003. Nonnative fish removal efforts in Grand Canyon: A proposed modification to ongoing activities. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Cole, T.M. and S. Wells. 2000. CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model, Version 3.

Converse, Y.K., C.P. Hawkins, and R.A. Valdez. 1998. Habitat Relationships of Subadult Humpback Chub in the Colorado River through Grand Canyon: Spatial Variability and Implications of Flow Regulation. Regulated Rivers 14(3):267-284.

Davis, E., and W.W. Batham. 2003. Stranding of rainbow trout during experimental fluctuating releases from Glen Canyon Dam on the Colorado River. Final Report. EcoPlan Associates, Inc., Mesa, Arizona.

Dawdy, D.R. 1991. Hydrology of Glen Canyon and Grand Canyon. Pages 40-53 in Colorado River Ecology and Dam Management. Proceedings of a symposium, May 24-25, 1990. National Academy Press, Washington, DC.

Day, K.S., K.D. Christopherson, and C. Crosby. 1999. An assessment of young-of-year Colorado pikeminnow Ptychocheilus lucius use of backwater habitats in the Green River, Utah. Report B in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City, Utah.

DeLoach, C.J. 1991. Saltcedar, an exotic weed of western North American riparian areas: a review of its taxonomy, biology, harmful and beneficial values, and its potential for biological control. Contract No. 7-AG-30-04930. Report to the Bureau of Reclamation, Boulder City, Nevada.

Douglas, M.E., and P.C. Marsh. 1996. Population estimates/population movements of Gila cypha, an endangered cyprinid fish in the Grand Canyon region of Arizona. Copeia 1996:15–28.

Douglas, M.R., and M.E. Douglas. 2007. Genetic structure of humpback chub *Gila cypha* and roundtail chub *G. robusta* in the Colorado River ecosystem. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Finney, S,T. Modde, B. Haines, and K. Christopherson. 2004. Yampa Canyon Population of Humpback Chub: Past, Present, and Future. U.S. Fish and Wildlife Service. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

Freeman, M.C., Z.H. Bowen, K.D. Bovee, and E.R. Irwin. 2001. Flow and habitat effects on juvenile fish abundance in natural and altered flow regimes. Ecological Applications 11(1):179-190.

Garrett, D., J. Baron, V. Dale, L. Gunderson, A. Howard, D. Hulse, J. Kitchell, J. Loomis, M. Palmer, R. Parker, D. Robertson, D. Schwartz, and J. Watkins. 2003. Evaluating a Glen Canyon Dam temperature control device to enhance native fish habitat in the Colorado River: a risk assessment by Adaptive Management Program Science Advisors. July 2003.

Gloss, S.P., Lovich, J.E., and Melis, T.S., eds. 2005. The state of the Colorado River ecosystem in Grand Canyon: U.S. Geological Survey Circular 1282, Reston, Virginia. 220 p.

Goeking, S.A., J.C. Schmidt, and M.K. Webb. 2003. Spatial and temporal trends in the size and number of backwaters between 1935 and 2000, Marble and Grand Canyons, Arizona. Department of Aquatic, Watershed, and Earth Resources. Utah State University. Report prepared for U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Gorman, O.T., and D.M. Stone. 1999. Ecology of spawning humpback chub (*Gila cypha*) in the Little Colorado River near Grand Canyon, Arizona. Environmental Biology of Fishes 55:115–133.

Gorman, O.T. and R.R. VanHoosen. 2000. Experimental growth of four native Colorado River fishes at temperatures of 12, 18 and 24 °C. Draft final report submitted to Grand Canyon Monitoring and Research Center, Flagstaff. U.S. Fish and Wildlife Service, Willow Beach Arizona.

Grabda, J. 1963. Life cycle and morphogenesis of Lernaea cyprinacea L. Acta Parasitologica Polonica XI:169–199.

Granath, W.O., Jr., and G.W. Esch. 1983. Seasonal dynamics of Bothriocephalus acheilognathi in ambient and thermally altered areas of a North Carolina cooling reservoir. Proceedings of the Helminthological Society Washington 50:205–218.

Grand, T., C.S.F. Railsback, J.W. Hayse and K.E. LaGory. 2006. A physical habitat model for predicting the effects of flow fluctuations in nursery habitats of the endangered Colorado pikeminnow Ptychocheilus lucius. River Research and Applications 22:1125-1142.

Hamman, R.L. 1982. Spawning and culture of humpback chub. Progressive Fish-Culturist 44:213–216.

Haden, G.A., D.W. Blinn, J.P. Shannon, and K.P. Wilson. 1999. Driftwood: an alternative habitat for macroinvertebrates in a large desert river. Hydrobiologia 397:179–186.

Hazel, J.E., M. Kaplinksi, R. Parnell, M. Manone and A. Dale. 1999. Topographic and bathymetric changes at thirty-three long-term study sites. Pages 161-183 in Webb, .H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. American Geophysical Union monograph 110.

Hendrickson, D.A. 1993. Progress report on study of the utility of data obtainable from otoliths to management of humpback chub (*Gila cypha*) in the Grand Canyon. Non-Game and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix.

Hoerling, M. and J. Eischeid. 2006. Past peak water in the Southwest. Southwest Hydrology 6(1).

Hoffnagle, T.L. 1996. Changes in water quality parameters and fish usage of backwaters during fluctuating vs. short-term steady flows in the Colorado River, Grand Canyon. Arizona Game and Fish Dept. Prepared for Glen Canyon Environmental Studies, U.S. Bureau of Reclamation.

Hoffnagle, T.L. 2000. Humpback chub *Gila cypha* health and parasites, 1998–1999. Arizona Game and Fish Department. Final Report to U.S. Fish and Wildlife Service, Grand Canyon Fishery Resource Office, Flagstaff, Arizona.

Hoffnagle, T.L., R.A. Valdez, and D.W. Speas. 1999. Fish abundance, distribution, and habitat use. Pages 273–287 in R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The controlled flood in Grand Canyon. Geophysical Monograph 110, The American Geophysical Union, Washington, D.C.

Howard, A., and R. Dolan. 1981. Geomorphology of the Colorado River in the Grand Canyon. Journal of Geology 89:269–298.

Intergovernmental Panel on Climate Change. 2007. Summary for Policymakers, in Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, eds., Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, New York.

Jackson, J. 2004a. Westwater Canyon Humpback Chub Population Estimates. Utah Division of Wildlife Resources. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

Jackson, J. 2004b. Desolation and Gray Canyon Humpback Chub Population Estimate 2001-2003. Utah Division of Wildlife Resources. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

James, M.A. 2005. Final biological assessment; Colorado River Management Plan. Grand Canyon National Park, National Park Service. 69 pp + appendices.

Johnstone, H.C., and M. Lauretta. 2004. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2003. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Johnstone, H.C., and M. Lauretta. 2007. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2004. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Johnstone, H.C., M. Lauretta, and M. Trammell. 2003. Native Fish Monitoring Activities in the Colorado River within Grand Canyon during 2002. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Kaeding, L.R., B.D. Burdick, P.A. Schrader, and C.W. McAda. 1990. Temporal and spatial relations between the spawning of humpback chub and roundtail chub in the Upper Colorado River. Transactions of the American Fisheries Society 119:135-144.

Kaeding, L.R. and M.A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado rivers of the Grand Canyon. Transactions of the American Fisheries Society. 112:577-594.

Karp, C.A., and Tyus, H.M. 1990. Humpback chub (*Gila cypha*) in the Yampa and Green rivers, Dinosaur National Monument, with observations on roundtail chub (*G. robusta*) and other sympatric fishes. Great Basin Naturalist 50:257–264.

Kennedy, T.A. 2007. A Dreissena Risk Assessment for the Colorado River Ecosystem. U.S. Geological Survey open file report 2007-1085.

Kolluru, V. and M. Fichera. 2003. Development and Application of Combined 1-D and 3-D Modeling System for TMDL Studies. Reprinted from Estuarine and Coastal Modeling Proceedings of the Eight International Conference American Society of Civil Engineers, Monterey, California.

Korman, J., M. Kaplinski, J.E. Hazel III, and T.S. Melis. 2005. Effects of the experimental fluctuating flows from Glen Canyon Dam in 2003 and 2004 on the early life history stages of rainbow trout in the Colorado River. Final Report to Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Korman, J., M. Kaplinski and J. Buszowski. 2006. Effects of air and mainstem water temperatures, hydraulic isolation, and fluctuating flows from Glen Canyon Dam on water temperatures in shoreline environments of the Colorado River in Grand Canyon. Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Korman, J, S.M. Wiele, and M. Torizzo. 2004. Modeling effects of discharge on habitat quality and dispersal of juvenile humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon. Regulated Rivers 20:379-400.

Korn, J. and B. Vernieu. 1998. Mainstem and tributary temperature modeling in Grand Canyon Arizona. U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Kubly, D.M. 1990. The endangered humpback chub (Gila cypha) in Arizona: a review of past studies and suggestions for future research. Arizona Game and Fish Department, Phoenix, Arizona.

Lanigan, S.H., and H.M. Tyus. 1989. Population size and status of the razorback sucker in the Green River basin, Utah and Colorado. North American Journal of Fisheries Management 9:68–73.

Lauretta, M. V. and K. M. Serrato. 2006. Native fish monitoring activities in the Colorado River within Grand Canyon during 2005, draft annual report. SWCA, Inc., Final Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Liebfried, B., K. Hilwig, K. Serrato, and M. Lauretta. 2006. Restoring native fish habitat in selected tributaries of Grand Canyon National Park. SWCA, Inc., Draft Report to the National Park Service, Grand Canyon National Park, Arizona.

Leibfried, W.C., H. Johnstone, S. Rhodes, and M. Lauretta. 2005. Feasibility study to determine the efficacy of using a weir in Bright Angel Creek to capture brown trout. Final Report to Grand Canyon Monitoring and Research Center from SWCA Environmental Consultants, Flagstaff, Arizona.

Ligon, J.S. 1961. New Mexico Birds and where to find them. The University of New Mexico Press, Albuquerque, New Mexico. 360 p.

Lupher, M.L., and R.W. Clarkson. 1994. Temperature tolerance of humpback chub (*Gila cypha*) and Colorado squawfish (Ptychocheilus lucius), with a description of culture methods for humpback chub. Glen Canyon Environmental Studies phase II 1993 annual report. Arizona Game and Fish Department, Phoenix.

Maddux, H.R., D.M. Kubly, J.C. DeVos Jr., W.R. Persons, R. Staedicke, and R.C. Wright. 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand Canyons. Arizona Game and Fish Department. Final Report to Bureau of Reclamation, Salt Lake City, Utah.

Marsh, P.C. 1985. Effect of incubation temperature on survival of embryos of native Colorado River fishes. Southwestern Naturalist 30:129–140.

Marsh, P.C., and M.E. Douglas. 1997. Predation by introduced fishes on endangered humpback chub and other native species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126:343–346.

Marsh, P.C., and M.S. Pisano. 1982. Influence of temperature on development and hatching success of native Colorado River fishes. Culturing of Threatened and Endangered Species Session, Western Division of the American Fisheries Society, Annual Meeting, Las Vegas, Nevada.

McAda, C.W. 2004. Black Rocks Humpback Chub Population Estimate 2003. U.S. Fish and Wildlife Service. Presentation at Population Estimates Workshop II, August 24-25, 2004, Grand Junction, Colorado.

McGuinn-Robbins, D.K. 1995. Comparisons in the number and area of backwaters associated with the Colorado River in Glen, Marble and Grand Canyons, Arizona. Draft report to Glen Canyon Environmental Studies, U.S. Bureau of Reclamation. Arizona Game and Fish Department, Phoenix, Arizona.

McKinney, T., and W.R. Persons. 1999. Rainbow Trout and Lower Trophic Levels in the Lee's Ferry Tailwater Below Glen Canyon Dam, Arizona: A Review. Arizona Game and Fish Department Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

McKinney, T., D.W. Speas, R.S. Rogers and W.R. Persons. 1999. Rainbow trout in the Lees Ferry recreational fishery below Glen Canyon Dam, Arizona, following establishment of minimum flow requirements. Arizona Game and Fish Department, Final Report submitted to Grand Canyon Monitoring and Research Center, Phoenix, Arizona.

McKinney, T., D.W. Speas, R.S. Rogers and W.R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

Meffe, G.K., and W.L. Minckley. 1987. Persistence and stability of fish and invertebrate assemblages in a repeatedly disturbed Sonoran Desert stream. American Midland Naturalist. 117:177-191.

Meko, D., C. Woodhouse, C. Baisan, T. Knight, J. Lukas, M. Hughes, and M. Salzer. 2007. Medieval drought in the upper Colorado River basin. Geophysical Research Letters 34.

Melis, T.S., S.J.D. Martell, L.G. Coggins, W.E. Pine, III, and M.E. Andersen. 2006. Adaptive management of the Colorado River ecosystem below Glen Canyon Dam, Arizona: using science and modeling to resolve uncertainty in river management, in Specialty Summer Conference on Adaptive Management of Water Resources, CD-ROM Proceedings (ISBN 1-882132-71-8). American Water Resources Association, Middleburg, Virginia.

Melis T.S., S.A. Wright, B.E. Ralston, H.C. Fairley, T.A. Kennedy, M.E. Andersen, and L.G. Coggins, Jr. 2005. Knowledge assessment of the effects of Glen Canyon Dam on the Colorado River ecosystem: an experimental planning support document. Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Meretsky, V.J., R.A. Valdez, M.E. Douglas, M.J. Brouder, O.T. Gorman, and P.C. Marsh. 2000. Spatiotemporal variation in length-weight relationships of endangered humpback chub: implications for conservation and management. Transactions of the American Fisheries Society 129:419–428.

Meretsky, V. and D. Wegner. 1999. Kanab ambersnail at Vaseys Paradise, Grand Canyon National Park, 1998 monitoring and research. Report to SWCA, Inc., Flagstaff, Arizona. 9 p.

Miller, R.R. 1946. Gila cypha, a remarkable new species of cyprinid fish from the Colorado River in Grand Canyon, Arizona. Journal of the Washington Academy of Sciences 36: 409-415.

Miller, R.R. 1955. Fish remains from archaeological sites in the lower Colorado River basin, Arizona. Papers of the Michigan Academy of Science, Arts, and Letters XL: 125-136.

Minckley, C.O. 1996. Observations on the biology of the humpback chub in the Colorado River Basin, 1908–1990. Doctoral Dissertation. Northern Arizona University, Flagstaff.

Minckley, W.L. 1991. Native fishes of the Grand Canyon region: An obituary? Pages 124-177 in Colorado River Ecology and Dam Management. Proceedings of a symposium, May 24-25, 1990. National Academy Press, Washington, DC.

Minckley, W.L., D.A. Hendrickson, and C.E. Bond. 1986. Geography of western North American freshwater fishes: Descriptions and relations to intracontinental tectonism. Pages 519-613 *in* Zoogeography of North American freshwater fishes, C.H. Hocutt and E.O. Wiley, eds. John Wiley and Sons, New York.

Minckley, W.L. and G.K. Meffe. 1987. Differential selection for native fishes by flooding in streams of the arid American Southwest. P. 93-104 in W.J. Matthews and D.C. Heins, eds., Ecology and Evolution of North American Stream Fish Communities. University of Oklahoma Press, Norman, Oklahoma.

Minckley, W.L., and J.N. Rinne. 1985. Large woody debris in hot-desert streams: an historical review. Desert Plants 7(3):142-153.

Moyle, P.B. 2002. Inland fishes of California. 2nd edition. University of California Press, Davis, California.

Mueller, G. 1999. Scientific Panel Review of the Glen Canyon Dam Modifications to Control Downstream Temperatures, Plan and Draft Environmental Assessment (EA) / Gordon Mueller, Carl Walters, Paul Holden, Pete Walker, Jerry Landye and Brett Johnson. Bureau of Reclamation, Salt Lake City, Utah.

Mueller, G.A. and P.C. Marsh. 2002. Lost, a desert river and its native fishes: A historical perspective of the Lower Colorado River. U.S. Geological Survey Information and Technology Report 2002-0010, Denver, Colorado. 69 p.

Muth, R.T. 1990. Ontogeny and taxonomy of humpback chub, bonytail, and roundtail chub larvae and early juveniles. Doctoral Dissertation. Colorado State University, Fort Collins, Colorado.

Muth, R.T., L.W. Crist, K.E. LaGory, J.W. Hayse, K.R. Bestgen, T.P. Ryan, J.K. Lyons, and R.A. Valdez. 2000. Flow and temperature recommendations for endangered fishes in the Green River downstream of Flaming Gorge Dam. Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Parnell, R., A. Springer and L. Stevens. 1997. Flood-induced backwater rejuvenation along the Colorado River in Grand Canyon, Arizona: 1996 final report. Northern Arizona University, Flagstaff. 67 p.

Paukert, C.P., L.G. Coggins, and C.E. Flaccus. 2006. Distribution and movement of humpback chub in the Colorado River, Grand Canyon, based on recaptures. Transactions of the American Fisheries Society 135:539-544.

Paukert, CP, D.L. Ward, P.J. Sponholtz, and K.D. Hilwig. 2005. Effects of repeated hoopnetting and handling on bonytail chub. Journal of Freshwater Ecology 20:649-653.

Peterson, J.H., and C.P. Paukert. 2005. Development of a Bioenergetics Model for Humpback Chub and Evaluation of Water Temperature changes in the Grand Canyon, Colorado River. Transactions of the American Fisheries Society 134:960-974

Pfeifer, F., T. Modde, C. McAda, D. Propst, and G. Birchell. 2002. Area Report for the Upper Colorado River Basin. Proceedings of the Desert Fishes Council, Volume XXXIV:37-38.

Phillips, A.R. 1948. Geographic variation in Empidonax traillii. The Auk 65:507-514.

Pilsbry, H.A. 1948. Land Mollusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II:521-1113.

Rakowski, C.L., and J.C. Schmidt. 1999. The geomorphic basis of Colorado pikeminnow nursery habitat in the Green River near Ouray, Utah. Report A in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Final Report to Upper Colorado River Endangered Fish Recovery Program. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Ralston, B. E., M.V. Loretta, and T.A. Kennedy. 2007. Draft report on comparisons of water quality and biological variables from Colorado River shoreline habitats in Grand Canyon, Arizona, under steady and fluctuating discharges from Glen Canyon Dam. Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 29 p.

Robinson, A.T. and M.R. Childs. 2001. Juvenile growth of native fishes in the Little Colorado River and in a thermally modified portion of the Colorado River. North American Journal of Fisheries Management 21:809-815.

Robinson, A.T., R.W. Clarkson, and R.E. Forrest. 1998. Dispersal of larval fishes in a regulated river tributary. Transactions of the American Fisheries Society 127:722–786.

Rogers, R.S. and , A.S. Makinster. 2006. Grand Canyon Long-term Nonnative Fish Monitoring, 2003 Annual Report. Report submitted to Grand Canyon Monitoring and Research Center Cooperative Agreement 02WRAG0030, February 2005.

Rogers, R.S., W.R. Persons, and T. McKinney. 2003. Effects of a 31,000-cfs spike flow and low steady flow on benthic biomass and drift composition in the Lees Ferry tailwater. Cooperative Agreement 1425-98-FC-40-22690 (mod3). Arizona Game and Fish Department, Flagstaff, Arizona.

Ruppert, J.B., and R.T. Muth. 1997. Effects of electrofishing fields on captive juveniles of two endangered cyprinids. North American Journal of Fisheries Management 17: 314–320.

Schmidt, J.C. 1999. Summary and synthesis of geomorphic studies conducted during the 1996 controlled flood in Grand Canyon. P 329-342 in Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. American Geophysical Union monograph 110.

Schmidt, J.C., D.J. Topping, P.E. Grams, and J.E. Hazel. 2004. System wide changes in the distribution of fine sediment in the Colorado River corridor between Glen Canyon Dam and Bright Angel Creek, Arizona. Final Report of the Fluvial Geomorphology Laboratory, Utah State University, Logan, Utah. 99 p.

Schultz. A.A., O.E. Maughan, S.A. Bonar, and W.J. Matter. Effects of Flooding on Abundance of Native and Nonnative Fishes Downstream from a Small Impoundment. North American Journal of Fisheries Management 23:503-511.

Seager, R., M. Ting, I. Held, Y. Kushnir, J. Lu, G. Vecchi, H. Huang, N. Harnik, A. Leetmaa, N. Lau, C. Li, J. Velez, and N. Naik. 2007. Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. Science.10:1126.

Sorenson, J.A. 2005. Kanab ambersnail 2005 progress report: status of translocated populations and initial results from the November 2004 habitat mitigation experiment. Nongame and Endangered Wildlife Program Technical Report 243. Arizona Game and Fish Department, Phoenix, Arizona.

Sorenson, J.A. and C.B. Nelson. 2002. Interim Conservation Plan for *Oxyloma* (*haydeni*) *kanabensis* complex and related ambersnails in Arizona and Utah. Nongame and Endangered Wildlife Program Technical Report 192. Arizona Game and Fish Department, Phoenix, Arizona.

Speas, D. W. 2004. Effects of Low Steady Summer Flows on Rainbow Trout in the Lee's Ferry Tailwater, 2000. Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Speas, D. W., W.R. Persons, R.S. Rogers, D.L. Ward, A.S. Makinster, and J.E. Slaughter, IV. 2004. 2001 Fish Investigations in the Lee's Ferry Tailwater. Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Sponholtz, P.J. and D.R. VanHaverbeke. 2007. Bright Angel Creek trout reduction project: summary report of fall 2006 weir and electrofishing efforts. U.S. Fish and Wildlife Service report (Interagency Agreement R8219070736) to the National Park Service, Grand Canyon National Park. 19p.

Stevens, L. 1983. The Colorado River in Grand Canyon: A comprehensive guide to its natural and human history. Red Lake Books, Flagstaff, Arizona. 113 pp.

Stevens, L.E. and T.L. Hoffnagle. 1999. Spatio-temporal changes in Colorado River backwaters downstream from Glen Canyon Dam, Arizona 1965-1997. Unpublished report available from U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky and J. Petterson. 1997a. The ecology of Kanab ambersnail (Succineidae: Oxyloma haydeni kanabensis Pilsbry, 1948) at Vaseys Paradise, Grand Canyon, Arizona: 1995 final report. Program Report, U.S. Bureau of Reclamation, Glen Canyon Environmental Studies, Flagstaff, Arizona.

Stevens, L.E., J. P. Shannon and D.W. Blinn 1997b. Colorado River benthic ecology in Grand Canyon Arizona: USA; dam, tributary and geomorphic influences. Regulated Rivers 13:129-149.

Stone, D.M. 1999. Ecology of Humpback Chub (Gila cypha) in the Little Colorado River, near Grand Canyon, Arizona. M. S. Thesis. Northern Arizona University, Flagstaff, Arizona.

Stone, D.M. 2006. Monitoring in 2006 of humpback chub (*Gila cypha*) and other fishes above lower Atomizer Falls in the Little Colorado River, Arizona. May 23–29 and June 28–July 3, 2006, Trip Report (USFWS-AZFRO-FL-07-002) to U.S. Geological Survey, Grand Canyon Monitoring and Research Center Flagstaff, Arizona.

Stone, D.M. 2007. Monitoring in 2007 of humpback chub (*Gila cypha*) and other Fishes above lower Atomizer Falls in the Little Colorado River, Arizona. June 1–7 and June 26–July 2, 2007 Trip Report (USFWS-AZFRO-FL-07-010) to U.S. Geological Survey, Grand Canyon Monitoring and Research Center Flagstaff, Arizona.

Stone, D.M., and O.T. Gorman. 2005. Ontogenesis of Endangered Humpback Chub (*Gila cypha*) in the Little Colorado River, Arizona. The American Midland Naturalist 155:123-135.

Stone, D.M., D.R. VanHaverbeke, D.L. Ward, and T.A. Hunt. 2007. Dispersal of nonnative fishes and parasites in the intermittent Little Colorado River, Arizona. Southwestern Naturalist 52(1):130-137.

SWCA, Inc. Environmental Consultants. 1999. Strategies for developing the Little Colorado River management plan. SWCA, Inc. Environmental Consultants, Flagstaff, Arizona.

SWCA, Inc. Environmental Consultants. 2005. Little Colorado River management plan. SWCA, Inc. Environmental Consultants, Flagstaff, Arizona.

SWCA, Inc. and Grand Canyon Wildlands Council. 2007. A proposal to translocate humpback chub into Shinumo Creek, Grand Canyon. Draft Report to National Park Service, Grand Canyon, Arizona.

Topping, D.J., T.S. Melis, D.M. Rubin, and S.A. Wright. 2004. High-Resolution Monitoring of Suspended-Sediment Concentration and Grain Size in the Colorado River in Grand Canyon Using a Laser-Acoustic System. Pages 2507-2514 in C. Hu and Y. Tan, eds., Proceedings of the Ninth International Symposium on River Sedimentation. Tsinghua University Press, Yichang, People's Republic of China.

Topping, D.J., D.M. Rubin, and L.E. Vierra, Jr. 2000. Colorado River sediment transport 1. Natural sediment supply limitation and the influence of Glen Canyon Dam. Water Resources Research 36:515-542.

Topping, D.J., J.C. Schmidt, and L.E. Vierra, Jr. 2003. Computation and analysis of the instantaneous-discharge record for the Colorado River at Lees Ferry, Arizona-May 8, 1921, through September 30, 2000. U.S. Geological Survey Professional Paper 1677, Reston, Virginia.

Trammell, M. A. and T. E. Chart. 1999. Colorado pikeminnow young-of-year habitat use, Green River, Utah, 1992-1996. Report C in Flaming Gorge Studies: Assessment of Colorado pikeminnow nursery habitat in the Green River. Utah Division of Wildlife Resources, Final Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Trammell, M., R. Valdez, S. Carothers, and R. Ryel. 2002. Effects of a low steady summer flow experiment on native fishes of the Colorado River in Grand Canyon, Arizona. SWCA Environmental Consultants. Final Report (Contract Number 99-FC-40-2260). Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

U.S. Bureau of Reclamation. 1995. Operation of Glen Canyon Dam, final environmental impact statement. Upper Colorado Region, Salt Lake City, Utah.

U.S. Bureau of Reclamation. 1996. Operation of Glen Canyon Dam, record of decision. Upper Colorado Region, Salt Lake City, Utah.

U.S. Bureau of Reclamation. 2002. Proposed experimental releases from Glen Canyon Dam and removal of non-native fish. U.S. Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.

U.S. Bureau of Reclamation. 2007a. Biological assessment on the operation of Glen Canyon Dam and proposed experimental flows for the Colorado River below Glen Canyon Dam during the years 2008-2012. U.S. Bureau of Reclamation, Upper Colorado River Region, Salt Lake City, Utah.

U.S. Bureau of Reclamation. 2007b. Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead, final environmental impact statement. U.S. Bureau of Reclamation, Upper and Lower Colorado River Regions. Four volumes.

U.S. Bureau of Reclamation. 2007c. Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead, record of decision. U.S. Bureau of Reclamation, Upper and Lower Colorado River Regions.

U.S. Bureau of Reclamation. 2007d. Biological assessment of the Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead, final environmental impact statement. U.S. Bureau of Reclamation, Boulder Canyon Operations Office, Boulder City, Nevada.

U.S. Fish and Wildlife Service. 1990. Humpback chub recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 43 p.

U.S. Fish and Wildlife Service. 1991. Final rule determining endangered status for the razorback sucker. Federal Register 56:54957-54967.

U.S. Fish and Wildlife Service. 1994. Final rule, determination of critical habitat for the Colorado River endangered fishes: razorback sucker, Colorado squawfish, humpback chub, and bonytail chub. Federal Register 59:13374-13400.

U.S. Fish and Wildlife Service. 1995. Final Biological Opinion on the Operation of Glen Canyon Dam (2-21-93-F-167). U.S. Fish and Wildlife Service, Albuquerque, New Mexico, January 7, 1995.

U.S. Fish and Wildlife Service. 1995a. Kanab ambersnail (Oxyloma haydeni kanabensis) recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado.

U.S. Fish and Wildlife Service. 1995b. Final rule determining endangered status for the southwestern willow flycatcher. Federal Register 60:10694-10715.

U.S. Fish and Wildlife Service. 1997. Final rule, determination of critical habitat for the southwestern willow flycatcher. Federal Register 62:39129-39146.

U.S. Fish and Wildlife Service. 1998. Razorback sucker recovery plan. Mountain-Prairie Region, Denver, CO. 81 p.

U.S. Fish and Wildlife Service. 2002a. Humpback chub recovery goals: amendment and supplement to the humpback Chub recovery plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

U.S. Fish and Wildlife Service. 2002b. Razorback sucker recovery goals: amendment and supplement to the razorback sucker recovery plan. USFWS, Mountain-Prairie Region (6) Denver, Colorado.

U.S. Fish and Wildlife Service. 2002c. Southwestern willow flycatcher recovery plan. Region 2, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 2005a. Biological and conference opinion on the lower Colorado River multi-species conservation program, Arizona, California, and Nevada (02-21-04-F-0161). U. S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Fish and Wildlife Service. 2005b. Final rule, designation of critical habitat for the southwestern willow flycatcher: Final Rule. Federal Register 70:60886-61009.

U.S. Fish and Wildlife Service. 2006. Biological opinion on the National Park Service Colorado River management plan (02-21-89-F-0106-R1). U.S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Fish and Wildlife Service. 2007. Final biological opinion for the proposed adoption of Colorado River interim guidelines for lower basin shortages and coordinated operations for Lake Powell and Lake Mead. Consultation number 22410-2006-F-0224. U.S. Fish and Wildlife Service, Phoenix, Arizona.

U.S. Geological Survey. 2004. Endangered fish threatened by Asian fish tapeworm: The Asian fish tapeworm may inhibit the recovery of the humpback chub in the Grand Canyon. NWHC Information Sheet, August 2004.

U.S. Geological Survey. 2006. Grand Canyon humpback chub population stabilizing. U.S. Geological Survey Fact Sheet 2006–3109, July 2006.

U.S. Geological Survey. 2007a. Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona. 104 p.

U.S. Geological Survey. 2007b. Grand Canyon Monitoring and Research Center 2007 Work Plan. Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Utah Division of Wildlife Resources. 2004. Humpback chub population estimate in Cataract Canyon, Colorado River, Utah. Report to Upper Colorado River Endangered Fish Recovery Program, Denver, Colorado.

Valdez, R.A. 1990. The endangered fish of Cataract Canyon. (Contract Number 6-CS-40-03980.) BIO/WEST, Inc., Report to U.S. Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A. 1994. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase I. Bio/West, Inc., Final Report to Glen Canyon Environmental Studies.

Valdez, R.A., S.W. Carothers, M.E. Douglas, M. Douglas, R.J. Ryel, K.R. Bestgen, and D.L. Wegner. 2000b. Research and implementation plan for establishing a second population of humpback chub in Grand Canyon, Final Report to U.S. Department of the Interior, U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Valdez, R.A., S.W. Carothers, D.A. House, M.E. Douglas, M. Douglas, R.J. Ryel, K.R. Bestgen, and D.L. Wegner. 2000a. A program of Experimental Flows for Endangered and Native Fishes of the Colorado River in Grand Canyon. SWCA, Inc., Report to U.S. Geological Survey, Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Valdez, R.A. and G.C. Clemmer. 1982. Life history and prospects for the recovery of the humpback chub and bonytail chub. Pages 109-119 in W.H. Miller, H.M. Tyus, and C.A. Carlson, eds., Fishes of the upper Colorado River system: Present and future. Western Division, American Fisheries Society 182:29-39.

Valdez, R.A., B.R. Cowdell, and E. Pratts. 1995. Effects of interim flows from Glen Canyon Dam on the aquatic resources of the lower Colorado River from Diamond Creek to Lake Mead: Phase II, Bio/West, Inc., Final Report to Glen Canyon Environmental Studies.

Valdez, R.A., P.B. Holden, and T.B. Hardy. 1990. Habitat suitability index curves for humpback chub of the Upper Colorado River Basin. Rivers 1:31-42.

Valdez, R.A., and T.L. Hoffnagle. 1999. Movement, habitat use, and diet of adult humpback chub. Pages 297–307 in R.H. Webb, J.C. Schmidt, G.R. Marzolf, and R.A. Valdez eds., The controlled flood in Grand Canyon. Geophysical Monograph 110. American Geophysical Union, San Francisco, California.

Valdez, R.A., and W.J. Masslich. 1999. Evidence of reproduction by humpback chub in a warm spring of the Colorado River in Grand Canyon, Arizona. Southwestern Naturalist 44(3):384-387.

Valdez, R.A., and R.J. Ryel. 1995. Life history and ecology of humpback chub (*Gila cypha*) in the Colorado River, Grand Canyon, Arizona. BIO/WEST, Inc. Final report (TR-250-08) to the Bureau of Reclamation, Salt Lake City, Utah.

Valdez, R.A., and R.J. Ryel. 1997. Life history and ecology of the humpback chub in the Colorado River in Grand Canyon, Arizona. Pages 3–31 in C. van Riper, III and E.T. Deshler, eds., Proceedings of the Third Biennial Conference of Research on the Colorado Plateau. National Park Service Transactions and Proceedings Series 97/12.

Valdez, R. A., and D. W. Speas. 2007. A risk assessment model to evaluate risks and benefits to aquatic resources from a selective withdrawal structure on Glen Canyon Dam. Bureau of Reclamation, Salt Lake City, Utah.

Van Haverbeke, D.R., R.S. Rogers, M.V. Lauretta, and K. Christensen. 2007. 2005 Grand Canyon Long-Term Fish Monitoring Colorado River, Diamond Creek to Lake Mead. 2005 Annual Report to Grand Canyon Monitoring and Research Center from U.S. Fish and Wildlife Service, Hualapai Tribe, and SWCA Environmental Consultants, Flagstaff, Arizona.

Vermeyen, T.C., DeMoyer, W. Delzer, and D. Kubly. 2003. A survey of selective withdrawal systems. Denver Technical Service Center Water Resource Services, Bureau of Reclamation, Denver, CO. 15 p. + 2 appendices.

Ward, D.L. and S.A. Bonar. 2003. Effects of cold water on susceptibility of age-0 flannelmouth sucker predation by rainbow trout. Southwestern Naturalist 48:43-46.

Ward. D.L., O.E. Maughan, S.A. Bonar, and W.J. Matter. 2002. Effects of temperature, fish length, and exercise on swimming performance of age-0 flannelmouth sucker. Transaction of the American Fisheries Society 131:492-497.

Webb, R.H., P.G. Griffiths, C.S. Magirl, and T.C. Hanks. 2005. Debris flows in Grand Canyon and the rapids of the Colorado River. Pages 139-152 in Gloss, S.P., J.E. Lovich, and T.S. Melis, eds., The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

Webb, R.H., J.C. Schmidt, G.R. Marzolf, and R.A. Valdez. 1999. The controlled flood in Grand Canyon. American Geophysical Union monograph 110. 367 p.

Weiss, J. 1992. The relationship between flow and backwater fish habitat of the Colorado River in Grand Canyon. Draft Report. Glen Canyon Environmental Studies, Bureau of Reclamation, Flagstaff. 13 p.

Whitfield, M.J. 1990. Willow flycatcher reproductive response to brown-headed cowbird parasitism. Master's Thesis, California State University, Chico, California. 25 p.

Wiele, S.M., J.B. Graf, and J.D. Smith. 1996. Sand Deposition in the Colorado River in the Grand Canyon from Flooding of the Little Colorado River. Water Resources Research 32:3579-96.

Wiele, S.M., E.D. Andrews, and E.R. Griffin. 1999. The Effect of sand concentration on depositional rate, magnitude, and location in the Colorado River below the Little Colorado River. Pages 131-145 in J.C. Schmidt R.H. Webb, G.R. Marzolf, and R.A. Valdez, eds., The Controlled Flood in Grand Canyon. Geophysical Monograph 110.

Wieringa, M.J. and A.G. Morton. 1996. Hydropower, adaptive management, and biodiversity: Environmental Management 20(6):831-840.

Wright, S.A., T.S. Melis, D.J. Topping, and D.M. Rubin. 2005. Influence of Glen Canyon Dam operations on downstream sand resources of the Colorado River in Grand Canyon. Pages 17-31 in Gloss, S.P., J.E. Lovich, and T.S. Melis, eds., The state of the Colorado River ecosystem in Grand Canyon. A report of the Grand Canyon Monitoring and Research Center 1991-2004. USGS Circular 1282. U.S. Geological Survey, Flagstaff, Arizona.

TABLES AND FIGURES

Table 1. Glen Canyon Dam release constraints as defined by Reclamation in the 1996 Record of Decision (U.S. Bureau of Reclamation 1996).

Glen Canyon Dam Release Constraints		
Parameter	**Release Volume (cfs)**	**Conditions**
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

1 May be exceeded for emergency and during extreme hydrological conditions.

2 Daily fluctuation limit is 5,000 cubic feet per second (cfs) for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Table 2. Projected Glen Canyon Dam releases for Water Year 2008 (U.S. Bureau of Reclamation 2007a).

	No Action				**Proposed Action**			
Month	**Monthly Volume (maf)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Monthly Volume (maf)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	600	9,758	6,800	12,800	601	9,774	6,800	12,800
Nov	600	10,083	7,100	13,100	604	10,134	7,200	13,200
Dec	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Jan	800	13,011	9,000	17,000	800	13,011	9,000	17,000
Feb	600	10,804	7,800	13,800	600	10,804	7,400	13,400
Mar	600	9,758	6,800	12,800	830	13,499	7,200	13,200
Apr	600	10,083	7,100	13,100	550	9,243	6,200	12,200
May	600	9,758	6,800	12,800	555	9,042	6,000	12,000
Jun	650	10,924	7,900	13,900	650	10,924	7,900	13,900
Jul	850	13,824	9,800	17,800	820	13,336	9,300	17,300
Aug	900	14,637	10,600	18,600	820	13,336	9,300	17,300
Sep	630	10,588	7,600	13,600	600	10,083	10,083	10,083

Table 3. Projected releases from Glen Canyon Dam without the proposed action (under current conditions) under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012 (U.S. Bureau of Reclamation 2007a).

	7.48 maf			8.23 maf			12.3 maf		
Month	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	7,502	5,300	10,300	9,758	6,800	12,800	9,378	6,800	12,800
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	7,100	13,100	10,588	7,600	13,600	21,056	19,400	25,000

Table 4. Projected releases from Glen Canyon Dam under the proposed action under dry (7.48 maf), median (8.23 maf), and wet (12.3 maf) conditions, 2009-2012 (U.S. Bureau of Reclamation 2007a).

	7.48 maf			**8.23 maf**			**12.3 maf**		
Month	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**	**Mean (cfs)**	**Min (cfs)**	**Max (cfs)**
Oct	7,502	7,002	8,002	9,758	9,258	10,258	9,378	8,878	9,878
Nov	7,563	5,900	10,900	10,083	7,100	13,100	9,075	7,100	13,100
Dec	9,378	6,800	12,800	13,011	9,000	17,000	12,503	9,000	17,000
Jan	12,503	9,000	17,000	13,011	9,000	17,000	17,510	14,200	22,200
Feb	8,470	7,800	13,800	10,804	7,800	13,800	13,903	13,700	21,700
Mar	9,378	6,800	14,800	9,758	6,800	12,800	14,776	11,400	19,400
Apr	7,563	5,900	10,900	10,083	7,100	13,100	14,551	12,200	20,200
May	9,378	6,800	12,800	9,758	6,800	12,800	14,880	11,500	19,500
Jun	9,075	7,100	13,100	10,924	7,900	13,900	17,009	14,900	22,900
Jul	12,503	9,000	17,000	13,824	9,800	17,800	19,776	16,600	24,600
Aug	12,503	9,000	17,000	14,637	10,600	18,600	23,883	20,900	25,000
Sep	9,075	8,575	9,575	10,588	10,088	11,088	21,056	20,556	21,556

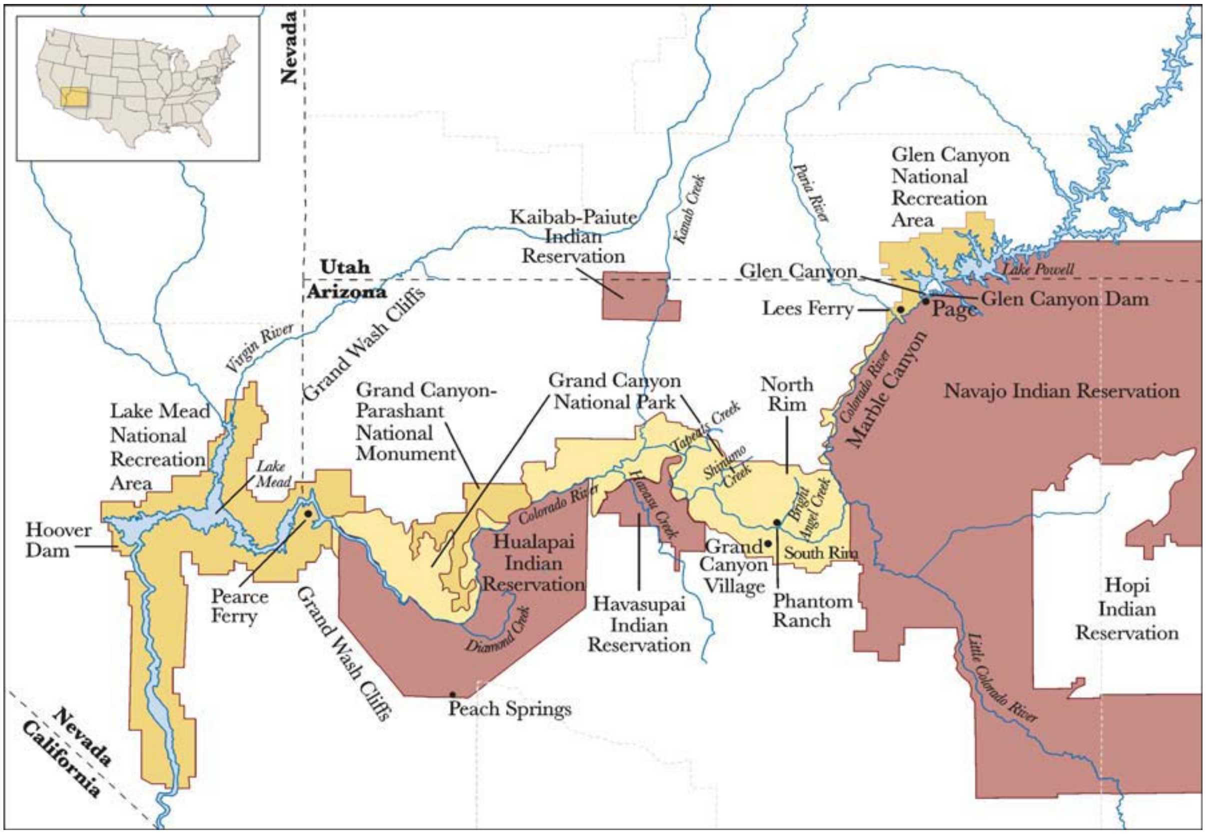

Figure 1. Action Area.

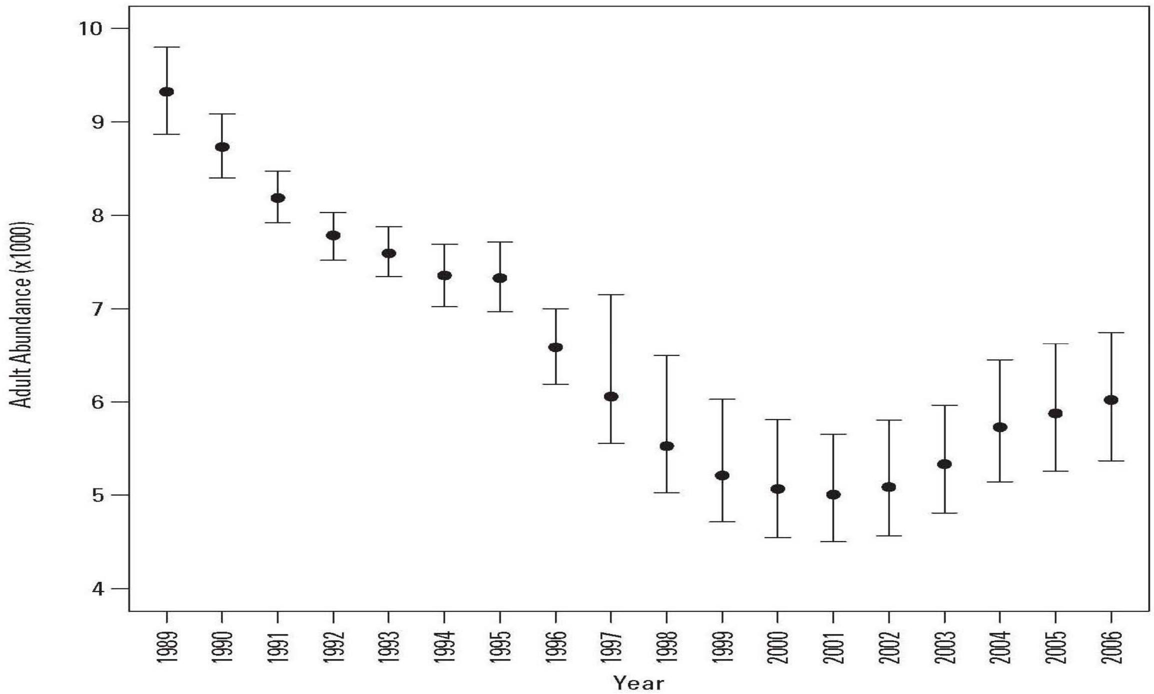

Figure 2. Adult (age 4+) humpback chub population estimates (1989-2005) for the Little Colorado River. Error bars are 95 percent Baysian credibility intervals and reflect uncertainties in assignment of age (Coggins 2007).

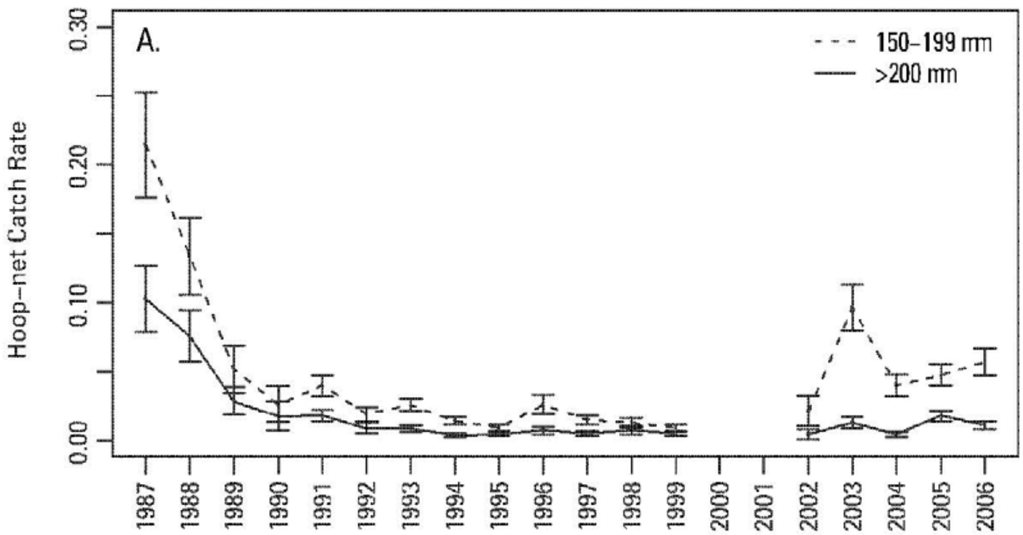

Figure 3. Relative abundance indices of sub-adult (150–199 mm [5.91-7.83 in] total length [TL]) and adult (≥200 [7.87 in] mm TL) humpback chub based on hoop-net catch rate (fish/hour) in the lower 1,200 m [3,937.0 ft] section of the Little Colorado River (Coggins 2007).

APPENDIX A: CONCURRENCES

Concurrence for Glen Canyon Dam Operations for the Period 2008-2012

FWS File No. 22410-1993-F-167R1

Proposed Project

This appendix contains the FWS concurrence with the determinations made by Reclamation for its implementation of proposed Glen Canyon Dam operations for the period 2008-2012 (U.S. Bureau of Reclamation 2007a). The proposed Federal action is described in the Proposed Action section of the attached biological opinion. Reclamation determined that the proposed action may affect, but is not likely to adversely affect, the razorback sucker and southwestern willow flycatcher, or adversely affect critical habitat for the razorback sucker. We concur with those determinations for the reasons described below.

RAZORBACK SUCKER AND ITS CRITICAL HABITAT

Status in the Action Area

The razorback sucker was listed as an endangered species October 23, 1991 (FR 56 54957; U.S. Fish and Wildlife Service 1991). The Razorback Sucker Recovery Plan was released in 1998 (U.S. Fish and Wildlife Service 1998). The Recovery Plan was updated with the Razorback Sucker Recovery Goals in 2002 (U.S. Fish and Wildlife Service 2002b). Critical habitat was designated in 15 river reaches in the historical range of the razorback sucker on March 21, 1994 (FR 59 13375; U.S. Fish and Wildlife Service 1994). Critical habitat includes portions of the Colorado, Duchesne, Green, Gunnison, San Juan, White, and Yampa rivers in the Upper Colorado River Basin, and the Colorado, Gila, Salt, and Verde rivers in the Lower Colorado River Basin.

Razorback sucker appear to use all riverine habitats available at some point in their lives in riverine reaches where they still occur, like the Green River, but habitat studies suggest that they may avoid whitewater reaches, and historically may have been uncommon in the turbulent canyon reaches of the Colorado River such as Grand Canyon. More typically, razorback sucker are found in calm, flatwater river reaches (Lanigan and Tyus 1989, Bestgen 1990). Razorback sucker have not been found in Grand Canyon (from Glen Canyon Dam to upper Lake Mead) since 1995, and only 10 razorback suckers (all adults) have been reported from Grand Canyon (Valdez 1996). A small, but reproducing population occurs in nearby Lake Mead, primarily in Las Vegas Bay, Echo Bay, and the Virgin and Muddy river inflow areas (Albrecht et al. 2007). Radiotagged razorback suckers released in spring of 1997 in the Lake Mead inflow eventually moved into the reservoir and no specimens have been reported from the inflow in recent surveys (Ackerman et al. 2006; Van Haverbeke et al. 2007). Critical habitat in the action area is present from the Paria River confluence to Hoover Dam (U.S. Fish and Wildlife Service 1994).

Reclamation has committed to investigating the potential to improve the status of razorback sucker in the action area, in collaboration with the AMP, MSCP, NPS, GCMRC and other stakeholders as part of their proposed action for the Shortage Guidelines. Reclamation will commit funding to evaluating potential habitat within the AMP for possible razorback sucker augmentation. If augmentation is deemed appropriate, the source of augmented fish and the spatial extent of augmentation will be coordinated with FWS.

Analysis of Effects

Adult razorback sucker are unlikely to be affected by the high flow test because they should be able to withstand high flows and cold temperatures with little or any adverse effect. Steady flows in September and October would likely benefit razorback suckers by providing for more stable and productive habitats. However, because the species is very rare or absent in the action area, the probability of an adverse or beneficial effect is extremely unlikely. Habitat suitability for razorback sucker in general in the action area remains in question. Reclamation's efforts to evaluate the potential for razorback sucker habitat and suitability for augmentation will address this need. If suitable habitat exists, augmentation could result in an expansion of the range of the species and an improvement in its status.

Conclusions

After reviewing the status of the razorback sucker including the environmental baseline for the action area, and the effects of the proposed action, we concur that the proposed action may affect, but is not likely to adversely affect the razorback sucker or its critical habitat, based upon the following:

- The species is extremely rare in the action area, and ongoing monitoring should detect changes in its occurrence;

- Reclamation will undertake an effort to examine the potential of habitat in Grand Canyon for the species, and institute an augmentation program in collaboration with FWS, if appropriate.

SOUTHWESTERN WILLOW FLYCATCHER

Status in the Action Area

The southwestern willow flycatcher was listed as endangered without critical habitat on February 27, 1995 (60 FR 10694; U.S. Fish and Wildlife Service 1995b). Critical habitat was later designated on July 22, 1997 (62 FR 39129; U.S. Fish and Wildlife Service 1997). On October 19, 2005, the FWS re-designated critical habitat for the southwestern willow flycatcher (70 FR 60886; U.S. Fish and Wildlife Service 2005b). A total of 737 river miles across southern California, Arizona, New Mexico, southern Nevada, and southern Utah were included in the final designation. The lateral extent of critical habitat includes areas within the 100-year floodplain. The primary constituent elements of critical habitat are based on riparian plant species, structure and quality of habitat and insects for prey. A final recovery plan for the southwestern willow flycatcher was completed in 2002 (U.S. Fish and Wildlife Service 2002b).

Flycatchers have consistently nested along the Colorado River in Grand Canyon over the last 30 years, with territories typically located in tamarisk-dominated riparian vegetation along the river corridor (James 2005). Suitable habitat is extremely disjunct from approximately RM 28 to RM 274 (Gloss et al. 2005, James 2005, Christensen 2007). Surveys conducted between 1992 and 2007 indicate a very small resident breeding population in upper Grand Canyon, mostly at RM 50-51 and the area around RM 28-29, although only 1 to 5 territories have been detected in any one year. Another area of importance in the mid-1990s was RM 71-71.5. However, that area does not appear to have been occupied for the last 10 years (Gloss et al. 2005, James 2005). The Lower Gorge area of Grand Canyon (RM 246-272) supported as many as 12 territories in 2001, but with drought and low reservoir elevations in Lake Mead, this area has since supported only a single successful nesting pair in 2004; new habitat is emerging and may soon be occupied.

Analysis of Effects

The southwestern willow flycatcher can be adversely affected by high flows through scouring and destruction of willow-tamarisk shrub nesting habitat or wetland foraging habitat, or conversely, through a reduction in flows that desiccate riparian and marsh vegetation. Willow flycatcher nests in Grand Canyon are typically above the 45,000 cfs stage (Gloss et al. 2005), which will not be exceeded for the high-flow test. Flycatchers breed from April through August (U.S. Fish and Wildlife Service 2002c), thus the time frame for the planned high-flow test is also outside of the nesting period for southwestern willow flycatchers. Flycatchers nest primarily in tamarisk shrub in the lower Grand Canyon which is quite common and is not an obligate phreatophtye, thus capable of surviving lowered water levels (DeLoach 1991). Therefore, neither the high flow test nor the potentially lower flows in September and October of the proposed action are expected to kill or remove tamarisk, and no loss of southwestern willow flycatcher nesting habitat is anticipated.

An important element of flycatcher nesting habitat is the presence of moist surface soil conditions (U.S. Fish and Wildlife Service 2002b). Moist surface soil conditions are maintained by overbank flow or high groundwater elevations supported by river stage. During September and October, steady flows under the proposed action will likely be somewhat lower than those found under the no-action peak releases. The potential exists for groundwater elevations adjacent to the channel to decline through the steady flows, which could desiccate nesting habitat. However, September and October are outside of the normal nesting period for southwestern willow flycatcher. The short time period and small change in flow volume lessens the likelihood that any flycatcher habitat will be permanently affected. Thus the proposed action will likely have little effect on the abundance or distribution of southwestern willow flycatcher in the action area or regionally.

Conclusions

After reviewing the status of the southwestern willow flycatcher including the environmental baseline for the action area, and the effects of the proposed action, we concur that the proposed action may affect, but is not likely to adversely affect the southwestern willow flycatcher. No southwestern willow flycatcher critical habitat occurs in the action area, thus none will be affected. We base our concurrence on the following:

- Flycatcher habitat in the action area consists of tamarisk, which is not likely to be affected by either the high flow test or the relatively brief periods of slightly lower flows during the proposed steady releases.

- The timeframe for the main elements of the proposed action are outside of the flycatcher breeding season.

Appendix D. CRSP power customers by state

Arizona State	Colorado State	Nebraska State
Arizona Electric Power Coop	Aspen City	Tri-State Nebraska:
ED2 Pinal	Center City	Northwest Rural Public PD
Mesa City	Colorado Springs Utilities	Panhandle REA
Ak-Chin Indian Community	Delta City	Chimmey Rock Public PD
Chandler Heights ID	Fleming City	Wheat Belt Public PD
Cocopah Indian Tribe	Frederick City	The Midwest Electric Cooperative Corp.
Colorado River Agency (BIA)	Fort Morgan City	Roosevelt Public PD
Colorado River Indian Tribes	Glenwood Springs	
ED3-7	Grand Valley Rural	**Nevada State**
Fort Mohave Indian Tribe	Gunnison City	Colorado River Commission of Nevada:
Fort McDowell Yavapai Nation	Haxtun City	Valley EA
Gila River Indian Community	Holy Cross Electric Cooperative	Overton PD
Havasupai Tribe	Holyoke	Boulder City
Hualapai Tribe	Intermountain Rural Electric Association	AMPAC
Luke AFB	Lamar Utilities Board (ARPA)	Duckwater Shoshone Tribe
Maricopa County Municipal WCD	Oak Creek City	Ely Shoshone Tribe
Navopache Electric	Platte River Power Authority:	Las Vegas Paiute Tribe
Navajo Tribal Utility Authority	Ft. Collins	Mt. Wheeler Power
Ocotillo ID	Loveland	Yomba Shoshone Tribe
Page City	Longmont	
Pascua Yaqui Tribe	Estes Park	**Wyoming State**
Quechan Indian Tribe	Pueblo Army Depot	Bridger Valley EA
Queen Creek ID	Southern Ute Indian Tribe	Torrington City
Roosevelt ID	Tri-State Colorado:	Tri-State Wyoming:
Roosevelt WCD	Delta-Montrose Electric Assoc.	Big Horn REC
Safford City	Empire Electric Assoc.	Carbon Power & Light
Salt River Pima-Maricopa Indian Community	Gunnison County Electric Assoc.	Garland Light & Power Co.
Salt River Project	Highline Electric Assoc.	High Plains Power
San Carlos Apache Tribe	K.C. Electric Assoc.	High West Energy
San Carlos IP (BIA)	LaPlata Electric Assoc.	Niobrara Electric Assoc.
San Tan ID	Morgan County REA	Wheatland REA
Thatcher City	Mountain Parks Electric, Inc.	Wyrulec County
Tohono O'Odham Utility Authority	Mountain View Electric Assoc.	Willwood City
Tonto Apache Tribe	Poudre Valley REA	Wind River Indian Reservation
Welton-Mohawk ID	San Isabel Electric Assoc.	Wyoming Municipal Power Agency:
White Mountain Apache Tribe	San Luis Valley REC	Cody
Yavapai Apache Nation	San Miguel Power Assoc.	Powell
Yavapai Prescott Indian Tribe	Sangre de Cristo Electric Assoc.	Ft. Laramie
Yuma Proving Grounds	Southeast Colorado Power Assoc.	Guernsey
	United Power	Lingle
	White River Electric Assoc.	Lusk
	Y-W Electric Assoc.	Pine Bluff
	Ute Mountain Ute Tribe	Wheatland
	Wray City	
	Yampa Valley REA	
	Yuma City	

Key: AFB=Air Force Base; Assoc=association; ED=electric district; ID=irrigation district; WCD=water conservation district; continued on next page.

Appendix D continued

New Mexico State	Utah State
Pueblo of Acoma	Brigham City
Alamo Navajo Chapter	Confederated Tribes of the Goshute Reservation
Aztec City	Defense Depot Ogden
Cannon AFB	Dixie-Escalante REA
Canoncito Navajo Chapter	Flowell EA
Central Valley Electric Coop.	Garkane PA
Cochiti Pueblo	Helper City
DOE-Albuquerque	Hill AFB
Farmers Electric Coop.	Moon Lake EA
Farmington City	Paiute Indian Tribe of Utah
Gallup City	Price City
Holloman AFB	Skull Valley Band of Goshute Indians
Pueblo of Isleta	St. George City
Pueblo of Jemez	Tooele Army Depot
Jicarilla Apache Tribe	Utah Assoc. Municipal Power Systems:
Kirtland AFB	Beaver
Pueblo of Laguna	Blanding
Lea County Electric Coop.	Bountiful
Los Alamos County	Central Utah WCD
Mescalero Apache Tribe	Enterprise
Nambe Pueblo	Ephraim
Navopache Electric	Fairview
Picuris Pueblo	Fillmore
Tri-State New Mexico:	Heber
Central New Mexico Electric Coop.	Holden
Columbus Electric Coop.	Hurricane
Continental Divide Electric Coop.	Hyrum
Jemez Mountains Electric Coop.	Kanosh
Kit Carson Electric Coop.	Kaysville
Mora-San Miguel Electric Coop.	Lehi
Northern Rio Arriba Electric Coop.	Logan
Otero County Electric Coop.	Meadow
Sierra Electric Coop.	Monroe
Socorro Electric Coop.	Morgan
Southwestern Electric Coop.	Mt. Pleasant
Springer Electric Coop.	Murray
Pojoaque Pueblo	Oak City
Ramah Navajo Chapter	Paragonah
Raton (ARPA)	Parowan
Roosevelt County Electric Coop.	Payson
San Felipe Pueblo	Santa Clara
San Ildefonso Pueblo	Spring City
San Juan Pueblo	springville
Sandia Pueblo	South Utah Valley ESD
Santa Ana Pueblo	Washington
Santa Clara Pueblo	Weber Basin WCD
Santo Domingo Pueblo	Utah Municipal Power Agency:

Taos Pueblo	Levan
Tesuque Pueblo	Manti
Truth or Consequences City	Nephi
Zia Pueblo	Provo
Zuni Indian Tribe	Salem
	Spanish Fork
	University of Utah
	Utah State University
	Ute Indian Tribe of the Uintah & Ouray Reservation

Appendix E Synthesis of Comments and Responses

Comment	Response
The purpose and need statement should be written more clearly with stated objectives, including linkage to the Grand Canyon Protection Act.	This comment has been incorporated in the revised EA. The proposed action has not changed, but greater clarity and explanation of the purpose and need is included in response to these comments.
Scientific citations should be updated and effects narrative technically strengthened.	This comment has been incorporated in the revised EA. Sufficient analysis has been conducted to determine the effect of the proposed action.
The EA should include a range of alternatives.	This EA analyzes a single proposed action alternative that was developed from the recent history of GCDAMP discussions and during informal consultation with the FWS in October - November 2007. This informal consultation recognized new information regarding the status of the humpback chub, continued implementation of the 1996 Record of Decision, and identified experimental flows. In addition, Reclamation considered the likelihood of potential litigation. The proposed action does not preclude additional activities that could be proposed or developed through the GCDAMP as a recent *Federal Register* notice on the Long-term Experimental Plan describes.
Economic analysis should be included to clarify the true cost of the experiment, including the science monitoring and research costs.	This comment has been incorporated in the revised EA. The economic analysis for hydropower was developed by Argonne National Labs, for the recreation impacts through conversations between NPS and the river guides, and for the science plan through procurement discussions between GCMRC and scientific contractors. GCMRC has verified that there is no redundancy between these experimental plan science costs and the other monitoring and research costs of the Adaptive Management Program.
The economic impact on power users from the test should be clarified, including how increased costs would occur.	This comment has been incorporated in the revised EA.

Comment	Response
Additional high flow tests should be included in the proposed action.	The proposed action covers a high flow test in March 2008 and expects that sufficient scientific analysis will occur to answer the questions associated with this high flow test under unique highly enriched sediment conditions. The EA does not preclude additional future tests, but is clear that the test will be immediately followed by this essential analysis (as described on page 7 of the Biological Assessment). It would be premature at this time to propose additional high flow tests until the results of this test are incorporated into that of previous tests and made available for public review. This approach is the fundamental concept of adaptive management.
Post-high flow test flows should attempt to maximize the retention of new sand deposits.	This element is already embedded in the proposed action. Monitoring of sediment transport during 2003 to the present indicates that rapid erosion of newly built sandbar deposits occurs during high release periods. In 1996, the high flow test was followed by about 1 1/2 years of flows which reached or exceeded 20,000 cfs. In 2004, the high flow test was followed by 3 months of high fluctuations up to 20,000 cfs designed to suppress trout spawning. Both of these periods resulted in increased downstream sediment transport. In contrast, the proposed action does not include these high releases, which should limit sediment transport. In addition, the fall steady flows should also result in sediment conservation and provide potential benefits to the humpback chub.
The EA should explain how the proposed action addresses ESA concerns and how other non-flow conservation measures would be implemented.	The proposed action of the EA is identical to that of a recent consultation under ESA with the FWS. The FWS issued a biological opinion on February 27, 2008 which provides the best source of information on the expected effects of the proposed action. This biological opinion is included as an appendix to the EA. Reclamation will work collaboratively with other resource management agencies in implementing conservation measures of this and the 2007 Shortage biological opinions.

Comment	Response
The experimental plan should include desired future conditions or targets to allow evaluation of the success of the proposed action.	The GCDAMP is in the process of developing desired future conditions, starting initially with sediment and humpback chub. In addition, Reclamation believes it important to agree on the metrics used in assessing the status of resources and the success of the proposed action.
The experiment should be delayed until 2009 to allow more time for development of science efforts and environmental compliance.	The accumulation of sediment during 2006 and 2007 presents a unique opportunity to test sandbar building under the highly enriched sediment concentrations that currently exist. If delayed, sediment would continue to be transported downstream. While the magnitude of additional tributary inputs are uncertain in 2008, it is likely that the high flow test would be more effective in 2008 than in 2009.
Mitigation measures which address adverse effects to recreation interests and local businesses should be included in the document.	The EA inadvertently omitted these measures from this section, as the incomplete sentence on page 13 would indicate. These measures have been added.
The downramp rate for the high flow test should be reduced to produce more connected backwaters and more gradually sloping beaches rather than the steep cut banks that may result from a rapid downramp.	Reclamation has not included the requested change to the Proposed Action. Reclamation's proposed March 2008 hydrograph is consistent with GCMRC's proposed experiment which replicates the 2004 high flow test but under highly enriched sediment conditions. It is likely the proposed hydrograph shape will provide greater areas and volumes of sand to test the aeolian transport hypothesis associated with archeological site protection, and would increase the amount of aeolian transport in the spring of 2008.
The science plan should be included and linkages drawn to the proposed action.	This comment has been incorporated in the revised EA and the science plan has been added as an appendix.
The steady flow portion of the proposed action creates new threats to the humpback chub through warm water nonnative fish predation and should be documented.	Reclamation recognizes that increased habitat temperature or stability could result in both positive impacts to the chub and increased proliferation of warm water nonnative fish, and it has incorporated it’s assessment of that risk into the steady flow aspect of the Proposed Action. Monitoring throughout the term of the Proposed Action will assess the effect of the Proposed Action. A warm water nonnative fish control program is being developed by GCMRC to counter the potential of adverse impacts to the humpback chub and would be implemented

	through the GCDAMP.

Comment	**Response**
Replacing fluctuating flows with steady flows would negatively impact aquatic food base and drift, reducing food availability.	This is a valid hypothesis, as is the hypothesis that steady flows would conversely increase aquatic productivity. The science plan will make intensive measurements of algal/invertebrate biomass, invertebrate and fish feeding habits, and invertebrate and fish growth indicators in order to answer this question.
The Adaptive Management Work Group has not recommended either part of the proposed action.	This is a true statement; there has not been a formal recommendation for either part of the proposed action, however the Adaptive Management Work Group has been extensively consulted on the high flow aspect of the Proposed Action. In addition, the steady flow aspect of the proposed action builds on prior discussions within the Adaptive Management Work Group and the AMP. The Department believes that these actions will result in both positive impacts to downstream resources and increased scientific understanding.
The discussion about determining September and October monthly release volumes should be clarified.	Agree. This comment has been incorporated in the revised EA.
The Basin Fund should be reimbursed for the costs of conducting the proposed action.	The proposed approach to this experiment is consistent with the high flow test in both 1996 and 2004. In neither case was the Basin Fund reimbursed for the cost of replacement power required as a result of the experiment.
Sediment augmentation should be explored as a means of attaining sediment conservation.	Agree. In 2007, the Adaptive Management Program funded a preliminary evaluation of sediment augmentation, including potential options and their costs. In determining whether sediment augmentation is required, the proposed action represents an important research effort in determining the long-term sustainability of the sediment resource.

The EA should recognize the potential for extended drought to reduce Glen Canyon Dam water levels to below the penstock intakes.	Agree. Based upon the indexed sequential method currently utilized, Reclamation has estimated that the current annual probability of the reservoir elevation dropping below the powerplant penstock intake levels during any one of the next five years is less than 1%. This information has been incorporated into the EA.

Comment	**Response**
The proposed action should pay greater attention to archeological sites and their preservation.	Agree. The proposed action is fundamentally concerned with rebuilding sandbars and beaches key to the preservation of archeological resources, including the scheduling of a high flow test prior to the spring windy season (which is hypothesized to protect sites subject to gully erosion through aeolian transport of sediment) and the monitoring of archeological sites to determine the effects of the proposed action.
This high flow test must be the last instance of this type of experiment. Future high flows must conform to the constraints of the 1996 ROD (undertaken only to avoid a "spill").	Disagree. This proposed experiment neither mandates nor precludes future experimentation. Rather, this proposed experiment was developed consistent with the principles of adaptive management to require full analysis of the effects of the experiment and integration of such results into future decision making. See discussion at page 7 of the BA and section 2.2 of the EA.
Explanation and justification of the September - October period of steady flows should be included in the EA.	Agree. This comment has been incorporated in the revised EA. Additional explanation has been added from the recently issued Biological Opinion and incorporates the triggering concepts from the 2008 Biological Opinion April 2007 science workshop associated with the Long-Term Experimental Plan.
A science plan should be prepared that addresses the steady flow component of the proposed action.	We agree and have discussed this with GCMRC. Reclamation is committed to start more formal work on the steady flow science plan beginning in April 2008. In addition, the scientific research and appropriated funding of this research associated with the May - September monitoring trips has been strengthened to assess backwater characteristics and use by native and nonnative fish. The existing science plan will also monitor the effects of flows following the high flow test on sediment transport.

The Long-term Experimental Plan process should be reassessed to develop a program of experimental actions designed to meet the intent of Grand Canyon Protection Act.	Agree. The Department has committed to that course of action (see 73 Fed. Reg. 8062 (Feb. 12, 2008))
Reclamation has not complied with procedural elements of NEPA (comment periods, public notice, range of alternatives, etc.).	Disagree. The EA details the numerous steps that Reclamation has taken to comply with all procedural and substantive aspects of NEPA. Reclamation has met and exceeded the legal requirements that are applicable to environmental assessments, including the requirements for providing opportunities for public review and comment.

Comment	**Response**
The Proposed Action impermissibly limits the options that may be considered in the Long-Term Experimental Plan.	We disagree. Reclamation can only proceed with the proposed action if it determines that it will not cause significant impacts, and, as discussed in Section 2.2 of the EA, the proposed action does not limit future experimentation with either high flow tests or steady flows. The nature and scope of the alternatives to be analyzed in the Long-Term Experimental Plan process had not been finalized, and the Department has specifically committed to proceed with a re-assessment of the Long-Term Experimental Plan process following the completion of the analysis of this proposed action. See 73 Fed. Reg. 8062 (Feb. 12, 2008).
No criteria for evaluation or thresholds of significance are identified.	Comment noted. Reclamation is aware that some agencies rely on voluntary, informal policy statements to determine the significance of proposed actions in the NEPA process. Reclamation does not feel that this approach is appropriate for this NEPA process. Instead, Reclamation will use its standard practice of determining the significance of the proposed action based on the appropriate legal and factual criteria that are specific to the action.
Concern about legal authority for future power plant bypass flows.	Comment noted. Consistent with past practice, any decisions regarding future bypass flows will be made in accordance with the Law of the River.

The lack of Seasonally-Adjusted Steady Flows releases violates the 1995 Biological Opinion.	Reclamation does not agree with this assertion. Moreover, this comment does not apply to the Proposed Action because the Fish and Wildlife Service has issued a Final Biological Opinion on the Proposed Action that “replaces the 1995 Final Biological Opinion on the Operation of Glen Canyon Dam (U.S. Fish and Wildlife Service 1995, consultation number 2-21-93-F-167).” The Fish and Wildlife Service further noted in its Final Biological Opinion that “[a]t the end of the five-year period of the proposed action, it is expected that Reclamation will reconsult with FWS.”

FINDING OF NO SIGNIFICANT IMPACT

Final Environmental Assessment for
Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012
Colorado River Storage Project
Coconino County, Arizona

United States Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Salt Lake City, Utah

Recommended by:

RPeterson

Randall Peterson
Program Manager

2/29/08
Date

Approved by:

Larry Walkoviak

Larry Walkoviak
Regional Director

2/29/08
Date

FINDING OF NO SIGNIFICANT IMPACT

PROPOSED EXPERIMENTAL RELEASES FROM GLEN CANYON DAM

The Department of the Interior, acting through the Bureau of Reclamation (Reclamation), is proposing a series of experimental releases of water from Glen Canyon Dam to help native fish, particularly the endangered humpback chub, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

The purpose of the proposed experimental releases from Glen Canyon Dam is to determine if prescribed releases can benefit resources located downstream of the dam in Glen, Marble, and Grand canyons, Glen Canyon National Recreation Area and Grand Canyon National Park, respectively, in accordance with applicable federal law, including the Grand Canyon Protection Act, while meeting the project purposes of the dam. Specifically, the purpose of the high flow test portion of the proposed action is to rebuild sandbars and beaches and rejuvenate backwaters – which may be important rearing habitat for native fish – during a period of enriched sediment storage conditions and to monitor changes over time. The purpose of the steady flow portion of the experiment is to potentially enhance the continuance of recent positive trends in the population of humpback chub and test the impact of fall steady flows on the endangered humpback chub and other aspects of the aquatic environment, particularly backwater environments.

This proposed action is needed because (1) much of the positive initial results of previous high flow tests have eroded, impacting recreational use and aquatic habitat; (2) previous tests were conducted under depleted and moderately enriched sediment conditions and there is a strong need to assess effects under current enriched sediment conditions; (3) the scientific information from the proposed high flow test will help inform the evaluation of long-term sustainability of the sediment resource; (4) there is a desire to enhance the current positive trends in the humpback chub population; and (5) there is a need to test whether recruitment of humpback chub can increase under fall steady flows. While recent population estimates show an improving humpback chub population, the experiment is designed to help scientists better understand the cause of this improvement and methods by which further improvement could occur.

The proposed action builds on decades of scientific monitoring and research conducted during the preparation of the 1995 Operation of Glen Canyon Dam Environmental Impact Statement and during subsequent efforts of the Glen Canyon Dam Adaptive Management Program (GCDAMP). Specific experiments conducted since formation of the GCDAMP in 1997 include steady flows, high flow tests, mechanical removal of predatory nonnative fish, nonnative fish suppression flows, and humpback chub and Kanab ambersnail translocation efforts. Experimentation was designed to assess relationships between dam operations and resources in and along the Colorado River in Glen Canyon National Recreation Area and Grand

Canyon National Park. Results from these scientific efforts helped inform the development of the proposed action.

Proposed Action

The Proposed Action[1] consists of two major elements:

1. an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours beginning March 4, 2008; and
2. steady flows in September and October of each year, 2008 through 2012.

The March 2008 high flow test hydrograph would include the following elements:

- on March 4, 2008 at 2200 hours the modified low-fluctuating flows described in Reclamation (1995) would increase at a rate of 1,500 cfs/hour until powerplant capacity is reached;
- on March 5 once powerplant capacity is reached, each of the four bypass tubes would be opened, where once every three hours bypass releases would be increased by 1,875 cfs until all bypass tubes are operating at full capacity for a total bypass release of 15,000 cfs;
- an essentially constant flow of 41,500 cfs would be maintained for 60 hours;
- discharge would then be decreased at a down-ramp rate of 1,500 cfs/hour until the normal powerplant releases scheduled for March have been reached.

Conservation of fine sediment is a key objective for both the Department of the Interior and the GCDAMP. Determining the long-term sustainability of the sediment resource is a critical objective of the proposed action. Significant progress has been made in understanding sediment transport processes over the last decade, particularly as a result of high flow tests, but the long-term sustainability question cannot yet be answered. The proposed action is an essential step in that effort. This portion of the proposal is similar to high flow tests conducted in 1996 and 2004, but is unique in proposing a high flow test during enriched sediment conditions, to be followed by modified low fluctuating flow operations during a low annual release year.

Steady flow releases during September and October of 2008 through 2012 would include the following constraints:

- typical monthly dam release volumes would be maintained in all water years except 2008, where reallocation of water would occur due to the high flow test in March;
- dam releases for September and October would be steady[2] with a release rate

1 The proposed action described in and approved by this Finding of No Significant Impact is the proposed action submitted to the US Fish and Wildlife Service in Reclamation's December 21, 2007 Biological Assessment.
2 Regulation release capacity of ± 1,200 cfs within each hour will be available if needed for hydropower system regulation during the fall steady flow periods. Each hourly average release is expected to be very close to the steady flow target for the day. Also, spinning reserves will be available if needed for emergency response purposes.

determined to yield the appropriate monthly release volumes;

- if possible, dam operations would be managed so September and October releases would be similar (Table 3), but September releases may be structured to provide a transition between August and October monthly volumes.

The proposed action relies on the best and most recent scientific information regarding the status and population trend of the humpback chub. This includes recognition that recent improvement in the humpback chub population began between 1994 and 1999 - before any of the recent suite of specific actions to benefit the species were undertaken - and that significantly greater numbers of young humpback chub have been found in the mainstem Colorado River during 2002 through 2006, including above the Little Colorado River. These improvements were seen during implementation of modified low fluctuating flow as adopted in the 1996 Record of Decision. The positive response of the humpback chub and the risks associated with warming of fish habitats were primary factors in the FWS conclusion that a conservative approach was warranted. The FWS issued a final biological opinion on the proposed action in a February 27, 2008 Biological Opinion[3].

In addition, the 2008 biological opinion uses an adaptive management approach to the implementation of steady flows and describes triggers which would lead to reinitiation of formal consultation under ESA, in the event that either a significant decline in the Grand Canyon population of humpback chub occurs or a single year population estimate of 3,500 fish or less was calculated. The purpose of reinitiating such consultation would be to evaluate and determine the cause of the decline and propose actions to reverse the decline. Potential actions could include expanding the months when steady flows would be released from the dam as well as other responses to scientific assessment of the causative factors.

During the public review process for this proposed action, a number of entities have advocated additional steady flows or high flows in the future or management actions. This proposed experiment neither mandates nor precludes future experimentation. Rather, this proposed experiment was developed consistent with the principles of adaptive management to require full scientific and public analysis of the effects of the experiment and integration of such results into future decision making.

Mitigation Measures

The following measures have been agreed upon to remove or mitigate potentially negative effects of the proposed action.

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[3] Reclamation's proposed action consists of continued implementation of Modified Low Fluctuating Flows selected in the 1996 record of decision (Interior 1996) with the added elements of identified experimental dam operations for the five-year experimental period (the remainder of water year 2008 through 2012). Accordingly, the FWS issued a biological opinion on the proposed action on February 27, 2008 which "…replaces the 1995 final biological opinion on the operation of Glen Canyon Dam (FWS 1995; Consultation No. 2-21-93-F-167)." The FWS further noted in its final biological opinion (FWS 2008) that "[a]t the end of the five year period of the proposed action, it is expected that Reclamation will reconsult with FWS" under the ESA.

The timing of the high flow test was established to minimize adverse impacts to recreation, tamarisk seedling dispersal, the aquatic foodbase, and the Kanab ambersnail.

Reclamation will, through the AMP, temporarily remove and safe-guard all Kanab ambersnails found in the zone that would be inundated during the high flow test, as well as approximately 15 percent of the Kanab ambersnail habitat that would be flooded by the experimental high flow test. The ambersnails would be released above the inundation zone, and habitat would be held locally above the level of inundation until the high flow test has ended (approximately 60 hours). Habitat will be replaced in a manner that will facilitate regrowth of vegetation. Subsequent monitoring of this conservation measure will be coordinated with the Grand Canyon Monitoring and Research Center (GCMRC).

Reclamation, US Fish and Wildlife Service (FWS), National Park Service (NPS), and Arizona Game and Fish Department (AGFD) will propose creation of an ad hoc group within the GCDAMP to facilitate discussion among angling guides, dependent local businesses, and the public, and consideration of updating the Lees Ferry Management Plan. With respect to the Lees Ferry Management Plan, the NPS and AGFD have primary authority and responsibility for this action, with the FWS and Reclamation participating in an advisory role. If this proposal was accepted by these agencies, workshops could be used to help develop the specific aspects of the management plan.

Analysis Regarding Whether the Proposed Action Will Have a Significant Effect on the Human Environment— As defined in 40 CFR § 1508.27, significance is determined by examining the following criteria:

- **Impacts that May Be Both Beneficial and Adverse**
- **Degree of Effect on Public Health or Safety**
- **Unique Characteristics of the Geographic Area of the Proposed Action**
- **Degree of Controversy for Effects of the Proposed Action**
- **Degree to which Effects of the Proposed Action are Highly Uncertain**
- **Degree to which the Proposed Action Sets a Precedent for Future Actions with Significant Effects or Represents a Decision in Principle about a Future Consideration**
- **Whether the Action is Related to other Actions with Individually Insignificant but Cumulatively Significant Impacts**
- **Degree to which the Action may Adversely Affect Historic Properties or Cause Loss or Destruction of Significant Cultural Resources**
- **Degree to which the Action may Adversely Affect Federally Listed Species or their Critical Habitat**
- **Whether the Action Threatens a Violation of Federal, State, or Local Environmental Protection Law**
- **Impairment of Park Resources or Values**

Each element is discussed as follows:

Impacts that May Be Both Beneficial and Adverse— As fully discussed in the environmental assessment, the proposed action will not affect NPS operations or employee and visitor health and safety. The proposed action could affect soils and biotic communities, Federally listed species and their critical habitats, recreational angling and boating, trout and other non-native fishes, tribal cultural resources and sacred sites, environmental justice, and hydropower generation. The long-term expected outcome of the proposed action is to benefit native fish, principally the endangered humpback chub, and to conserve fine sediment in the Colorado River and its riparian corridor. Negative effects, where they occur, are based on available information and predicted to be minor and temporary.

Degree of Effect on Public Health or Safety— The only potential effects on public health or safety could occur in conjunction with the effects of changes in dam releases on recreational angling and boating on the Colorado River, particularly due to the high flow test. All daily fluctuations, minimum flows, and maximum flows in the proposed action are within the range experienced by recreationists in the past. Furthermore, an incident command center has been established by the NPS. It will be used whenever necessary to further protect public health or safety of these individuals.

Unique Characteristics of the Geographic Area of the Proposed Action —The proposed action will occur within the confines of Glen Canyon National Recreation Area and Grand Canyon National Park. Sand beaches are an important feature and habitat within the Grand Canyon National Park and are expected to be benefited by the proposed action. A portion of the floodplain and some wetland plants will be inundated and likely scoured by the high experimental flows. The plant species affected by the high flow recolonize quickly, however, and the effect will only be temporary. No wild and scenic rivers will be affected by the proposed action. No Indian Trust Assets are found in the project area. Some effects on ecologically critical areas will occur during experimental flows, but the effects will be temporary in nature and the long-term effects are expected to be beneficial.

Degree of Controversy for Effects of the Proposed Action— Four aspects of the proposed action have generated public controversy. First, several Native American tribes consider the salt mines and the confluence of the LCR and Colorado River sacred, and are concerned about potential adverse impacts from the high flow test. This portion of the proposed action is designed to benefit the natural ecosystem in Grand Canyon and should result in positive benefits. The proposed high flow is well within historic flows, both pre-dam and post-dam. Second, the Hualapai Tribe is concerned with potential adverse economic impacts to their boating industry and structures as a result of the high flow test. The third area of controversy is over impacts to the food base, fishery, and fishing industry in the Lees Ferry reach due to the high flow test. Past tests have affected these resources to some degree, but impacts were generally minor and of short duration. A fourth area of controversy involves the potential temporary release of water at levels in excess of powerplant capacity and the reduction of hydropower revenues. Reclamation believes that this limited component of the experiment is consistent with applicable provisions of federal law.

Degree to which Effects of the Proposed Action are Highly Uncertain—The proposed action is being carried out as part of the Glen Canyon Dam Adaptive Management Program to achieve goals of that program. It is being carried out as an experiment that will be monitored under the auspices of the Grand Canyon Monitoring and Research Center using a science plan developed specifically to assess this action. As an experiment, the proposed action operates on hypotheses constructed from the best available scientific information after years of study by scientific researchers in the Grand Canyon. As with all experiments, this action has some uncertainty in outcomes; however, the level of uncertainty, particularly given the feedback system to resource managers built into accompanying research and monitoring, does not rise to the level of highly uncertain, unique or unknown risks.

Degree to which the Proposed Action Sets a Precedent for Future Actions with Significant Effects or Represents a Decision in Principle about a Future Consideration—The GCDAMP operates under the principles of adaptive management in which lessons learned by doing, through scientific experiments, are built into present and future management decisions. The iterative approach taken in this process helps to ensure that changes in management direction are not so large as to have a significant adverse effect on the system and its resources. Neither does any single outcome represent a decision in principle about a future consideration because the outcome of each experiment is added to the knowledge gained in previous experiments in making prospective management decisions.

Whether the Action is Related to other Actions with Individually Insignificant but Cumulatively Significant Impacts—No non-Federal projects were identified as planned, in progress, or completed in the project area. No other GCDAMP actions are proposed at present, but may be considered in the future as part of either NPS, FWS, or AGFD management responsibilities or through recommendations to the Secretary of the Interior.

Degree to which the Action may Adversely Affect Historic Properties or Cause Loss or Destruction of Significant Cultural Resources—There will be no adverse effects to historic properties as a result of implementing the preferred alternative.

Degree to which the Action may Adversely Affect Federally Listed Species or their Critical Habitat— Four Federally listed species, three of which have designated critical habitat, occur in the proposed action area. Two of those species, the Kanab ambersnail and the humpback chub received "may affect, likely to adversely affect" determinations in the biological assessment due to potential take of individuals during the high flow test. Identified adverse effects on listed species or their critical habitat are short-term in nature, and long-term consequences of the proposed action are expected to be beneficial. Conservation measures have been identified for Kanab ambersnail and humpback chub to assist in the conservation of these species and to reduce potential negative effects of the proposed action. The remaining impacts to listed species or their critical habitat are expected to be negligible to minor.

Whether the Action Threatens a Violation of Federal, State, or Local Environmental Protection Law— The proposed action violates no federal, state, or local environmental protection laws.

Impairment of Park Resources or Values— The proposed action is designed to enhance, rather than impair the resources and values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established. In fact, both elements of the proposed action were specifically designed to enhance such resources and values: to assist in the conservation of endangered native fish, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park. There will be no significant adverse effects to park values from the proposed action.

Decision

The proposed action will not have a significant adverse effect on the human environment. The proposed action is designed to improve the conservation of sediment and humpback chub. Negative environmental impacts that could occur are negligible to moderate, and could be short to long term in effect. No significant unmitigated adverse impacts on public health, public safety, threatened or endangered species, historic properties, or other unique characteristics of the region have been identified as a result of analysis of the proposed action. No highly uncertain or controversial impacts, unique or unknown risks, significant cumulative effects, or elements of precedence were identified. Implementation of the proposed action will not violate any federal, state, or local environmental protection law.

Based on the Environmental Assessment, an analysis of all oral and written comments received on the EA, and the foregoing, a finding of no significant impact is justified for the proposed action. Therefore, an environmental impact statement is not necessary to further analyze the environmental effects of the proposed action.

United States Department of the Interior
BUREAU OF RECLAMATION
Upper Colorado Regional Office
125 South State Street, Room 6107
Salt Lake City, Utah 84138-1147

TAKE PRIDE IN AMERICA

IN REPLY REFER TO:
UC-700
ENV-6.00

FEB 29 2008

Interested Persons, Organizations, and Agencies

Subject: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012 Final Environmental Assessment and Finding of No Significant Impact

Please be advised that in compliance with National Environmental Policy Act requirements, the Bureau of Reclamation has completed the Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012, Final Environmental Assessment and a Finding of No Significant Impact (FONSI). We have enclosed a copy of these documents for your information.

The proposed action analyzed in this environmental assessment and approved in the FONSI is a series of experimental releases of water from Glen Canyon Dam to help native fish, particularly the endangered humpback chub, and to conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

The draft environmental assessment was circulated for a 15-day public review, which ended on February 22, 2008. Comments during the review period were incorporated into the final environmental assessment. This document and the FONSI are also available on the internet at www.usbr.gov/uc/envdocs/ea/gc/2008hfe/index.html. If you have questions, please contact Mr. Randall Peterson, Bureau of Reclamation, Upper Colorado Region, 801-524-3758.

Sincerely,

Larry Walkoviak

Larry Walkoviak
Regional Director

Enclosure

1

From: "Mary Broniarczyk" <MBroniarczyk@azgfd.gov>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 9:29 AM
Subject: Experimental Releases from Glen Canyon Dam - AZ Game and Fish Response

Please let me know if you need anything else.
Thank you.

Mary Broniarczyk
Az Game and Fish Department
Program & Project Specialist
MBroniarczyk@azgfd.com
623-236-7601- Phone
623-236-7366- Fax

THE STATE OF ARIZONA
GAME AND FISH DEPARTMENT
5000 W. CAREFREE HIGHWAY
PHOENIX, AZ 85086-5000
(602) 942-3000 • WWW.AZGFD.GOV

February 22, 2008

Mr. Dennis Kubly
U.S. Bureau of Reclamation
Upper Colorado Regional Office
Environmental Resources Division
125 South State Street, Room 6107
Salt Lake City, Utah 84138

Dear Mr. Kubly:

The Department has reviewed the Environmental Assessment for Experimental releases from Glen Canyon Dam. We understand that the Environmental Assessment was developed under very narrow time constraints based upon the proposed timing for the beginning of experimental releases. The contracted period over which the EA was developed and the narrow window available for public and agency review are unfortunate consequences of the timeline that Reclamation and the Department of the Interior established for this experiment. It is unclear what prompted the need for this rapid decision-making process. It appeared to the Department that the same experiment could have been planned and executed with nearly the same sediment loading conditions during water year 2009, without the contracted planning and decision making period. While undoubtedly there may have been multiple factors influencing the timing of this experiment, no alternative proposing this experiment for water year 2009 was either described or identified as rejected.

Little detail or description of the proposed experimental component of proposed action is provided in the EA. The effects assessment is, as we understand it, focused on the releases and the effect of the releases. The absence of some detailed description of the science plan left the reader unable to connect the experiment to the release pattern. The proposed action (section 2.2) indicates that "...this experimental design is fully reflected in the science plan developed by GCMRC." The Glen Canyon Dam Adaptive Management Program's Science Advisors indicated in their review of the science plan that "...more information is needed to structure and test effective hypotheses [about backwaters] in this high flow event", suggesting that this aspect of the justification for the experiment may be premature. It is essential that detailed study plans for this aspect of the experiment, and allied research into the relative importance of various potential rearing habitats be developed before the experiment rather than after it has commenced.

The Department does not object to this proposed action. However, we believe that there are portions of the EA that could be improved upon. Reclamation and Department of Interior leaders should be more fully informed as they formulate their decision on whether or not to proceed with the experiment as proposed.

A stated purpose of the proposed experiment is to determine or understand potential benefits of backwaters created by the high-flow release for native fish, particularly humpback chub. That purpose is predicated on a hypothesis that backwaters are disproportionately valuable as rearing habitat for young humpback chub. This is uncertain. This experiment does not evaluate backwater habitat value as opposed to other near shore habitats and other monitoring and experiments not addressed in this Assessment will have to shed light on those relationships. The assessments of benefits regarding backwaters under the proposal (section 3.1.4.6) and native fish under the proposal (section 3.1.8) are perhaps overstated because of that uncertainty. Impacts to humpback chub and other native fishes are unlikely to differ greatly from the no action alternative. Benefits accruing from the experiment are more aligned with determining the value or lack of value of high flow events as management tools in the restoration of the population of humpback chub in Grand Canyon.

Reclamation has committed to a strategy of mitigation for Kanab ambersnail (sections 2.2.1 and 3.1.6.1) modeled upon successful strategies implemented during prior events. The Department has worked closely with the Bureau, the National Park Service, and Grand Canyon Monitoring and Research Center on those mitigation strategies and believes they are effective. The Department is a willing cooperator in this effort.

The Department appreciates that the trout fishery at Lees Ferry was noted as a resource of concern in the Environmental Assessment, both as a wildlife resource and a recreational value. The trout fishery, initiated in partnership with the Bureau of Reclamation under Section 8 of the Colorado River Storage Project Act, is among the values for which Glen Canyon National Recreation Area was established and hence afforded appropriate consideration under the Grand Canyon Protection Act. The trout population is a valuable wildlife resource asset belonging to the people of the State of Arizona under the stewardship of the Arizona Game and Fish Department.

We concur that direct effects to the trout population will be transitory. However, the fishery includes the recreational use and benefits that are derived from it. We believe the discussion of impacts to fishing recreation under the proposal (section 3.3.2.2) underestimates the effects of the proposed action. The discussion focuses on three days of disruption of angling recreation. However, it is our understanding that the indirect effects of the event prompt anglers to cancel reservations and fishing plans at the site, and stay away from Lees Ferry for some protracted period following the event based on their concerns that the fishery has been disrupted. We have partnered with the Grand Canyon Monitoring and Research Center to dispel misperceptions, however; the effects were described by business owners at Marble Canyon in meetings you reported in section 3.3.2.1, were included in reports to Reclamation, and may be very real. In turn, your discussion of net economic value under the proposal (section 3.3.2.6) may grossly underestimate the effect on regional economic activity of the proposed experiment. That estimate, which we assume is based upon a personal communication of expected expenditures by anglers in the local economy over three days, might be extended for weeks or months beyond the three days of proposed high flows. The Environmental Assessment indicates that Reclamation will assist in implementing the measures described in section 2.2.1. However, it appears upon reading that section that it is incomplete, and ends with the phrase "These proposed measures include:". We recognize that the start of the high flow experiment was shifted by several days which may or may not reduce impact to fishing recreation, and that Reclamation is committed to working with the Department, the U.S. Fish and Wildlife Service, and the National Park Service to propose measures within the Adaptive Management Program to improve communication with that local business community. The proposed mitigation measures were omitted from the document. The Department requests the opportunity to discuss those mitigation measures with Reclamation prior to the decision to proceed.

Because the community at Marble Canyon is small, remote, employs local residents beyond hotel/restaurant owners and fishing guides (sections 3.3.4 and 3.4), and its economic well-being is directly linked to angler visitors; the issue of direct and indirect impact of the proposed experiment should be evaluated as a possible environmental justice issue (Executive Order 12898). The Department does not have the economic expertise that Reclamation can bring to bear on this aspect, however if this aspect of the issue has not been evaluated for decision makers perhaps it should be.

Sincerely,

Bob Broscheid
Assistant Director, Wildlife Management Division

BB:lr

cc: Brenda Burman, Deputy Assistant Secretary, U.S. Department of the Interior
Steve Spangle, Field Supervisor, U.S. Fish and Wildlife Service - Ecological Services
Sam Spiller, Lower Colorado River Coordinator, U.S. Fish and Wildlife Service
Stewart Jacks, Project Leader, Arizona Fisheries Resources Office, U.S.F.W.S.
John Hamill, Chief, Grand Canyon Monitoring and Research Center

2

From: "Casey Tyson" <casey@arcieromiller.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 8:36 PM
Subject: I SUPPORT the NO ACTION ALTERNATIVE

I am writing to give comments in regard to the "PROPOSED" series of experimental releases of water from Glen Canyon Dam to help native fish, particularly the endangered humpback chub, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

I do not think this is an effective use of our dollars & in fact I think it has been proven that the such releases will NOT achieve the stated objectives. Please reconsider this experiment & allow more time to come up with more efficient ways to achieve some of these goals.

I would also like to take this chance to voice my strong concern over low steady flows in September and October. I feel like this would be two steps back & we should be using Glen Canyon dam as a source for CLEAN ENERGY. The costs of energy are sky rocketing in this country & the issue is not going away. I think it will look really silly when oil is $130/barrel & nat gas is $10 at the end of this year & we put through a proposal to cut flows at Glen Canyon Dam.

Thank you for taking my stance of opposition into consideration. I support the NO ACTION ALTERNATIVE.

Casey Tyson

Chief Financial Officer

Arciero-Miller Racing LLC

www.vwmotorsportusa.com

<http://www.arcieromiller.com/> www.arcieromiller.com

949-461-7100: Office

602-214-6364: Mobile

3

From: "Chad H" <chadjan@gmail.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 4:59 PM
Subject: No to controlled flooding on the Colorado river

Do not conduct this experiment, instead investigate nondestructive methods of building beaches in the Grand Canyon and to use common sense and sound judgment in dealing with this and all future planned experiments on the Colorado River.

Complete waste of money doing an Environmental Assessment, Spend the money on keeping Zebra Mussels out of our lakes and waterways.

I support clean energy and encourage the use of power generation from Glen Canyon Dam.
I support the NO ACTION ALTERNATIVE

Thank you
Chad Humphrey
970 252 0811

4

From: <rockarosa@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 3:05 PM
Subject: March High Flows

Dear Sirs,
? I encourage you to look at a moderation of the down ramping after this test flow. I have been down the river many times after test flows and the subsequent quick down ramping and witnessed the resulting steep beaches and calving of beaches. The result has been that after a few months the sand has moved back into the river and the beaches are not much improved as a result. A natural flood event does not end quickly like these artificial flood events. Take a hint from the natural processes and try do duplicate it this time. You only get to do these flows every once in a while so try to get it right when you have the chance.

Sincerely,
David P. Christensen
Former River Guide and Park Service Employee

5

From: "Bob Sweet" <trouttramp@sweetdecks.com>
To: "river" <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 2:05 PM
Subject: GC experimental releases

Once again a goverment dept./bureau is kicking a dead horse so to speak. Previously the Bureau of Reclimation has experimented and failed in The Grand Canyon. They need to consider other non destructive methods of building beaches in the GC. There are always alternative answers, one which can accomplish the desired goal and sustain all recreational activities and thier associated economies.

In this time of record high fossil fuel costs, depleted supplies and most importantly the need for clean energy sources, to plan to reduce flows in September and October, which of course will lower electrical output from Glen Canyon Dam, requiring made up electric to be generated elsewhere in a non clean energy plant. I oppose the scheduled low flow .

I as well support the No Action Alternative

C

From: "Liquidity Group" <liquiditygroup@jps.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 1:06 PM
Subject: Support for March High-Flow release

Hello,

I understand the multiple-mission conflicts of BuRec, but in order to have a reasonably balanced approach to management, a flood flow is not unreasonable. The environment always takes a back seat to other concerns; this is not a lot to ask! Credible scientists feel this is the right time to try it again, so please go ahead with it.

Randy Michaels

7

From: Doni Kelly <dkelly04@earthlink.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 12:09 PM
Subject: In support of Grand Canyon River Guides position

Dear Sir;
I have read the position paper by the Grand Canyon River Guides and believe that their points are well thought out and based on both scientific principles and many years of personal observations of the river. While I can't speak to the scientific points regarding the chub (paragraph 3), I have observed the progressive subsidence and calving of beaches during 4 separate Grand Canyon river trips, from 1987 through 1994. As noted in paragraph 2, the rapid downramping of flows caused significant calving of beaches; overnight subsidence leaving a 3-4 foot wide beach in the morning after having camped on a beach 5 times that size the night before. It's also reasonable to test the high flows for a year without committing to a 5 year time frame.
I hope that you will consider the position of the Grand Canyon River Guides as a positive and thoughtful approach to preserving the Grand Canyon for all stake holders.
Sincerely,
Donell D. Kelly
Tucson, AZ

Doni

8

From: Richard Herron <RHerron@maximsys.com>
To: "'GCexpReleases@uc.usbr.gov'" <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 11:53 AM
Subject: Stop the flush

Hello,
I support the "NO ACTION ALTERNATIVE". I feel that if it is beaches that are the prime reason behind this scheme, then why can they not use the debris from the deepening of Castle Rock Cut project at Lake Powell. This is a waste of tax payer dollars for this flush and only benefits a very small number of rafters. Then there is the issue of previous floods killing endangered chubs. Stop the flood.
Respectfully,
-rich herron
San Diego, CA

Richard Herron
Senior Software Engineer
Office: 619-574-2257
Fax: 619-692-3597
Cell: 619-994-6380
rherron@maximsys.com

9

From: "Alanna M. Larson" <AlannaMarlene@msn.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 10:39 AM
Subject: Fw: GCRG comments on EA

We are totally in agreement with the Grand Canyon River Guides, Inc. view.
Alanna Larson
Prescott, AZ

----- Original Message -----
From: Lynn Hamilton<mailto:gcrg@infomagic.net>
To: Undisclosed-Recipient:;<mailto:Undisclosed-Recipient:;>
Sent: Wednesday, February 20, 2008 11:28 AM
Subject: GCRG comments on EA

Hi everyone,

I have attached Grand Canyon River Guides' official comments on the Environmental Assessment concerning the High Flow Experiment (HFE). As you know, GCRG is strongly supportive of the HFE. We are also recommending a more gradual downramp rate to maximize the effectiveness and longevity of resource benefits for this experiment. In other words, subsequent flows are every bit as critical as the High Flow Experiment itself.

If you have not already done so, PLEASE send comments to GCexpReleases@uc.usbr.gov<mailto:GCexpReleases@uc.usbr.gov> by close of business on February 22, 2008 (that's this Friday!)

This EA is an outstanding opportunity for the Bureau of Reclamation to hear directly from the river community on these important issues. Please let your voice be heard at this critical juncture. Your individual comments are vital. Thanks for your advocacy on behalf of Grand Canyon and the resources downstream of Glen Canyon Dam.

Sincerely,

Lynn Hamilton
Executive Director
Grand Canyon River Guides, Inc.

GRAND CANYON RIVER GUIDES
PO Box 1934
Flagstaff, AZ 86002
(928) 773-1075 phone
(928) 773-8523 fax
gcrg@infomagic.net
www.gcrg.org

Comments on Environmental Assessment

Date: February 20, 2008

To: Dennis Kubly, Bureau of Reclamation

From: Grand Canyon River Guides, Inc.

Re: Comments on Environmental Assessment of High Flow Experiment (HFE).

1) Grand Canyon River Guides strongly supports this High Flow Experiment.

We are fairly certain that an HFE will result in deposition of many new sand bars at higher elevations throughout the river ecosystem. We advocate for post-test flow regime that maximizes learning and resource benefits for as long as possible. Our objectives are to solve problems and improve conditions in the downstream river ecosystem, while minimizing impacts to hydropower, the trout fishery, and other ancillary benefits of the dam.

2) Stable beach profile for recreation and cultural resources:

We are concerned that the steep down ramp following the high release will create an unstable beach profile, leading to calving-off of water-saturated, newly deposited sand bars. This may result in rapid slope retreat, especially when daily high releases reach 17k cfs in July and August. This was a principle scientific conclusion of the Glen Canyon Dam EIS in 1995. A more gradual down ramp may rework the new deposits to a more stable beach profile. This should provide terraces at levels accessible to recreational boaters while leaving large sand areas upslope for wind distribution into the higher pre-dam terraces where archaeological and cultural resources are located.

3) Backwater habitat:

We are concerned that the steep down ramp following the high release will not optimize backwater habitat for young-of-year chub in the newly formed deposits. Backwaters formed at 41k cfs may become perched and/or drained when lower flows are later released. A more gradual down ramp may create a beach profile in the new deposits accessible to fish at lower flows.

4) Run the High Flow test as a discrete experiment. Do not commit to a five-year, Sept.-Oct. steady flow experiment at this time.

It seems that this five-year steady flow proposal has not been scientifically analyzed well enough to know that it is the best route to take. Perhaps try it for one year to see if steady fall flows are optimal for sampling and maintenance of backwater habitats. Seine net sampling during the subsequent year should determine if the fall steady flows should be continued in subsequent years or modified.

5) Summary:

Grand Canyon River Guides appreciates Reclamation's support of the HFE and interest in using steady flows to mitigate ecosystem problems. Similarly, GCMRC with the AMWG stakeholders have produced an excellent effort to plan for these activities. We already know from previous HFE experiments that sand can be re-distributed to higher elevations, but less attention has been paid to making those newly formed sand bars effective and last for longer periods of time. If the post-HFE hydrograph was designed more carefully to optimize ecosystem goals, it may reduce the urgency for subsequent HFEs and more effectively achieve goals to restore the Colorado River ecosystem below Glen Canyon Dam.

Thank you for the opportunity to comment on this Environmental Assessment.

Andre Potochnik, Ph.D.
Grand Canyon River Guides, Adaptive Work Group Representative

Lynn Hamilton
Grand Canyon River Guides, Executive Director

Sam Jansen
Grand Canyon River Guides, President

10

From: "Tiffany Mapel" <tmapel@durango.k12.co.us>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 10:24 AM
Subject: Grand Canyon flood comments

Dear Mr. Kubly,

I support the NO ACTION ALTERNATIVE in regard to the proposed Grand Canyon flood in March. With the low water level in Lake Powell, this flood is not needed or justified at this time.

Thank you,
Tiffany Mapel
549 E. 5th Ave.
Durango, CO 81301

11

From: "Richard" <mokimac@mokimac.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 9:35 AM
Subject: Comments on High-Flow Experiment

Attached are comments submitted by Moki Mac River Expeditions

Thank you.

Comments on Environmental Assessment

Date: February 20, 2008

Dennis Kubly, Bureau of Reclamation
Upper Colorado Regional Office
125 S. State Street
SLC, UT 84138

Re: Comments on Environmental Assessment of High Flow Experiment (HFE).

Submitted via e-mail to GCexpReleases@uc.usbr.gov February 20,2008

As a National Park rafting concessionaire providing outfitted trips down the Colorado River through Grand Canyon, we support the concept of the currently proposed High Flow Experiment (HFE).

As we witnessed after the last such high water release, beneficial results, particularly sand bar deposition, were realized. We would anticipate similar or even more beneficial results from the proposed HFE given the current heavy sediment load that has been building in the river channel over the last several years.

Management practices that result in "beach building" along the river corridor in the Grand Canyon is a worthwhile endeavor, in part because recreation resources are enhanced. Beyond that, and in some assessments more importantly, we are after all talking about one of this country's premier National Parks – and the river corridor through the Park is its heart and soul. The more that can be learned about protecting and returning in so far as is practical the river corridor to pre-dam conditions, the better.

In this regard, we would suggest consideration for and development of a post-test flow regime that maximizes benefits for as long as possible. Following the last high release experiment, we were struck how rapidly the new beaches that were produced began to erode away – not lasting even for the rest of that season. We appreciate and encourage objectives designed to solve ecological problems and improve conditions in the downstream river ecosystem, while minimizing impacts to hydropower, the trout fishery, and other benefits of the dam.

Sincerely,

Clair Quist, President
Moki Mac River Expeditions

12

From: <Nazelectricmotor@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 9:32 AM
Subject: Attn: Dennis Kubly Re: High Water Flush

Dear Sir:

I support the "NO ACTION ALTERNATIVE" concerning the high flow experiments being considered for Marble and Grand Canyons from Glen Canyon Dam and Lake Powell.

Experts have recommended that this experiment NOT be exercised to appease scientist and special interest groups as Living Rivers and the Grand Canyon Trust. The recommendations of the experts and VOTE AGAINST the high flow by 14 of the 16 members of the water management board should stand and be recognized and followed.

Thank You '

Ronald Paul
Flagstaff,Az

13

From: <erthquest@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 21, 2008 1:07 AM
Subject: high flow test releases.

Call me a cynic,
?I've guided?In the Grand for 40 years. All I see is sediment going downstream with very little replacement. That's a given to the present system.What don't you get? How much revenue has to be spent to say that beach and river bottom sands are going to fill Lake Meade and won't be replaced?

Ramping rates will affect the speed of erosion. DUH. I worked in the 70's when daily flows went from 6k to 30+k cfs that's when beaches really dissappeared. Your flood flows don't amount?to a hill of beans compared to normal fluctuations in the 70's. 45k was often seen then.

I was an emergency hire NPS river ranger in '83 -- I've seen some big water. I also was on the river in '77 when we ran on dam "seepage" 800cfs at best.

What exactly are you guys trying to prove here? I would really like an honest answer. All my experience tells me sediment moves downstream and in an artificial environment nothing will rectify it.

Saludos,

Yerry Brian

When you

14

From: "Jay and Linda Moyer" <stanlee2@cox.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 10:12 PM
Subject: 2008 FLUSH OF GLEN CANYON DAM

Please do not continue with these "flushes". I believe it will not help anyone or anything. It is detrimental to Lake Powell, the fish below the dam, and the Colorado below.and beyond.

I objected to this at the Phoenix BOR meeting in early 2007 (or late 2006) and I still object to this ridiculous waste of tax payer's money.

Thank you,

Jay Moyer

Fountain Hills, Arizona

Great fan and user of Lake Powell

15

From: <cheavnrich@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 9:53 PM
Subject: feedback

To whom it may concern

I've been a river guide in the Canyon since 1978, and have watched as the operation of the dam has wreaked havoc downstream. In the

first "spike" flow event in '96, I watched as the beaches were repopulated by an additional 35% in just the first 48 hours. Then, for the rest

of the summer, I watched those beaches shrink dramatically due to high flows for an extended time. I believe the flows were around 27,000

for some of that time. To protect the beach building portion of the proposed high flow event in March, it would be crucial to change the downramp

schedule to reflect this concern. Take more time, use less change per hour in the downramp schedule, and preserve the positive input of the

higher flows.

Thank You

Charly Heavenrich

Canyon Explorations Guide (and proud of it)

303-545-5414

16

From: <Luv10sMargie@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 8:40 PM
Subject: (no subject)

i strongly Oppose.. thank you john fraser

17

From: "Mario Kowalski" <kowalski3@cox.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 8:39 PM
Subject: High Flow Experiment

Please support the high flow experiment with a gradual return to normal flows. Not only will this help build beaches, but also allow a more gradual slope which will aid chub and other fish not get caught as the flows fluctuate from high to low.

Thanks!

Mario Kowalski

Phx, AZ

"Live simply, love generously, care deeply, and speak kindly. Leave the rest to God"

18

From: "the baileys" <baileys@montrose.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 8:31 PM
Subject: Flush

Dennis , I only have one thing to say. "STOP THE FLUSH" It's just no good!!!

19

From: "Paul Weitz" <pweitzq13@npgcable.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 4:39 PM
Subject: Glen Canyon Dam releases

Mr. Kubly - I am an Arizona resident with no commercial interest in any aspect of river flows out of Glen Canyon Dam. With regard to the proposed experimental releases from the dam, I strongly support the "No Action Alternative" proposal. I vigorously oppose the high flow test and any proposal for steady flows during any part of the year. If GC Dam were in the proposal stage, I would contribute to any effort to defeat it; however, the dam is there, and people need to recognize that and learn to live with it. Sincerely, Paul Weitz

20

From: sarah kuhn <kuhndaug@yahoo.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 12:18 PM
Subject: HFE

To whom it may concern;

I am a member of Grand Canyon Rivers Guides and on behalf of everyone who has fallen in love with rivers I would like to make a short comment regarding the upcoming High FLow Experiment (HFE).

Recently, I was fortunate to receive an invitation to go down Grand Canyon on a private river trip that would launch on the fifth of March, the first day of the proposed HFE. Prior to actually receiving the invitation, I was made aware of the private permit's existance by a friend who stressed that a beach building flow was going to be released. As we talked about how it would change the rapids and where we would camp, I was struck by the potential for BIG beaches. I had to on that trip and if not that trip, a trip, any trip that would allow me to be down there to see those beaches, to see the Colorado like that.

I have been a professional boater for 10 years and I have been on many rivers, dammed and undammed, and I can honestly say that you can tell a lot about a river by the condition of its beaches and right now the Colorado through Grand Canyon is on the verge of being ill.

Thank you for all you do to keep the river healthy. Sarah Kuhn

----

21

From: "Lynn Hamilton" <gcrg@infomagic.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Wed, Feb 20, 2008 11:37 AM
Subject: Grand Canyon River Guides comments on EA

Attached please find Grand Canyon River Guides' official comments on the Environmental Assessement for a High Flow Experiment. If you have any questions, please let us know. Thank you for the opportunity to provide input.

Sincerely,

Lynn Hamilton
Executive Director
Grand Canyon River Guides, Inc.

CC: "Dennis Kubly" <DKUBLY.4ucro.ibr4dm10@uc.usbr.gov>, "Andre Potochnik" <apotochnik@prescott.edu>

GRAND
CANYON
RIVER
GUIDES

PO Box 1934
Flagstaff, AZ 86002
(928) 773-1075 phone
(928) 773-8523 fax
gcrg@infomagic.net
www.gcrg.org

Comments on Environmental Assessment

Date: February 20, 2008

To: Dennis Kubly, Bureau of Reclamation

From: Grand Canyon River Guides, Inc.

Re: Comments on Environmental Assessment of High Flow Experiment (HFE).

1) Grand Canyon River Guides strongly supports this High Flow Experiment.

We are fairly certain that an HFE will result in deposition of many new sand bars at higher elevations throughout the river ecosystem. We advocate for post-test flow regime that maximizes learning and resource benefits for as long as possible. Our objectives are to solve problems and improve conditions in the downstream river ecosystem, while minimizing impacts to hydropower, the trout fishery, and other ancillary benefits of the dam.

2) Stable beach profile for recreation and cultural resources:

We are concerned that the steep down ramp following the high release will create an unstable beach profile, leading to calving-off of water-saturated, newly deposited sand bars. This may result in rapid slope retreat, especially when daily high releases reach 17k cfs in July and August. This was a principle scientific conclusion of the Glen Canyon Dam EIS in 1995. A more gradual down ramp may rework the new deposits to a more stable beach profile. This should provide terraces at levels accessible to recreational boaters while leaving large sand areas upslope for wind distribution into the higher pre-dam terraces where archaeological and cultural resources are located.

3) Backwater habitat:

We are concerned that the steep down ramp following the high release will not optimize backwater habitat for young-of-year chub in the newly formed deposits. Backwaters formed at 41k cfs may become perched and/or drained when lower flows are later released. A more gradual down ramp may create a beach profile in the new deposits accessible to fish at lower flows.

4) Run the High Flow test as a discrete experiment. Do not commit to a five-year, Sept.-Oct. steady flow experiment at this time.

It seems that this five-year steady flow proposal has not been scientifically analyzed well enough to know that it is the best route to take. Perhaps try it for one year to see if steady fall flows are optimal for sampling and maintenance of backwater habitats. Seine net sampling during the subsequent year should determine if the fall steady flows should be continued in subsequent years or modified.

5) Summary:

Grand Canyon River Guides appreciates Reclamation's support of the HFE and interest in using steady flows to mitigate ecosystem problems. Similarly, GCMRC with the AMWG stakeholders have produced an excellent effort to plan for these activities. We already know from previous HFE experiments that sand can be re-distributed to higher elevations, but less attention has been paid to making those newly formed sand bars effective and last for longer periods of time. If the post-HFE hydrograph was designed more carefully to optimize ecosystem goals, it may reduce the urgency for subsequent HFEs and more effectively achieve goals to restore the Colorado River ecosystem below Glen Canyon Dam.

Thank you for the opportunity to comment on this Environmental Assessment.

Andre Potochnik, Ph.D.
Grand Canyon River Guides, Adaptive Work Group Representative

Lynn Hamilton
Grand Canyon River Guides, Executive Director

Sam Jansen
Grand Canyon River Guides, President

22

From: William Wen <williamwen@hotmail.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 19, 2008 10:31 PM
Subject: NO ACTION ALTERNATIVE

Dear Madam or Sir,

I am adamantly opposed to the proposed high flow schedule that is tentatively scheduled for early March, 2008. This experimental flow is a total waste of resources and the motivation and science behind its reasoning is inconclusive and deceptive. The trout *ARE* here to stay. There has been no proof that the rainbow trout are predatory and responsible for deaths of native species. The brown trout are already being removed from Bright Angel Creek. If there's a real desire to create better conditions for native species then spend the time and energy to make the dam modification necessary to warm up the water being released and not on random guesses which cost the tax payers millions of dollars.

I am also opposed to the low experimental flows proposed for September and October. This will promote the increase of greenhouse gases as needed by other means of power generation. Is anyone not aware of all the "green" trends that are currently taking place?

I take monthly trips up to the Glen Canyon area and have been for the last 5 years. Year after year, the habitat decreases and the environmental impact from these rash decisions are evident. The beaches are the same as they ever were and the river habitat becomes less and less lush. Trout aside, this is bad for wildlife in general and decreases the interest level for people to visit the area to appreciate this valuable natural resource.

I suport the "NO ACTION ALTERNATIVE" and oppose the following:

1) high flows in March 2008 (and others thereafter)

2) low flow regime in September/October 2008 (and others thereafter)

Sincerely,

William Wen

23

From: "Joe Gregory" <joekgregory@gmail.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 19, 2008 11:21 AM
Subject: Experimental Flood of the Grand Canyon

Dear sir, I 'am writing to voice my adamant objections to the proposed experimental flood of the Colorado river down stream from Glenn Canyon dam scheduled for March 2008. I believe this proposed flood is ill advised and is being done over the objections of the AMWG which voted 14 to 2 against the proposed flood. To date, none of the previous floods have shown to be an effective means of moving sediment in the Grand Canyon. It is time to develop appropriate and effective means to improve the Grand Canyon ecosystem rather then doing the same thing without achieving any discernible results.

The economic impact this will have on an already strained economy is like wise inappropriate. The proposed steady flows recommended for Sep. and Oct. will eliminate desperately need electricity for an area of the country that has already experienced significant shortages over the past few years.

I am encouraging you to take the no action alternative at this time.

Joe Gregory

24

From: <oldwest@oldwestmarine.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 19, 2008 11:19 AM
Subject: "Environmental Assessment Experimental from Glen Canyon Dam, Arizona 2008 through 2012

The subject Environmental Assessment fails to take account of the effect on Lake Powell, above Glen Canyon Dam. It is recognized that the total water release for the water year will be the same under both alternatives but there are short term 2008 impacts that have been ignored.

1. Marina Facilities

Table 7 (page 48) shows that no consultation has been made with marina operators with respect to the impact on their facilities of the lake level dropping 2.5 feet in a short period at a time when the lake is typically at its lowest point. Economic and safety factors need to be addressed.

2. Castle Rock Cut

There is no analysis regarding the impact of the lower level on the opening of the Castle Rock Cut which could be delayed by up to seven days if the lake level is temporarily dropped. This variable needs to be analyzed against the proposal to deepen the cut that has yet to release its Environmental Assessment. Variables to be taken into account include additional gasoline consumption, safety response times and others as listed in the scoping documents for that project (available from the National Park Service).

3. Land Facilities

During the period when the lake is at its lowest, the length of the ramps will have been artificially extended by 250 ft. (typical for a ten per cent grade). The impact of this on the tractor/trailers hauling boats in and out has not been analyzed.

In addition, the Environmental Analysis makes no mention of the additional loss of water due to the higher evaporation rate at Lake Mead versus Lake Powell. While this will recover under either alternative there will be additional water lost as water will be staged in Lake Mead longer under the high flow alternative.

Reclamation has continued their practice of allowing only the minimum comment period required by law for these floods which does not embrace the spirit of full consultation with stakeholders. You are encouraged to raise your standards beyond the legal minimum.

Sincerely

Len Cook
President
Old West Marine Services INC
PO Box 4798
Page, AZ 86040

Voice: 928 645 2705
Fax: 928 645 2542

CC: <dkubly@uc.usbr.gov>

25

From: <Steve_P_Martin@nps.gov>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 19, 2008 11:02 AM
Subject: Fw: DELIVERY FAILURE: Comments on EA

Sent using BlackBerry

----- Original Message -----
From: Steve_P_Martin
Sent: 02/19/2008 09:28 AM MST
To: GCexpRelease@uc.usbr.gov; rpeterson@uc.usbr.gov
Subject: Comments on EA

Delivery Failure Report

Your message: Comments on EA
was not delivered to: GCexpRelease@uc.usbr.gov
because: 550 No such recipient

What should you do?

You can resend the undeliverable document to the recipients listed above by choosing the Resend button or the Resend command on the Actions menu.

Once you have resent the document you may delete this Delivery Failure Report.

If resending the document is not successful you will receive a new failure report.

Unless you receive other Delivery Failure reports, the document was successfully delivered to all other recipients.

Routing Path

NP003DENVER/MTA/NPS;NP057WASHDC/MAIL/NPS

Original message follows-----------------------

To: GCexpRelease@uc.usbr.govrpeterson@uc.usbr.gov
Cc:
Subject: Comments on EA
Date: 02/19/2008 11:28:05 AM

Randy..

Call if you have questions.

(See attached file: BOR-EA.doc3.doc)

____
Steve Martin

Superintendent
Grand Canyon National Park
Phone: 928-638-7945
FAX: 928-738-7815

The National Park Service cares for special places saved by the American people so that all may experience our heritage.

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United States Department of the Interior

NATIONAL PARK SERVICE
GRAND CANYON NATIONAL PARK
P.O. BOX 129
GRAND CANYON, ARIZONA 86023-0129

IN REPLY REFER TO:
N1632(GRCA)

February 19, 2008

Mr. Randall Peterson
Bureau of Reclamation
Upper Colorado Region
125 South State Street, Room 6103
Salt Lake City, Utah 84138

Reference: Environmental Assessment for Experimental Releases from Glen Canyon Dam, Coconino County, Arizona, 2008 through 2012

Dear Mr. Peterson:

On February 8, 2008, the Bureau of Reclamation released for public comment an Environmental Assessment (EA) on the proposed high-flow and fall steady flow experiment on the Colorado River. This experiment is proposed to occur downstream from the Glen Canyon Dam and through Grand Canyon National Park in early March of 2008 and subsequently September and October for the next five (5) years.

Accordingly, Grand Canyon National Park is submitting comments on the EA during the public comments period that ends on February 22, 2008. The following are Grand Canyon's comments on the EA divided into three (3) sections – Key Concerns, General Comments and Specific Section Comments.

Grand Canyon National Park believes that the execution of high flow experiments is consistent with the Grand Canyon Protection Act, the NPS management policies of 2006, the results of recent science, the 1996 ROD on the operation of the Glen Canyon Dam. We do have concerns over the costs of the experiment and the lack of use of scientific information and study results to discuss the need for future high flow experiments that could benefit the resources of Grand Canyon National Park.

Analysis of the draft Environmental Assessment and proposed action (including strict limitations on future flows, a short-duration steady flow regime in the latter part of the monsoonal period, and other key factors) indicates these measures would likely result in impairment of the resources of Grand Canyon National Park. The EA as written appears to be in conflict with NPS 2006 Management Policies, may not be consistent with CEQ guidelines and is significantly in conflict with out understanding of the science and inconsistent with the intent of the Grand Canyon Protection Act and the 1996 ROD. We also believe that if significant changes are made to the EA, these impacts could be avoided.

While we regret that we were not included as a cooperator nor included in deliberations on this issue, we remain committed to making changes to the EA that address the key concerns outlined below and will allow the experimental high flow to move forward. It is our position that a FONSI cannot be signed unless these key concerns are met and changes to the document are made regarding the resources of Grand Canyon National Park.

Key Concerns

1. The purpose and need and the reasons for the action need to be more closely tied to the Grand Canyon Protection Act, the Secretaries responsibilities under the Act, and the approved Science Plan for the experimental flow. This discussion must include a connection to the 5 years of the fall steady flow. Currently, the EA does not clearly express the purpose and need, proposed action or how the addition of steady flow periods articulates with the science plan. We request that the steady flow component be separated out of this document and simply focus this EA on the March high flow event.

2. Results of research over the past 10 years need to be utilized and cited to support the creation of action alternatives and impact analyses. The citations in the EA are limited and dated, and personal communications should not be the basis for such important decisions. It is not apparent where the 80 million dollars in research, conducted over the last 10 years has been used in this decision making process. Our analysis shows that this document is not consistent with current best information.

3. A reasonable range of alternatives has not been presented and analyzed, including seasonally adjusted steady flows as originally articulated by the USFWS. Since this EA is intended to tier to previous environmental documents, enhancing the range of alternatives by using alternatives developed in previous environmental documents would provide an avenue for addressing many of the concerns relative to the original Record of Decision and subsequent legal challenges.

4. An economic analysis needs to be accomplished that is supported by independent research to address the concerns raised relative to costs and environmental justice. Those costs that are truly related to the experimental plan need to be reflected in the EA.

5. A review of the costs (approximately 4 million dollars) associated with the science plan needs to be accomplished that shows the true cost of the experimental plan research vs. the on-going costs associated with routine research and monitoring. Only those costs that are truly related to the experimental plan need to be reflected in the EA. These costs should be discussed in the EA in a section that is not devoted to hydropower. We recommend a detailed analysis into the value of the current science program, a review of the deliverables, a review of the use of science in the AMP process and the efficiency of the current science program. Our analysis shows that significant savings to power revenues could occur through a more effective AMP process and more efficient science program. The document gives the impression that the inflated costs of this experiment are the norm, when significant data could be gathered from a HFE for 25% of the costs of this experiment. This should be made clear in the document.

6. If this EA is to reflect an experiment over the next 5 years, inclusion of additional high flow experiments must be included. This needs to be clarified in the EA and decision document to indicate that DOI expects to consider additional high flow tests within the implementation period of the EA to test the hypotheses of long-term sediment sustainability. NPS, Reclamation and USFWS need to be involved in determining resource triggers (both humpback chub and sediment) to justify and guide the experimental flow program into the future. Based on current scientific information lack of inclusion of additional high flows could lead to impairment of the resources of Grand Canyon National Park.

7. Explanation of the 2-month steady flow portion of the proposed action lacks scientific evidence related to resource benefits. The reasoning behind the timing and duration of the flow seems to

contradict statements in the document. Longer duration seasonal steady flows have been proposed by the USFWS as part of the Reasonable and Prudent Alternative (RPA) in the Glen Canyon Dam Environmental Impact Statement, with high steady flows in the spring and low steady flows in summer and fall. These provisions are part of the environmental commitments made by the Secretary upon signing the Record of Decision for Glen Canyon Dam operations in 1996. Per the RPA, Reclamation was to include a program of experimental flows to include seasonally adjusted steady flows as part of the adaptive management program. Inclusion of a seasonally adjusted flow regime per the RPA would be an appropriate alternative for this EA and would likely be the preferred alternative. If Reclamation, through this EA, is changing the 1996 commitment to a test of seasonally adjusted steady flow, it should be clearly articulated in this decision document.

8. The alternatives include information on post high flow event scenarios. Previous high flows have been followed by ROD flows that have been shown to be erosive. This experimental flow should be followed by prescriptive flows to insure the gains made (i.e. sandbars and backwaters) are not immediately eroded and research data preserved. This will also help prevent significant effects to the resources of Grand Canyon National Park. A seasonally adjusted flow scenario would accomplish this as would the proposed maintenance flows described in the 1995 FEIS.

9. Given that one of the primary purposes of the experimental flows was to provide further evidence and understanding of protected aquatic resources, the preferred alternative must address how the action will address Endangered Species Act concerns, most specifically the biological assessment/opinion for the humpback chub. The plan should state how the actions are being instituted to improve conditions for the chub in the system and how the conservation measures will be incorporated into the DOI decision. There needs to be a commitment as part of the implementation of this 5-year program to fund the conservation measures as part of the experimental program.

10. The plan should include targets or desired future conditions so that measurements can be made through the research and science program on the effectiveness of the action. Nowhere in the document are measures of success (or failure) articulated. These conditions need to be clearly stated so that the Secretary will know the value of his action.

<u>General Comments</u>

- Clarify the purpose of the action; why is BOR undertaking this action? The information provided in the introduction is contradictory, especially relative to the primary purpose of Glen Canyon Dam (is it water conservation and storage or is it water delivery?)

- The introduction needs to clarify what the experimental action is and why the agency is proposing to take it. Currently, the action is loosely described as the experimental high flow (presumably one flow) and steady flows (more than one). How can a 5 year program of steady flows be adequately addressed in this environmental assessment?

- The document claims to be tiered to the GRCA CRMP. This is incorrect; the CRMP is a visitor use document and the experimental flow(s) is unrelated to that management plan.

- The document is very general in its claims, with little specific information to lend credence to the statements made. More citations would help explain and justify the statements in the document.

- In the purpose and need section, the document needs to recognize that "project purposes of the dam" includes those purposes outlined in the Grand Canyon Protection Act, not just water conservation and storage.

- The purpose and need section should also articulate what the stated objectives are for this experimental high release in a similar way as the document explains what the objectives of prior high releases were (Schmidt et al 1999:30).

- If the GCMRC Science Plan is being used as the guiding document for the research to be conducted under this EA, more description needs to be included. On page 6 of the draft EA, the Science Plan is mentioned for the first time, without any explanation or context.

- The introduction of the steady flow component of the experiment is not well articulated and the science behind the notion of fall steady flows (rather than summer or seasonally adjusted) is not documented.

- For NEPA purposes, the document states that prior scoping and analyses were used, although it is unclear how or when information on the 2-month fall steady flow proposal was gained. Information was provided to back up the statement concerning high experimental flows (1996 and 2004), but there is no information to suggest that the 2-month fall steady flow period was ever scoped with the public or analyzed in other documents. If the fall (September and October) is the right period of time for steady flows, the document needs to reference the scientific work to support the claim.

- The document needs to explain the timing of the high flow with the steady flows. In section 1.3, Relevant Resources, the text states that "this new proposal follows the high flow with steady fall flows;" how do steady flows 6 months after the high flow equate to "follows" in the context of a holistic experiment?

- The preamble to the alternatives (section 2.0) should clearly state what the alternatives are intended to do. The text discusses population increases to the humpback chub and consultation efforts under the Endangered Species Act. It is hard to understand what or why the alternatives are what they are. Additionally, the document states that there are two experimental alternatives, yet one is the no action alternative (which does not have an experimental component). Therefore, there is really only one experimental alternative.

- The proposed action (2.2) needs clearer explanation of the reasoning behind the 2-month fall steady flow proposed for 2008 - 2012. Logic would suggest that if the high flow is intended to determine the effectiveness of sandbar building and backwater formation with the intent that humpback chub will use the backwaters, then it would seem that fluctuating flows would immediately diminish the newly created sandbars and backwaters. The timing of the steady flow in the fall is stated to be tied to young-of-year chub, yet in other places in the document the fall steady flows are attributed to concerns with environmental justice. The design of the experiment needs to be tied to science and the positive resource benefits we anticipate. Previous work has documented that ROD flows following high flow events erode the newly created sandbars. This experiment should not follow the same path as those of the past 10 years.

- In the description of the steady flows, it would be helpful to indicate what the flows will be; great detail is provided for the high flow event, yet little information is provided on the fall steady flows other than they will occur for 5 years in September and October.

- The explanation of the action is unclear (pages 10-11), with little value added by discussing the interim guidelines and the four tiers of operation.

- Reference is made to NHPA compliance, but it is unclear if this EA is a combined NEPA/NHPA compliance document or if NHPA will be addressed separately. The compliance requirement for the one site to be mitigated is actually being addressed through the 1994 Programmatic Agreement on Glen

Canyon Dam operations. The previous compliance should be referenced, especially given that this EA is tiered to previous compliance actions.

- The opening paragraph of section 3.0 needs to have additional information concerning the interdisciplinary team and how they determined that only one action alternative was appropriate and how they determined that the only adverse impact would be to hydropower ("a disproportionate and significant adverse impact on low-income power customers"). These statements are unsubstantiated.

- The environmental impacts section (3.0) should follow the list of issues as identified in Table 1. The section begins with Natural Resources, 3.1, and is not listed in the table.

- There is one cited reference that was not in bibliography (eGRID 2006) and one reference to an "unpublished report". There are also numerous (personal communication) references that overall represent the inadequacies of the entire EA.

Specific Section Comments

- Section 1.3 - No criteria for evaluation is identified. Usually definitions for "negligible" and "significant" impacts are defined or thresholds of significant impact are quantified for each of the primary resources evaluated. Without clear criteria for whether the impact is significant or not, how can an agency assign a FONSI or make any other determination?

- Section 2.2 – Need some example of hydrograph of proposed action. The table with min/max is not instructive.

- Section 2.2.1 – The document states "significant adverse environmental justice impact, the impact was reduced by proposing a steady flow test during the fall instead of the summer..." This is a major argument of this EA, yet there is no attempt to quantify the impact upon the consumer of the steady flows in either the fall or summer. This quantification is imperative to determine if, in fact, the impact is "significant".

- Section 3.0 - Introduction - "Disproportionate and significant adverse impact on low-income power customers" - Again, how do they define the minimal change in power rates as a "significant impact"?

- Section 3.1.4 – "uncertain of sandbar effects will persist"... Research clearly demonstrates that ROD flows following the HFE will degrade the sandbars. Therefore it is not uncertain, but in fact, very clear from the research that postponing the steady flows to the fall will degrade the sandbars.

- Section 3.1.4.2 – "A key question is whether a high flow under sediment enriched conditions might result in more lasting effect." This question is not being tested by GCMRC because BOR is not proposing steady flows after the HFE.

- Section 3.1.5 – Third paragraph – This document should cite all the work by Carothers et al. regarding the effects of the first 10 yrs of controlled flows; *Baccharis emoryi* is misspelled; Tamarisk is the dominant phreatophyte, all others are posers.

- Section 3.1.5.1 – First paragraph – The reliance on local demonstration of ecological phenomena (e.g., Stevens and Waring for flood impacts) indicates a dangerously insular view of the autecology of these species.

- Section 3.1.5.1 – Second paragraph/second sentence – What will be the riparian zone "alternate" (sentence 2)? Here and elsewhere in the document the impacts of day-to-day operations of the dam on vegetation composition and density are ignored. The vegetation section of the Kearsley et al. 2003 report on integrated resource monitoring showed definitively that things like the max flows or mean flows over a 3 month period had profound effects on the density and composition of vegetation in the riparian zone.

- Section 3.1.5.2 – First paragraph – This paragraph does not follow from its topic sentence. There is evidence of huge blooms of non-native Bermuda grass following the '96 high flows (see Art Phillips' report on Hualapai monitoring), and other high flow events (see Marianne Porter's MSc Thesis at the NAU Library).

- Section 3.1.5.2 – Second paragraph – The '96 high flows changed Kwagunt marsh into a wooded shrub land vegetation type. No wetland species benefited from the flows.

- Section 3.1.5.2 – Third paragraph – Again, post-flood, day-to-day operations have *at least* as great an effect on vegetation change as floods do. We suggest a discussion of the models in Kearsley's '03 report on vegetation monitoring.

- Section 3.1.5.2 – Fourth paragraph – Rather than being an argument for flooding, the Porter thesis showed pretty convincingly that the new habitats opened up after high flows were colonized quickly and completely by exotic species.

- Section 3.1.5.2 – Fifth paragraph – Succession and adaptation in the lower riparian area are more affected by day-to-day operations, not simply "along a gradient" specified here. This may be the biggest flaw in the vegetation section. Kearsley developed statistical models for cover and richness of vegetation in the 15, 25, 35, 45 and 60 kcfs stage elevations (plus in the general area of new high water zone) which included some elements of the flow regime of the previous 2 or 3 months to predict changes in vegetation density and vegetation species richness. GCMRC has these models created by Kearsley from the monitoring from 2001 to 2004 and should be able to make predictions regarding post-flow day-to-day operations.

- Section 3.1.6 – Third paragraph – This is misleading. Yes, Carpenter did show (as did Warren and Schwalbe before him) that the new high water zone has high herpetofauna densities, but both also showed that herpetofauna densities and activities are highest where the vegetation is minimal – herpetofaunas are cold-blooded and need basking sites and good line-of-sight opportunities (they are visual predators). This same misleading statement is repeated on the bottom of Section 3.1.6.2.

- Section 3.1.6.2 – Spence report is noted in bibliography as 1996 but in report as 1997. This report's conclusion that there are no expected impacts upon the frog population assumes that there is a robust population of frogs as was the condition during the 1996 report. That is not the case in 2008. With only two adults, it is uncertain what the impact of a high flow will be upon the frog population.

- Section 3.1.8 – Third paragraph/first sentence – Add "in the long term". In 1996, some of the rebound was due to the clear, aquatic conditions, i.e. limited tributary sediment input after the high flow. This paragraph should address the impact of weather after the high flow in the rebound of the benthic algal and invertebrates, including forecasts for this spring and summer.

- Section 3.1.8 – Fifth paragraph – Running fluctuating flows after the high flow will remove many of the newly built backwaters. To maximize the positive impact of steady flow, the steady flow should be run when there are the most backwaters, i.e. immediately after the high flow.

- Section 3.1.9 – SWWF and Eagle river mile locations should be removed from this report. Endangered Species information should be treated with the same security protocols about geographic locations as archeological sites. Add note that there have been no SWWF citing in the Marble Canyon in 2006 & 2007. Remove reference to Nankoweap Eagle congregation, flashing flooding destroyed trout breeding recently, so Eagles do not congregate at Nankoweap anymore.

- Section 3.1.10 – First paragraph – Need citation for conclusion that Cladophora have withstood much higher flows for longer duration (e.g. 1983-1986).

- Section 3.1.10 – Third paragraph – Word "flood" should be replaced with high flow.

- Section 3.2.1 – First sentence – Need citation for BOR Treatment Plan.

- Section 3.2.1 – Second sentence – Reword to read "Archaeological data recovery efforts are scheduled over the next 5-10 years."

- Section 3.3.6 - "Electrical costs would create a slight, but disproportionately adverse impact among low-income households..." How if the impact is "slight", can it be considered "significant"? A quick evaluation of Executive Order 12898 suggests that the Bureau may be misinterpreting this executive order. The language in the EO is disproportionately high and adverse effect, NOT disproportionately adverse impact (BOR language). The words are the same, but the meaning is totally different. One says that the impact needs to be way higher for the poor than others to be considered under this EO and the other simply makes the threshold as any impact that will affect the poor more than others. By using the BOR interpretation, a rise in the entrance fee at Grand Canyon would be considered a "significant" impact since it has a disproportionate affect upon the poor, i.e. a dollar to someone who makes $20K a year is more valuable to that individual who makes $100K a year. In evaluating the EO, we do not believe that was the intent.

Should you have any questions concerning these comments, please contact me at 928-638-7945.

Sincerely,

/s/ Steve Martin
Superintendent

26

From: Mari Carlos <macgcra@sbcglobal.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Mon, Feb 18, 2008 10:39 PM
Subject: Experimental Releases: Comment from Grand Canyon River Runners Association

February 18, 2008

Mr. Dennis Kubly
Bureau of Reclamation, Upper Colorado Regional Office
125 S. State St.
Salt Lake City, UT 84138

GCespReleases@uc.usbr.gov

Dear Mr. Kubly:

In response to the Bureau of Reclamation's request for public input on the proposed spring and fall experimental flow operations of the Glen Canyon Dam, the *Grand Canyon River Runners Association*, representing the interests of commercially outfitted river runners, wishes to express its support for the proposed action.

Since the closure of the dam conditions have deteriorated for river runners. In particular, sandbars and beaches have suffered from erosion, reducing the area available for camping and potentially increasing the impact of campers on beaches they can use. In addition, as a result of side stream floods which deposit boulders and debris which impede the main current, the severity of rapids is increasing. Eventually, some rapids could be rendered unrunnable.

According to the /Environmental Assessment for Experimental Releases from Glen Canyon Dam, AZ 2008 through 2012/ sediment accumulation in the Colorado is at the highest volume in approximately a decade, nearly three times the level sufficient to trigger the 2004 high flow experiment. The proposed experimental flow will be expected to result in substantial amounts of sandbar deposition and to allow ongoing scientific study of the processes of sandbar deposition and erosion along the river corridor. Hopefully, the size of camping beaches will be increased and the duration of the increase will be prolonged. Based on the results of the 2004 experimental flow, some rapids will be reworked, possibly improving boating conditions. We see both of these changes as positive outcomes of the proposed action for recreational river runners. We urge the Bureau of Reclamation to take advantage of the exceptional situation and to proceed with the experimental release in March 2008.

Very sincerely,

Mari Carlos, President
On behalf of the Board of Directors
Grand Canyon River Runners Association
P.O. Box 1833
Flagstaff, AZ 86002

27

From: Kathryn Bennett <bennett.kathryn@gmail.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Mon, Feb 18, 2008 9:09 PM
Subject: experimental flow release proposed for early March

I am writing to extend my full support of the experimental release being considered for the Colorado River below Glen Canyon dam. The health of the river has been seriously compromised by artificially controlling the flow and depriving the river system of natural floods. Please strongly consider the great need for this event and vote in its favor.

Sincerely,
Kathy Bennett

28

From: "Bob" <soule@canyoncountry.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Mon, Feb 18, 2008 4:15 PM
Subject: Experimental releases Glen Canyon Dam

This was done once before on a larger scale with questionable results and at great expense. How about we experiment when we are not in the midst of a prolonged drought . Even tho snowpacks look good this year its too early to predict a good year. The objectives of the proposal seem questionable especially since its labeled an experiment.

Bob Soule

Box 5081 Page AZ 86040

29

From: "Candy" <Quixly@cableone.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Mon, Feb 18, 2008 12:56 PM
Subject: Glen Canyon Flood Release - DISAPPROVAL

Dear GCA,
I have been living in Glen Canyon region for over 10 years and in southwest for over 30 years. I have designed and built power plants throughout the world and am intimately aware of water resources and conservation efforts required in desert regions.
I STRONGLY DISAGGREE with releasing water from Glen Canyon at this time when the southwest is STILL experiencing drought conditions and the major impact that that volume of water lost to the resource system that releasing water would do. IT IS A WASTE of our precious water resources at this time.
Having to reproduce beach erosion down in the Grand Canyon is a worthwhile effort - HOWEVER NOT AT THIS TIME!
ONLY - AND ONLY when the there is a glut of water in Lake Powell should this "experiment" be done.NOT when precious resource of southwestern water is needed by many!!!!! WATER IS PRECIOUS and THIS IS TRULY A PRECIOUS AND VALUABLE RESOURCE that should be preserved for all of the American public in the west that you are charged with being guardians of this USA public natural resource!!! NOT TO WASTE this resource - it is NOT yours to waste - this valuable commodity of water storage belongs to the American public!! Not to special interests or to the government to do wasting experimentation of a natural resource when the resource is at a most vulnerable position.
PLEASE PLEASE PLEASE delay any wasteful experimentation of water release for a later time when it is better suited to do so. NOT NOW!!
Resources are valued and belong to the American Public and MUST NOT be squandered within your guardianship in wasteful experiments!!!
Thank You kindly for listening and hopefully you will not be squander our precious water from glen canyon area.
CC Johnnie
Retired Engineering Program Manager in Page AZ

30

GCexpReleases GCexpReleases - Experimental High Colorado River flows

From: "jcady@cableone.net" <jcady@cableone.net>
To: <GCexpReleases@uc.usbr.gov>
Date: 2/18/2008 10:04:19 AM
Subject: Experimental High Colorado River flows

I am opposed to the wasteful experimental high flows proposed for the Colorado River on March 6-8,2008. I ask that the Bureau of Reclamation and other concerned agencies use common sense instead of politics regarding future planned experiments on the Colorado River.

I also oppose the proposed low flow and steady flow experiments planned for the Colorado River in September and October. These flows are wasteful and will disrupt the sorely needed clean energy produced by Glen Canyon Dam.

I recommend and support the NO ACTION ALTERNATIVE in regard to the experimental high flows and steady flows proposed for the Colorado River.

James
Cady
PO Box
4690
Page, AZ 86040

31

From: "kris mydler" <kris_mydler@hotmail.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Mon, Feb 18, 2008 9:42 AM
Subject: No High Test Flow

I STRONGLY OPPOSE THE RECLAMATION PROPOSED EXPERIMENTS, THE HIGH TEST FLOW AND THE FALL STEADY FLOWS.

I STRONGLY SUPPORT THE "NO ACTION ALTERNATIVE."

Please do not perform the high test flow which will destroy the rebuilding trout habitat.

Thank you,

Todd Mydler, MD

8935 Scenic Pine Drive

Parker, CO 80134

CC: <todd_mydler@yahoo.com>

32

From: Steven Quick <quickstevens@yahoo.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Sun, Feb 17, 2008 8:30 PM
Subject: Stop the Experiments!!

US Department of the Interior,

In regards to;

Environmental Assessment
Experimental Releases from Glen Canyon Dam, Arizona
2008 through 2012

My public comments are as follows:
1. Do not conduct this experiment and instead investigate nondestructive methods of building beaches in the Grand Canyon and to use common sense and sound judgment in dealing with this and all future planned experiments on the Colorado River.
2. Remove the proposal for low steady flows in September and October from the experiment. I support clean energy and encourage the use of power generation from Glen Canyon Dam.
3. I support the NO ACTION ALTERNATIVE.

CC: Terry Gunn <tgunn@hughes.net>

33

From: "Erle Swearingen" <erle_at_mka@msn.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Sun, Feb 17, 2008 5:42 PM
Subject: Colorado River Blowout

I urge the No Action Alternative!!!

Erle Swearingen

2 comments

34

From: <EQKID@aol.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 7:51 PM
Subject: Fwd: Proposed High-Flow and Steady Flow Experiment on the Colorado River

From Rick Holt.

The release of this level of water is damaging a precious resource and income stream to the people of Lee's Ferry. It is a waste of precious water.

Rick Holt.

From: jamesroache@earthlink.net
Reply-to: jamesroache@alumni.usc.edu
To: GCexpReleases@uc.usbr.gov
Sent: 2/15/2008 5:02:35 P.M. Pacific Standard Time
Subj: RE: Proposed High-Flow and Steady Flow Experiment on the Colorado River

To Whom It May Concern,

35

I have recently learned that there is yet another proposed high flow study for the Glen Canyon Dam area. As I recall there have been two high flow studies performed in the recent past that did not accomplish much of anything. The beaches downstream still come and go with nature, the Hump Back Chub continues to populate below the Little Colorado and it seems this is again is much to do about nothing. The AMWG already has made a 14-2 recommendation to the Secretary of the Interior against another high flow study, yet the study still remains proposed. I don't understand why.

While this water will be retained in Lake Mead and purportedly not wasted, you can't help to imagine that the silt removed from the river (and its down stream beaches) as a result of this flush, which runs clear and silt free from the base of Glen Canyon Dam, will end up in Lake Mead itself.

This proposal seems contrary to expert opinion, repetitive without desired results, and a complete waste of resources. I urge you to abandon this proposal.

Yours Truly,
James H. Roache, PharmD

President and CEO

Advanced Pharmacy & Respiratory Care Solutions

26611 Cabot Road, Suite B

Laguna Hills, CA, USA 92653

1-949-348-7900 Ext 141

36

From: Kent <azflyfisher@hotmail.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 7:17 PM
Subject: Comment on Experimental High Flow at Glen Canyon Dam

I have completed my review of the Environmental Assessment and the Science Plan for Potential 2008 Experimental High flow at Glen Canyon Dam and hereby express my strong support for the "No Action Alternative." For the past 25 years I have enjoyed regular fly fishing trips to the area and have witnessed negative impacts that a multitude of low and high flows have had on the trout fishery. And again, just when the fishery is poised for a strong comeback, another experiment will interrupt the food availability and jeopardize the health of the trout. In turn, this imposes a detrimental impact on the local businesses (e.g., guides, motels, restaurants) that rely upon sport fishing for their livelihood. I'm particularly concerned about the statement in the Science Plan report that, "....the economic impact to recreational fishing is uncertain and yet to be studied."

After the Glen Canyon Dam was constructed, the nature of the Colorado River below the dam changed permanently. By today's standards, environmental impact considerations were essentially non-existent 50 years ago. While the environmental attitude of our forefathers may seem irresponsible, sometimes the consequences have to be accepted. The plan to emulate pre-dam conditions through high water releases is wasteful, expensive, and destined to provide the same historical negative results. Trying to manage a warm water species living in a cold water environment is futile.

I support clean energy and support hydroelectric power generation from the Glen Canyon Dam. The proposal to conduct low steady flows in September and October should be abandoned as this represents a loss of clean energy production which must be made up by replacement power from the burning of fossil fuels.

I'm also disappointed that money may be wasted studying the preservation of archeological sites due to wind deposited sand! I believe in the preservation of such sites, but certainly a more efficient method can be researched and employed.

The uncertainties and conjecture that riddle these plans should be carefully considered before a final decision is made. As a reminder, "The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." I believe the interest of the American public includes making informed decisions based on common sense, sound judgment, without political predudice and includes the positive management of the trout fishery at Lee's Ferry.

Thank you for your consideration and the opportunity to comment.

Arizona Flyfisher

37

From: peri@plan-itconsulting.com
To: <GCexpReleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 2:25 PM
Subject: Glen Canyon Experimental Releases

Dear Secretary of the Interior,

In regard to the Glen Canyon Experiment Releases, I wish to state my support of the NO ACTION ALTERNATIVE.

I respectfully ask that you take more time to seriously consider the negative impacts that this may cause. Specifically I request NOT to conduct this experiment and instead investigate nondestructive methods of building beaches in the Grand Canyon and to use common sense and sound judgment in dealing with this and all future planned experiments on the Colorado River.

Please also consider the environmental impact of changing the flows in the fall. I urge you to remove the proposal for low steady flows in September and October from the experiment in the support of clean energy and encouraging the use of power generation from Glen Canyon Dam.
Sincerely,
Peri Gore

--
Peri Gore
Hm Ofc: 720-482-2823
Fax: 270-626-7282
Cell: 303-717-2197
Website: www.Plan-itConsulting.com <http://www.plan-itconsulting.com/>

38

From: Dan & Dottie Dreyer <dubled@npgcable.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 11:04 AM
Subject: Planned flow increases Lake Powell dam

Gentlemen:

Please do not carry out the current plan to increase flows to 42,000 starting March 5. This ill conceived plan will not achieve any positive long term result for the Colorado river--as previous "experiments" have shown. Slowed, steady flows in the fall are just is dumb. Please leave the Colorado River alone. This constant environmental tinkering has got to stop. The dam is there. Let it produce electricity and let the river system adapt accordingly.

Everything I read or see tells me this is expensive, wasteful and stupid action.

Please let me know who in Washington is capable of stopping the current bad plan for the Colorado. I would like to forward them some important information.

Daniel Dreyer

39

From: Adam Unrein <ajunrein@hotmail.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 9:51 AM

I am opposed to the underhanded handling of the Colorado River by government bureaucrats. It took years to regulate the water flow from Glen Canyon Dam to perserve the recreational benefits below the dam. The first planned FLOOD flow was hugely unsuccessful relative to the objectives (rebuild beaches in the Grand Canyon). I would like to know why another one is planned when the first was not successful. Who is behind these experiments? Where do we complain to Washington?

40

From: "Jeff G Schmitt" <jeffs@prodigy.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Sat, Feb 16, 2008 9:10 AM
Subject: NO Action Alternative at Glen Canyon Dam

The purpose of this e-mail is to provide my comments regarding the proposed series of experimental releases from Glen Canyon Dam. After reviewing all of the materials related to the previous flow experiments, and the one proposed now, I favor the NO Action Alternative.

I do not believe that previous flow experiments have been effective at achieving the stated purpose, even if the stated purpose is a valid reason for the experiments. The attempt to restore native species, when one has already modified the eco-system as significantly as placing a dam in the river does, simply does not make sense. While, in general, I am not in favor of damming up rivers, I do use the power these dams generate and once we've made the decision to place a dam on the river, we should do our best to build a new eco-system that matches the new conditions.

It is my understanding that the board that had local input over these flow experiments opposed them. That says a lot to me about both the validity of the experiment and the source of the proposal.

Once again, I favor the NO Action Alternative.

Jeff G. Schmitt

Austin, Texas

41

From: jamesroache@earthlink.net
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 15, 2008 6:03 PM
Subject: RE: Proposed High-Flow and Steady Flow Experiment on the Colorado River

To Whom It May Concern,

I have recently learned that there is yet another proposed high flow study for the Glen Canyon Dam area. As I recall there have been two high flow studies performed in the recent past that did not accomplish much of anything. The beaches downstream still come and go with nature, the Hump Back Chub continues to populate below the Little Colorado and it seems this is again is much to do about nothing. The AMWG already has made a 14-2 recommendation to the Secretary of the Interior against another high flow study, yet the study still remains proposed. I don't understand why.

While this water will be retained in Lake Mead and purportedly not wasted, you can't help to imagine that the silt removed from the river (and its down stream beaches) as a result of this flush, which runs clear and silt free from the base of Glen Canyon Dam, will end up in Lake Mead itself.

This proposal seems contrary to expert opinion, repetitive without desired results, and a complete waste of resources. I urge you to abandon this proposal.

Yours Truly,

James H. Roache, PharmD
President and CEO
Advanced Pharmacy & Respiratory Care Solutions
26611 Cabot Road, Suite B
Laguna Hills, CA, USA 92653
1-949-348-7900 Ext 141

42

From: Gore David <ljgore@sbcglobal.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 15, 2008 5:18 PM
Subject: Glen Canyon Experimental Releases

I am a fly fisherman who loves to fish the Colorado River below Glen Canyon Dam. I strongly recommend that you select the "No Action Alternative". It appears to me that when the Adaptive Management Work Group voted 14-2 against the program and local businesses and sport groups are against it that the No Action Alternative would be a no brainer. The only reason I can think of to proceed is pandering to one or more environmental groups in an election year.

David E Gore
Colleyville, TX

43

From: "Perry White" <pw3771@cableone.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Fri, Feb 15, 2008 1:54 PM
Subject: River Purge

I am highly opposed to the purging of the Colorado River. At this time we need all the storage of water we can get, Anything other than commitment or demand is such a waste. I have made 28 trips down the Colorado river (1967-1990) & I don't think to many people are going to tell me to much about the river I don't already know.
The "Monkey Wrench Gang" continues to try & destroy Glen Canyon Dam.

Perry L. White
P.O. Box 635
Page,AZ 86040

pw3771@cableone.net

"Together We Stand, Divided We Fall"

44

From: Jo Bjorholm <jobjorholm@msn.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Fri, Feb 15, 2008 8:57 AM
Subject: water release from Lake Powell

This idea of draining our lake even farther than it is so you can move sand bars around for the fish is even dumber than heating water for those very same fish. I cannot believe that we have to pay you out of taxpayer money to come up with these ideas. That is like paying someone in 1999 to invent a round wheel for a horse cart. A GROSS WASTE OF MONEY WE DON'T HAVE and a perfect example of too much Big Brother and not enough COMMON SENSE to know when enough is enough

45

From: "Glen Reeves" <gdreeves_3@msn.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 14, 2008 10:23 PM
Subject: Proposed High-Flow and Steady Flow Experiment on the Colorado River

I would like to express my strong support for the "No Action Alternative" described in the Environmental Assessment - Experimental Releases from Glen Canyon Dam, Arizona 2008 through 2012. My perspective is that of a sportsman and somewhat regular visitor to the Lees Ferry area. For the past six years I have enjoyed regular fly fishing trips to the area. In the past year I have observed that the trout population is by far the healthiest that I have seen during this time. I am quite fearful that a High-Flow Experiment at this time will do irreparable harm to the trout population. This in turn will have irreparable harm to those of us that take the opportunity to enjoy the sport of fly fishing in this region as well as the businesses that depend upon sport fishing such as the guides, restaurants, motels in the area. The Lee's Ferry fishery has been a victim of the water management practices of the past. Only in the last year have sportsman observed a return to fishing conditions that were common in the distant past before the water management practices took their toll.

I am not qualified to comment on the various scientific studies and forecasts that attempt to identify the possible impacts on the ecology of the river. What I do note however, is that there is not unanimous agreement within the scientific community on the potential impacts, nor does there seem to be a good understanding of just what effects the test will have on the building of sandbars and removal of near shore vegetation. There seems to be even less certainty on just what effects will occur to both the native and non-native fish populations. Many of us fear however that this drastic operation will have a significantly detrimental impact on the trout population in the Lee's Ferry area at a time when it has just begun to show signs of a return to health.

When the Glen Canyon Dam was constructed, the nature of the Colorado River below the Dam changed forever. The debate rages on concerning whether the dam should have been built or whether it should be removed. However while it is in place, efforts to replicate pre-Dam conditions are foolhardy and a waste of time and money. Rather, the focus should be on utilizing the new environment to the best possible extent. That use should include positive management of the trout fishery in the Lee's Ferry area.

Thank you for the opportunity to comment.

Glen D. Reeves
1343 E Greentree Dr
Tempe, Az 85284
602 838 6323

46

From: "Arizona Fly Fishing" <flyfish12@mindspring.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Thu, Feb 14, 2008 1:08 PM
Subject: No Action Alternative for Lee's Ferry

To Whom it may concern,

My name is Kevin Krai and I am Vice President of Arizona Fly Fishing in Tempe. I urge you to reconsider the experimental flows scheduled for Lee's Ferry in early March as well as the low flow experiments in September and October. I advocate the No Action Alternative. There is no scientific evidence to support the claims that this will help rebuild beaches in the Grand Canyon or help the Humpback Chub population. When Glen Canyon Dam was constructed it forever changed these stretches of the Colorado River. To think that any flow regime will return this stretch of river to how it was before there was a dam is naive. The reality is change is happening and it is how we learn to live with the changes that is important. I run a business that is effected by these changes. After the last "experiment" much of the food that the trout ate was the main causality. The fish became very skinny and the consequent spawns were not as prolific. Since that time the fishery at Lee's Fer
ry has started to rebound and we have seen more food and weeds in the system. This is good for business, not only in the Marble Canyon area, but has a big impact statewide. The sport fishing industry has put millions of dollars into this area and it would be a disservice to ignore their voice and only listen to a small group of Washington Lobbyist.

Sincerely,

Kevin Krai
Vice President
Arizona Fly Fishing
flyfish12@mindspring.com
480-560-9930

47

From: Tim Van Hemelryck <timdar@att.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Thu, Feb 14, 2008 9:53 AM
Subject: Flooding the Canyon

Dear Dennis Kubly,

Regarding the March 4 -9 scheduled flood in the Grand Canyon. This would seem to be a futile attempt at returning the area below the Glen Canyon Dam to its original condition. This has been attempted twice with the same results, which have been shown to be marginal at best. Repeating the same experiment over and over and expecting different results is just foolish.

According to the article in the Daily Sun, the experiment is expected to cost about 8 million dollars in research cost and lost power. If the intent is to saved the humpbacked chub, the 8 million dollars would go a long way to building a hatchery to raise and supply the river with chubs for many years to come.

We are completely against this redundant foolishness.

Sincerely,

Tim and Darlene Van Hemelryck
Page, AZ

48

From: "Bob and Ann Novak" <cancaper@commspeed.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 9:58 PM
Subject: 5 day flood from Glen Canyon Dam

Interested parties,
Arizona has been in a regional drought for several years now. Water is prescious! This is not a year to send a five day flood downriver from Glen Canyon Dam. If possible, we need to intake enough water in Lake Powell this year to allow boaters to take the shorter route uplake and avoid the Narrows. Thank you for your serious consideration to this matter.
Sincerely, Ann Novak

49

From: Bill Erickson <azcanyondreamer@yahoo.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 9:26 PM
Subject: flood comment

Please do not go forward with the experimental flood that is tenatively scheduled for next month. I feel that you are just stripping all of the sand from the upper reaches of the canyon. With the net gain of sand being minimal I do not believe this study is producing good results. Please do not go forward with the planned flood.

Bill Erickson
5913 SE Holgate
Portland, OR 97206

50

From: "Tom Zwack" <thomasez@cableone.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 8:35 PM
Subject: Glen Canyon Dam Flood Proposal

To Whom It May Concern:

I would like to take this opportunity to express my opposition to the proposed experimental release of water from Lake Powell at the rate of up to 40,000 cfs. The timing of this experiment is ill-advised. Common sense tells us that in a long-term drought situation, with the lake level currently below 50% of capacity, concerns about the water level intakes for SRP and the City of Page growing, and the loss of necessary power generation at Glen Canyon Dam, this is not the proper time to schedule an experimental massive water release. If, indeed, an experimental release is being considered, it must not be allowed to take place until Lake Powell has reached near full-pool.

We are all aware that the southwest has been in a severe drought situation for several years. Water conservation should be the major concern of the Bureau and of the Department of the Interior. Education of the public regarding conservation of our water resource, particularly in drought years, should be a priority, far above concerns for downstream beaches and sand bars. We must not waste this precious resource on an ill-timed experiment. An experiment that has been tried unsuccessfully in the past.

Thank you for your consideration.

Thomas Zwack
P.O. Box 4508
Page AZ 86040
thomasez@cableone.net

51

From: lori gervais <justjust4me@yahoo.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 3:53 PM
Subject: letting the water go

I don't agree with the letting go of the water down river.It seems to me that all of us could find a better reason to let the water go.Thank you for your time.

Get rid of all bitterness, passion,and anger. No more shouting or insults,no more hateful feelings of anysort. Instead, be kind and tenderhearted to one another, and forgive one another,as God has forgiven you!

52

From: "Judy Edwards" <lpvjudy@hughes.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 10:11 AM
Subject: Glen Canyon Dam Flood Due in March

I would like to voice my disapproval of this release. The proponents of these releases agree the first ones didn't work. Don't waste the water during our time of drought.

Judy Edwards
928-353-2241

53

From: "Vivian Firlein" <viva@hughes.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Wed, Feb 13, 2008 9:53 AM
Subject: Proposed river flooding

This seems to fly in the face of common sense. We are in a drought. There is increasing demand for electric energy. So we are going to bypass the Glen Canyon turbines and spill precious water down the Colorado "in hopes" to move some sand around and "maybe" improve some fish habitat?

I vote NO.

Vivian Firlein
928-691-0616
viva@hughes.net
Page, AZ

The hardest years in life are those between ten and seventy.
-Helen Hayes (at 73)

54

From: David Urias <davidurias1976@hotmail.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 8:32 PM
Subject: Lees Ferry

One of the best quotes I can cite regarding this situation is from a fellow angler. "I am curious how we can make the same mistake again. Lees Ferry is finally rebounding from the last experimental flood and we are deciding to do it once again? I sometimes wonder if the powers that be, give these ideas any thought whatsoever! I have friends that are finally starting to go there again after a several year hiatus, the guides and lodges are starting to make a little money again, this will be the death knoll for most of the businesses in the area. Is this the master plan? Are we trying to destroy the fishing and the fishing industry once again? I know many of the past and present guides on the river and in talking with most of them, a big downturn in the fishing will end their livelihood on the Colorado River."

"It's really too bad as some of my best experiences, fishing and non-fishing have been on that section of the Colorado. I have so many pleasant experiences with my father, brother, and many of my friends. It will be a shame that more people in the future will not be able to say the same thing. I guess the good ol' days will be all we have now."

What a shame!!

Paul Freeman

As a sportsman I have a tremendous respect for the beauty of the canyon. Its funny how our bureaucratic system has a say on what should survive and what should be removed. The sad reality is that the temperature of the river and the ecosystem changed forever when the usbr built the dam and changed the flow to a tailwater. If you could talk to historians, they would tell you that the river was and would still be a muddy river in which temperatures would be much warmer than 46 degrees. Its sad that you decide to experiment the flows ONCE AGAIN to try and restructure the ecosystem when the chubs and native fish would not successfully flourish under the current conditions that the usbr has built. They are warm water fish. This is just a partial view on what you plan to do not to mention destroy an economy that is on the border of a rebound. Hopefully you will all come to your senses and stop messing with the ecosystem that you continue to disrupt through your "experiments". Leave well enough alone.

Dave Urias
10115 E. Mountain View Rd Unit #2030
Scottsdale AZ. 85258

55

From: "Dave Kendall" <dken5@cox.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 5:19 PM
Subject: 62,000cfps release plan

Please do not go forward with this devasting plan. Not only would native chub minnows be harmed so would other species. Very bad Idea! Dave Kendall

56

From: Michael Faulkinbury <mfaulkinbury@msn.com>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 4:12 PM
Subject: Lees Ferry Flood.

This event has been executed twice before. Did you not pay attention then to the results it had? If in two tries you did not get information you needed why are you wasting my tax dollars to fail to get the data you want a third time? This plan has NO merit, it may further complicate the HBC population, and didn't you in the last two years kill trout at bright angle creek to protect the HBC?
In the hope of some common sense I urge the "The No Action Alternative"!

Regards
W.M. Faulkinbury

57

From: "Mike Kasulaitis" <Mike.Kasulaitis@cushwake.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 3:08 PM
Subject: Lee's Ferry Flows

Please refrain from initiating the flooding of Lee's Ferry on March 4th. Based on my knowledge of the river, conditions are better than they have been in years. Much of this, and I am not alone, has to do with the fact that they have not flooded the river in the last few years.
Additionally, you would be damaging the spawning grounds that the trout have just recently begun to use again.

If you're going to experiment, go release the flows on some other river.

Lastly, if you could forward me your hypothesis as it relates to this matter, that would be greatly appreciated.

Mike Kasulaitis
Associate Director

Cushman & Wakefield of Arizona, Inc.

2525 East Camelback Road, Suite 1000
Phoenix, Arizona 85016

Tel: (602) 229-5969
Mobile: (602) 769-2302
Fax: (602) 253-0528
Email: mike.kasulaitis@cushwake.com
www.cushmanwakefield.com <http://www.cushmanwakefield.com/>

58

From: <Aaron.A.Otto@wellsfargo.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 3:02 PM
Subject: Exp Flows Question.

Is this purely a financial decision based upon beach users as apposed to the local economics built around the fishery? I seem to remember last time how bad this was on the fishery, not really sure what justifies that kind of damage again. Hoping someone can help me understand.

Thanks,

Aaron Otto

480 724 2138

59

From: "Julie Hayes" <area51az@cableone.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 1:44 PM
Subject: The real reason you want to take water out of Lake Powell?

http://www.msnbc.msn.com/id/23130256

Dry Lake Mead? 50-50 chance by 2021 seen

Study cites warming, water use and growing Colorado River deficit

This view of Lake Mead was taken last July 26, during the seventh straight year of drought that had caused the lake to drop more than 100 feet to its lowest level since the late 1960s.

Ethan Miller / Getty Images file

MSNBC staff and news service reports
updated 1:57 p.m. ET Feb. 12, 2008

What are the chances that Lake Mead, a key source of water for more than 22 million people in the Southwest, would ever go dry? A new study says it's 50 percent by 2021 if warming continues and water use is not curtailed.

"We were stunned at the magnitude of the problem and how fast it was coming at us," co-author Tim Barnett of the Scripps Institution of Oceanography said in a statement. "Make no mistake, this water problem is not a scientific abstraction, but rather one that will impact each and every one of us that live in the Southwest."

"It's likely to mean real changes to how we live and do business in this region," added co-author David Pierce, a Scripps climate scientist.

The experts estimated that the Colorado River system, which feeds Lake Mead and Lake Powell, is seeing a net deficit of nearly 1 million acre-feet of water per year — an amount that can supply some 8 million people. That water is not being replenished, they noted, and human demand, evaporation and human-induced climate change are fueling the growing deficit.

The system is already at half capacity because of eight years of drought.

"When expected changes due to global warming are included as well, currently scheduled depletions are simply not sustainable," Barnett and Pierce write in the study.

The two analyzed federal records of past water demand as well as calculations of scheduled water allocations and climate conditions.

'Bucket' being depleted
"The biggest change right now is taking more water from the bucket than we are putting into it," Barnett said.

Lake Mead straddles the Arizona-Nevada border. Aqueducts carry water from the system to Las Vegas, Los Angeles, San Diego, and other communities.

The researchers also noted that their estimates are conservative — in other words, the water shortage is likely to be even more dire than they estimate. The conservative approach included basing their findings on:

- The premise that warming effects only started in 2007, though most experts consider human-caused warming to have likely started decades earlier.
- Averaging river flow over the past 100 years, even though it has dropped in recent decades.

The study has been accepted for publication, possibly next month, in the peer-reviewed Water Resources Research, a journal of the American Geophysical Union.

Barnett and Pierce also estimated:

- A 10 percent chance that Lake Mead could be dry by 2014.
- A 50 percent chance that reservoir levels will drop too low to allow hydroelectric power generation by 2017.

The uncertainty about when and if the lake will run dry stems from the natural fluctuations of the Colorado River, which feeds the lake, Barnett said. In recent months the flow has been above average, he said, after years below average.

'At or beyond the sustainable limit'
The system could still run dry even if recently proposed mitigation measures are implemented, the researchers said.

Laura Rauch / AP file
The reduction in water levels due to drought on Lake Mead can be seen by the white ring around the shore at Hoover Dam in this photo from July 21, 2006.

"Today, we are at or beyond the sustainable limit of the Colorado system," the study concludes. "The alternative to reasoned solutions to this coming water crisis is a major societal and economic disruption in the desert southwest; something that will affect each of us living in the region."

Lake Mead, which was created when Hoover Dam was buit, provides 90 percent of Las Vegas' water.

Scott Huntley, a spokesman for the Southern Nevada Water Authority, said his agency overseeing the Las Vegas area's water was concerned about reliance on Lake Mead as the major source for Las Vegas and officials were seeking alternate sources.

"While we wholeheartedly support the authors' call for greater urban water conservation, it is important to also remember that agriculture uses four-fifths of the Colorado River's flows, so meaningful solutions cannot be borne solely by urban users," he added.

Reuters contributed to this report.

60

From: "Paul Freeman" <pfreeman@idoc.idaho.gov>
To: <GCexpReleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 12:50 PM
Subject: Experimental flood

I am curious how we can make the same mistake again. Lees Ferry is finally rebounding from the last experimental flood and we are deciding to do it once again? I sometimes wonder if the powers that be, give these ideas any thought whatsoever! I have friends that are finally starting to go there again after a several year hiatus, the guides and lodges are starting to make a little money again, this will be the death knoll for most of the businesses in the area. Is this the master plan? Are we trying to destroy the fishing and the fishing industry once again? I know many of the past and present guides on the river and in talking with most of them, a big downturn in the fishing will end their livelihood on the Colorado River.

It's really too bad as some of my best experiences, fishing and non-fishing have been on that section of the Colorado. I have so many pleasant experiences with my father, brother, and many of my friends. It will be a shame that more people in the future will not be able to say the same thing. I guess the good ol' days will be all we have now.
What a shame!!
Paul Freeman

61

From: "Julie Hayes" <area51az@cableone.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Tue, Feb 12, 2008 9:31 AM
Subject: Lee's Ferry

I live in Page, Arizona and I am against releasing large amounts of water from Glen Canyon Dam. I enjoy trout fishing on the river below the dam. I pay good money for guides and equipment. I know of many Native Americans who make their living from the Lee's Ferry fishery through jobs in services at Marble Canyon, Cliffdwellers and Vermillion Cliffs. How can you ask these already poverty stricken people to give up even more? They can't make it on jewelry stands alone. Why does the U.S. government continue to oppress Native Americans? They have jobs now and will not after you guys flush the toilet that is Lake Powell. It happened last time and it will happen again.

This whole thing is ridiculous in my opinion. My guess is all the "reasons" for the big release are lame excuses for giving more water to Lake Mead, and that alone. I wouldn't be surprised if someone is getting paid off to lie about "native fish", sand bars, etc. Just leave the river alone, please!

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FEB 20 '08

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February 13, 2008

Dennis Kubly and Randall Peterson
Bureau of Reclamation, Upper Colorado Region
125 South State Street, Room-6103
Salt Lake City, UT 84138

Dear Mr. Kubly:

Regarding the upcoming proposed "flood" in the Grand Canyon, scheduled ~~for March 5th~~, I am absolutely shocked this flood has gotten pushed through as quickly as ~~it has~~. In seeking the final comments for this flood, the public only has two weeks to respond, and the addresses are vague at best where to direct our comments to. This whole situation seems fishy, and ought to be investigated. There are so many reasons *NOT* to do this flood:

- Lake Powell is down 110 feet. We are in a drought. Experimental floods should not even be considered until the water level is significantly higher. Not a good idea for a flood from a major water source for the western U.S. that is low (and predicted to go dry by 2021, from latest articles).
- March 5th is typically a low-flow period. A flood would seriously disrupt established riparian shoreline areas, young fish, beaver dens, and other endangered species.
- Look at the results from the last two floods of 1996 and 2004: beaches were replenished, then started to erode (that's typically what occurs in the Grand Canyon—millions of years of erosion) and most of the young Humpback Chubs, the endangered fish scientists are trying to preserve, were washed downstream toward Lake Mead.

If this flood absolutely has to happen, why do it so early? Can't it wait until the end of March or early April, when the normal spring runoff happens? Before the dams, that's the way it has happened for millions of years. And why a duration of 60 hours? Wouldn't 10 hours be sufficient?

I am outraged at the prospect of this needless flood. It is estimated that $8,000,000 will be lost in revenue—from clean hydroelectric power—for a 60-hour flood. That will be taken away from the grid, when it will sorely be needed this summer. In order to make up for the loss, it will come from coal-burning plants—pollution in excess of what should be normal. This is unacceptable.

Consider for a moment an opportunity: The Army Corps of Engineers **(Public Notice Number: SPK-2007-02165-DC)** is currently seeking public comments (until March 2) on deepening the Castle Rock Cut area at Lake Powell, just a few miles away from Glen Canyon Dam. This area is formerly lake bottom, and the project wants to remove 400,000 cubic yards of sand, rock, and sediment. This excavated material would be perfect to deposit near Lee's Ferry or even in the Paria River drainage, so precipitation could naturally wash it into the Canyon. These needed sediments could potentially replenish the Canyon all year long. This solution seems like a no-brainer to me. You could time it with the scheduled "flood" and spread even more sediment into the Canyon. But the flood would have to be postponed. The Castle Rock Cut deepening wouldn't be able to start until the end of March.

And in regard to the possibility of steady-flows from Glen Canyon Dam year-round in the Grand Canyon: **Another bad idea**. Since the dam went up in 1963, flows from the dam have fluctuated, just like the river did before the dam. This is for need during electrical periods when more power is needed vs. when power is not as needed. The plants and animals in Grand Canyon have adapted to fluctuating flows—it is a tidal ecosystem. To radically introduce change with steady flows sets up the system to have failures. The natural river never flowed at a constant amount.

Please consider my comments, and either eliminate or postpone this flood for a better time.

Thank you for your time,

Tiffany S. Mapel

Tiffany S. Mapel
549 E. 5th Ave.
Durango, CO 81301

cc to:

Dirk Kempthorne, Secretary
Department of the Interior
1849 'C' Street NW.
Washington, DC 20240

63

Mark Steffen
Federation of Fly Fishers/Northern Arizona Flycasters (FFF/NAF)
11475 Homestead Lane, Flagstaff Arizona 86004, 928-522-0617

02-12-08

Regarding: Reclamation Environmental Assessment, Experimental releases from Glen Canyon Dam, Arizona, 2008 through 2012.

I STRONGLY OPPOSE THE RECLAMATION PROPOSED EXPERIMENTS, THE HIGH TEST FLOW AND THE FALL STEADY FLOWS!

I STRONGLY SUPPORT THE "NO ACTION ALTERNATIVE", and offer the following comments:

It is unfortunate that Reclamation and the Department of the Interior, including the National Park Service (NPS) and the US Fish and Wildlife Service (FWS) have chosen to force these experiments on the public with a complete lack of consideration and in defiance of five years of collaboration by Stakeholders in the Glen Canyon Dam Adaptive Management Program (GCDAMP). Stakeholders including FFF/NAF worked hard to design appropriate flow experiments, only to be forced now to accept these Bureau of Reclamation experiments which were repeatedly voted down by GCDAMP Stakeholders.

Grand Canyon Monitoring and Research Center (GCMRC) scientists, Reclamation bureaucrats, the NPS, the FWS and the Grand Canyon Trust wear rose colored glasses and assume that high flows and steady flows will be a panacea for all resources downstream of Glen Canyon Dam. This is an outrageously fallacious, dangerous and irresponsible assumption that ignores the negative consequences of all past grandiose, extreme flow experiments that have had disastrous impacts on the aquatic ecosystem in a fanatical, zealous and blind obsession to manipulate sand in the Grand Canyon.

The comment period of 14 days is grossly inadequate and irresponsible for experiments this extreme, this excessive, this expensive and this controversial. Notification of the public for comments was extremely inadequate. Reclamation in an EA press release seeking comments, did not even give instructions on how the public should submit comments.

IMPACTS TO FISH AND FISH FOOD SUPPLIES:

1) The Little Colorado River (LCR) flooded in Late January and early February 2008 with a peak flow of 4,400 cfs. This flooding above the base flow of 200cfs certainly flushed many if not most of the young humpback chubs (HBC) born in 2007 in the LCR into the main Colorado River. The USFWS

Little Colorado River (the spring fed and all year round warm water home of HBC in Grand Canyon) from invasion of warm water non-native fish (channel catfish, small mouth bass, stripped bass etc.) from Lake Mead. This current Reclamation fall steady flow proposal that "might" benefit juvenile HBC by warming backwaters in the Colorado River, also will invite invasion of warm water non-native predacious fish from Lake Mead. These warm water non-native fish would be likely to enter the LCR and could exterminate all remaining HBC in the Grand Canyon. The past four years of government trout killing in the Colorado River has opened a niche and led to increases of existing non-native warm water fish (bullhead catfish and carp) in the Grand Canyon and perhaps in the LCR. Trout in the Colorado River almost never enter the LCR. After 1950 but prior to Glen Canyon Dam, highly predacious catfish were the dominant fish in Grand Canyon (Webb, Melis and Valdez, 2002) and would likely have led to extermination of HBC in Grand Canyon including the LCR. Cold water from Glen Canyon Dam and the No Action Alternative have protected and saved HBC in the Little Colorado River in Grand Canyon. The current Reclamation proposed steady flow experiment creates new threats to the Grand Canyon Little Colorado River HBC population that should not be acceptable.

HIGH FLOW TEST TIMING, MAGNITUDE AND DURATION:

6) There is no need for "expediting" a high flow test (page 6 EA). GCMRC has stated that the current enriched sediment condition will persist in the river for several years (Steffen 2007).

7) A high flow test in a low water month is inappropriate. Damage to the aquatic ecosystem would be less if the test occurred during a high water month such as January or July. Cladophora (aquatic algae) grows intensely in spring and fall with sharp decreases in mid-summer. Increased growth of Cladophora in spring coincided with rising base flow. (Pinney 1991)

8) GCMRC has not justified a need for the test flow duration as excessive as the 60 hours in the current Reclamation proposal. The GCMRC science plan does not consider the impact a 60 hour duration 41,000 cfs flow relative to the normal high flow of 13,000cfs, will have on the Aquatic Food Base (GCMRC 2007).

ADVICE IGNORED BY RECLAMATION:

9) The Federation of Fly Fishers and the Northern Arizona Flycasters are listed in the EA as having been consulted. ALL advice give by these organizations was ignored!

10) The Glen Canyon Dam Adaptive Management Work Group (AMWG) has not recommended a high flow test or steady flows. The Glen Canyon Dam Adaptive Management Technical Work Group (TWG) voted not to recommend an identical high flow test proposed by the Grand Canyon Trust in November 2007. The AMWG and TWG have repeatedly voted not to recommend any periods of steady flows.

11) In this EA, Reclamation continues to ignore advice from AMWG and TWG including AFB experiments proposed by WAPA and the Federation of Fly Fishers (FFF) to determine AFB impacts from fluctuating flows and steady flows. Experiments proposed by WAPA and FFF included brief but significant daily flow fluctuations that would attenuate to steady flows 60 miles downstream by the Little Colorado River and chub locations.

12) The expense of this test is grossly excessive. A total cost of twelve million dollars for benefits that will be minimal, maybe only to some camping beaches and to scientist's resumes (academic reports, graduate degree dissertations etc.).

BACKWATERS:

13) Backwaters are less than 5% of shoreline according to GCMRC data. Backwaters could be destroyed by a high flow. Vegetated shorelines are more important for chubs and may also be destroyed by high flow.

14) IF backwaters are improved even temporarily for chubs, the timing of the test in March will not benefit chubs. A test in July would produce the hypothetical improvement when chubs are actually flushed from the LCR, in July and August by monsoon rains.

STEADY FLOW ISSUES:

15) Steady flows in October will lead to colder, not warmer water temperatures in backwater areas, due to low air temperatures in October, negating and reversing the intent of creating warm backwaters. Fluctuating flows maintain a relatively warm temperature of 50 degrees Fahrenheit in backwater areas even in winter when steady flows would result in very cold shoreline water temperatures.

16) Steady flows would exacerbate the effect of low dissolved oxygen that can occur in fall. Fluctuations increase dissolved oxygen in dam water releases.

17) Reclamation and this EA irresponsibly disregard evidence of benefits and even dependence of aquatic plants, aquatic insects and fish, on daily fluctuating flows. The Colorado River Aquatic Ecosystem (CRE) has evolved, adapted and become dependent on daily flow fluctuations. The CRE is now essentially a "tidal" or "estuarial" ecosystem. Steady flows would be extremely disruptive and analogous to government bureaucrats proposing that some particular ocean organism would benefit if the government could only stop the ocean tides!

18) Cessation of fluctuating flows would likely reduce drifting simmulids, gammarus (fresh water shrimp) and chironomids, important food sources for HBC. Cladophora (aquatic algae) drift was significantly higher during upramp and downramp than during steady flows. Gammarus composed the bulk of HBC diet by volume, although simmulids were the most common by number. (Valdez 1995)

19) Fluctuating flows increase the availability of food, increasing the dislodgement and movement of algae and invertebrates. Invertebrates in trout stomachs increased during periods of fluctuating flow. Anglers favor fluctuating flows because they believe rising water stimulates feeding by fish. Trout growth rates could decline due to an absence of fluctuating flows. (GCES final report introduction January 1988)

20) Fluctuating flows can lead to increased diversity of diatoms that produce mucilage which protects Cladophora against effects of dessication from dewatering during fluctuating flows. (Peterson 1984)

21) Cladophora is conditioned evolutionarily for the submergence-emergence of fluctuating flows in regulated rivers. (Pinney 1991)

22) Cladophora composed 77% of HBC stomach contents in the 1980's, chironomids and terrestrial insects only 10%. (Kubly 1990)

23) Cladophora was heavily exploited by carp, trout, channel catfish, flannelmouth and bluehead suckers. Oil droplets from diatoms attached to Cladophora provide a major energy source for fish. (Carothers and Minkley 1981)

24) Cladophora and associated diatoms are the foundation of the aquatic food web and are utilized by both Gammarus and Rainbow Trout in Glen Canyon. (Pinney1991)

25) Diatoms associated with Cladophora provide 95% of Gammarus diet at Lees Ferry. Gammarus grazed on diatoms without ingesting the host Cladophora. (Pinney 1991)

26) Diatoms associated with Cladophora appear to be an important food source for Trout below Glen Canyon Dam. Trout derive nutritional benefit from diatom lipids and achieve increased digestive efficiency from a full stomach of indigestible Cladophora. . (Liebfried 1988)

27) Gammarus show a preference for ingesting diatoms that grow best on Cladophora during fluctuating flows versus diatoms that grow under steady flows. Achnanthes affinis-minutissima and Rhoicosphenia curvata versus Cocconeis pediculus. Gammarus had difficulty removing and ingesting the diatom pediculus from cladophora. Pediculus increased with steady flows and decreased with fluctuating flows. Ingestion of A. affinis was high during fluctuating flows and affinis exhibits "hitch hiking" ability on drifting Cladophora. (Pinney 1991)

28) Gammarus become mobile during fluctuating flows. (Pinney 1991)

29) Stomachs of HBC from the Colorado River contained more food than HBC from the Little Colorado River. (Minckley 1996)

Literature cited:

Barron, Dale, Fowler, Gunderson, Kitchell, Robertson, Tyus, Wohl and Garrett. 1-13-2008. Review of the "Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam".

GCMRC, 12-27-2007. Science Plan for Potential 2008 Experimental High Flow at Glen Canyon Dam.

GCMRC, 1-13-2008. GCMRC responses to SA comments on Science Plan for Potential 2008 Experimental High Flow.

Kubly, 1990.The endangered humpback chub in Arizona.

Liebfried and Blinn, 1986 The effects of steady versus fluctuating flow below Glen Canyon Dam.GCES report B-8

Liebfried,1988. The utilization of Cladophora and diatoms as a food resource by Trout in the Colorado river below Glen Canyon Dam.

Minckley, 1996. Observations on the biology of the HBC in the CR basin 1908-1990.

Peterson, 1984. Benthic diatom community dynamics in the Colorado river: Interactive effects of periodic dessication.

Pinney, 1991. The response of Cladophora and associated diatoms to regulated flow, and the diet of Gammarus, in the tailwaters of glen canyon Dam.

Reclamation, 12-2007. Biological Assessment on the Operation of Glen Canyon Dam and Proposed Experimental Flows for the Colorado River Below Glen Canyon Dam During the Years 2008-20012.

Steffen, 12-02-2007. Report on Lees Ferry meeting about 2008 Beach-habitat-building-flow.

Valdez, 1995 Life History and Ecology of the Humpback Chub in the Colorado River, Grand Canyon, Arizona.

Van Haverbeke, USFWS, May 2005. Monitoring of Native Fishes of the Little Colorado River Ecosystem in Grand Canyon. Spring 2005 trip report.

Webb, Melis and Valdez, 2002. Observations of Environmental Change in Grand Canyon, Arizona.

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From: Dennis Kubly
To: GCDExpPlan GCDExpPlan
Date: Tue, Feb 19, 2008 7:27 AM
Subject: Fwd: Questions on HFE EA process

>>> Andre Potochnik <arp4@infomagic.net> 02/13/08 11:04 AM >>>
Hello Dennis,
Attached is a memo with our questions on the relationship between the HFE EA and LTEP EIS. Any clarifications you provide will help us formulate our comments on the HFE EA.
Feel free to give me a call, if you prefer. My cell phone is best for the rest of this week.
thanks!
Andre
--
Andre Potochnik, Ph.D.
Adaptive Management Work Group
Grand Canyon River Guides, Inc.
PO Box 1934
Flagstaff, AZ 86002
(928) 774-0698 (office)
(928) 773-1075 (main office)
(928) 380-7745 (mobile)
(928) 773-8523 (fax)
arp4@infomagic.net

Memorandum

Date: February 13, 2008

To: Dennis Kubly and Randy Peterson, Bureau of Reclamation

From: Andre Potochnik, AMWG member, Grand Canyon River Guides

Re: GCRG Questions on the High Flow Experiment Environmental Assessment.

1) We are expecting a draft EIS in April, 2008 on the Long Term Experimental Plan. How will this EA affect the production of the draft LTEP EIS?

2) Does this EA require a linkage between the HFE and proposed Sept./Oct., 5-year steady flow experiment? Isn't this pre-decisional for the LTEP EIS?

3) Would it not be more appropriate to separate the analyses of the HFE and the Steady Flow experiment into separate documents? If not, then analyze the effects separately, so the responsible official has the appropriate and comprehensive decision space to approve part of the proposed action (HFE) while allowing another part (steady flows) to proceed to a more comprehensive analysis (EIS)?

We appreciate your interest in conducting this High Flow Test from the dam in March, 2008. We believe it is very timely and important, as it should provide both learning and resource protection. We do not wish to see it jeopardized by being attached to a steady flow proposal that was intended to be part of the LTEP process.

Thank you for your response to our questions.

Sincerely yours,

Andre Potochnik, Ph.D.
Grand Canyon River Guides

cc.
Brenda Burman

65

From: Dennis Kubly
To: GCDExpPlan GCDExpPlan
Date: Fri, Feb 15, 2008 11:46 AM
Subject: Fwd: High Flow experiment?

>>> Doug Hendrix 02/15/08 8:57 AM >>>
Here's a comment from a outside party that I received in today's email....

>>> "JONATHAN SCHULMAN" <jonschulman@msn.com> 02/14/08 10:59 PM >>>
Dear Sirs:
Once again this is another effort in creating jobs for scientists in the Grand Canyon. We can study this again and again for millions of dollars and come up with same different set of answers. Its not about the endangered species or the building of beaches for habitat. The bottom line is " its all about the water" The water needs to go south to expansive Nevada and southern Arizona. Save the tax payers of the country s millions of dollars and cancel the flood. Its government waste.

A Taxpaying American

Jon Schulman

G R A N D C A N Y O N T R U S T

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OFFICE OF THE EXECUTIVE SECRETARIAT

66

February 11, 2008 231439

Secretary Dirk Kempthorne
U.S. Department of the Interior
1849 C Street, N.W.
Washington, D.C. 20240

RE: SEASONALLY-ADJUSTED STEADY FLOWS IN GRAND CANYON

Dear Secretary Kempthorne:

The Grand Canyon Trust filed a Glen Canyon Dam lawsuit in federal court December 7, 2007, against the Bureau of Reclamation for violations of the Endangered Species Act and National Environmental Policy Act. Not only has Reclamation's operation of Glen Canyon Dam violated federal law for the last seven years, but current dam releases are damaging humpback chub habitat, and releases contemplated in the December 2007 Biological Assessment will continue to damage humpback chub habitat as well as other Grand Canyon resources.

Restoring humpback chub habitat in the Colorado River through Grand Canyon will require implementing the Seasonally-Adjusted Steady Flows (including periodic spike flows to replenish the eroded beaches and sediment-related habitats) that are described in the 1994 Biological Opinion. Scientists have recommended testing these flows for many years, and Reclamation originally agreed to implement them. In addition to sediment, Seasonally-Adjusted Steady Flows are required to produce the shoreline warming and stable near-shore flows that humpback chub need for significant spawning and rearing to occur in the Grand Canyon. If we are to retain humpback chub in the Colorado River through Grand Canyon, the best available science and current research point to steady flows being a big part of the equation.

Claims that the abundance of adult humpback chub in the Little Colorado River has stabilized do not change the science linking fluctuating flows with jeopardy of humpback in the Grand Canyon. Without the improvement in habitat conditions that steady flows can provide, humpback chub will remain vulnerable to extirpation from Grand Canyon due to its small size and reliance on reproduction in a short stretch of the Little Colorado River. Although the Little Colorado River currently provides adequate habitat conditions for spawning and rearing, it is threatened by changes in water quantity and quality.

The five-year/two-month-steady-flow proposal in the December 2007 Biological Assessment is a poor surrogate for the needed changes in dam operations, and it also violates NEPA. It shortchanges the public participation required for proposals with significant controversy in both science and law.

(over)

2601 N. Fort Valley Rd., Flagstaff, Arizona 86001 (928) 774-7488 FAX (928) 774-7570
www.grandcanyontrust.org

In short, we interpret Reclamation's recent proposal for a much-diluted steady flow regime to be an attempt to coax a supportive response from USFWS, even though such a response would be inconsistent with their own science and ESA law. Such a maneuver cannot be tolerated because it merely strives for inoculation against a lawsuit and against science, all to the detriment of the park so many of us love. We hope you will steer the Bureau of Reclamation away from its current path of doing as little as possible for Grand Canyon toward one that is consistent with science and law, one that will ultimately restore Grand Canyon National Park to the health and grandeur it deserves.

Sincerely,

Bill Hedden

Bill Hedden
Executive Director
Grand Canyon Trust
2601 N. Fort Valley Rd.
Flagstaff, AZ 86001

67

Loren Gronewold
125 Schuerman Dr.
Sedona, AZ 86336
Fax: 928-282-1488

Attention: Linda Whetton, UC-733 Management Analyst
Fax - 801 - 524 - 3858

January 31, 2008

Dear Bureau of Reclamation,

It doesn't take a genius to figure out what is wrong with a man made flood that you have scheduled for March, '08 for Lee's Ferry:

1. We are in a drought and need to save all the water we can in Lake Powell. Read the Feb. '08 issue of National Geographic's article entitled, " Drying of the West".

2. I have talked to many river rafter customers and there are hundreds of places down stream to camp. A sand bar is at what cost to fishermen?

3. The chub will not survive without warm water. Tail water fisheries are cold.

4. Why are you determined to kill a multi-million dollar fishery?

I have been an avid fishermen of Lee's Ferry for 22 years, several times a year. Fishing declined after the first flush. Fishing really declined after the 2004 flush. Four months after the flush the rocks were still scoured clear with no sign of aquatic insect life anywhere. What few fish we did catch and release, were 8-12" long and skinny. Thousands of other fish had been washed into the Grand Canyon.

I keep going back hoping things would improve. But they haven't. In the spring of '07 we finally started catching more fish and a few were 15-18" long. September and October '07, were fairly successful, along with 4 days in January '08. We noticed that the fish we caught during this time were all above 14" with a few going to 20", and all healthy and fat.

Another flush at the ferry will take 4 to 5 years for the trout to come back – if they come back at all! Lee's Ferry is my all time favorite place to fish, but if you flush it again, I and many other fishermen will be forced to take our passion for fly fishing trout, and our money to neighboring states such as Colorado, Utah, and New Mexico.

Why wasn't the general public informed about this months ago? I have only heard of this tragic event, by word of mouth from other anglers. Was it kept quiet so no one could protest? Shame on you!

I was always led to believe that environmentalists were all for preserving good things that nature has given us. Now I know that they basically have set common sense aside for their narrow minded actions.

Please do not go through with this stupidity!

Sincerely yours,

Loren Gronewold

Loren Gronewold

67

Loren Gronewold
125 Schuerman Dr.
Sedona, AZ 86336
Fax: 928-282-1488

Attention: Linda Whetton, UC-733 Management Analyst
Fax - 801-524-3858

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Sincerely yours,

Loren Gronewold

Loren Gronewold

68

From: lora colten <lcolten@yahoo.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 10:30 AM
Subject: comment on EA for High Flow Experiment Grand Canyon

Hello Mr. Kubly,

I have been a commercial river guide in Grand Canyon for fifteen years. I have seen a steady decline in some beaches, have spent much time throughout the canyon and have participated in the research on the 1996 flood collecting data on macro-invertebrates in the river.

I would like to voice my support for the upcoming March High Flow experiment.

I agree that these flows are critical for the downriver ecosystem and I support them. Following past test flows,I've witnessed the rapid decline of the new sediments back into the river when the banks are steep.
I support a measure to ramp the flow down slowly following the peak flood, to minimize the steepest banks from occurring and calving.

I value the continued study of these flows on the grand Canyon and river environment.

Thank you for taking my comments for consideration

Lora Colten

69

From: Lisa Iams
To: GCexpReleases@uc.usbr.gov
Date: Fri, Feb 22, 2008 12:38 PM
Subject: Fwd: Inquiry to UC Region

This message came in to the Public Affairs Office via the contact link on the UC Region Web site

>>> C. D. Springstun <amostex@aol.com> 2/22/2008 11:28:06 AM >>>

From C. D. Springstun (amostex@aol.com) on Friday, February 22, 2008 at 18:28:06

msgbody: I am voicing my opposition to proposed high water releases from Glen Canyon Dam scheduled for March 2008. Time and again this has proved fruitless and a waste of time money and resources which would be better spent elsewhere. Prior releases and endless studies have shown no value to this course of action. I support the "No Action Alternative".

Thank You,

C. D. Springstun
Flagstaff, AZ.

previous_page: http://www.usbr.gov/uc/envdocs/ea/gc/2008hfe/index.html

Submit: Send

REMOTE_HOST: 159.87.53.104

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From: Jeff English <flyguide@hughes.net>
To: <gcexpreleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 1:32 PM
Subject: I support the no action alternative

Dear BOR, I ask you to reconsider the proposed steady flow treatment designed in Sept & Oct 08 and continuing for the next five years. A process has been established, called the AMWG which is comprised of several cooperating agencies working togather to create a management plan that considers all participant inputs. How is it that one of those members (Grand Canyon Trust) decides on its own when things are not going the way they want, they decide to enlist attorneys, create a lawsuit, that forces everyone else out of the process as they launch their own beliefs upon all the rest of the cooperating members. I have a few questions regarding this situation

1) Does the furture of this process rest to the member who has the best attorneys?

2) At what point does a members behavior become so disruptive to the designed process, that they should be removed from the AMWG?

3) How can we hope for continued cooperation from all involved, if the Grand Canyon Trust is allowed to trump all other opinions with lawsuits?

Sincerely Jeff English

HC-67 Box 13
Marble Canyon, AZ 86036

(928) 355 - 2292

71

From: Terry Gunn <tgunn@hughes.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 2:12 PM
Subject: Experimental Flow Comment

I'm writing to you today to ask you to please consider NOT conducting the proposed experimental flow scheduled for March 2008 and September and October 2008-2112.

In my 25 years experience on this river I have witnessed flows from 500-cfs to 100,000 cfs and can assure you that experimental flows have a negative affect on the local aquatic ecology and economy. The last experimental flood occurred in 2004 and the river and the aquatic food base is just now beginning to recover to pre-flood conditions. If another flood were to occur at a time that the river is just starting to recover it could spell disaster to recreational sport fishing and the local economy that fishing supports.

As you drive to Lees Ferry it is evident that you are passing through the most economically depressed region in the United States (US Census Data). The local economy in the Lees Ferry-Marble Canyon area is strongly dependent on the millions of dollars that fishermen spend here. While travelers and river runners might visit our area for an evening (most river companies transport their guests in the day of departure), a fishermen's average stay is 3 nights at one of the local lodges. The fisherman's money stays in the local economy, supports many local Native Americans and their extended families and creates numerous jobs in the local area. Past experimental flows have been very destructive to the local economy and all of the local Marble Canyon businesses are opposed to this proposed experiment.

The November 2004 flood caused severe damage to the aquatic plants and insects that provide the food supply for Rainbow Trout at Lees Ferry and for Humpback Chubs in the Grand Canyon. Trout populations at Lees Ferry and in Marble Canyon have declined by as much as 50% since the 2004 flood (AGF data). The Marble Canyon area economy has suffered from a drastic reduction in Lees Ferry fishermen. The proposed spring experiment could also lead to aquatic food base damage as indicated by an AGF report that food (Algae) for fresh water shrimp was drastically reduced by the April 1996 flood.

It is my understanding that the major driving force for floods is to enhance recreational opportunities for river-runners and provide pristine beaches for camping. I assure you that people are not going to be canceling their scheduled river trip because there are no new pretty beaches to sleep on. I do guarantee you that fisherman will be canceling their fishing trips to Lees Ferry IF a flood is conducted. News reports of another flood will result in even fewer anglers traveling to fish Lees Ferry and will again seriously hurt the Marble Canyon economy. February though June is a very popular time to fish Lees Ferry and when most of the annual revenues for local businesses is generated.

I spend quite a lot of time traveling around the country promoting the Lees Ferry fishery and my business. The past couple of years, half of the people I speak to approach and ask "Are they planning another flush?" "I understand that the last flood wiped out the fish and food, "has the river recovered from the last flush?" 'Will they ever stop experimenting on this river and allow the fishery to recover?" I used to come up and catch 50 fish a day before they ruined it, I don't come anymore, the last time I was there we hardly caught any fish." These are the comments that I hear and this is the public perception. This negative perception translates into lost revenues and recreational opportunities. Is it fair to trade one recreational opportunity (beaches) for another (fishing)?

A local guide described it best when he said "using high water flows to build beaches is like using an atomic bomb to dig a hole," you'll certainly get a hole dug but at what other expense! Many believe that if you want beaches that will last in the Grand Canyon, there is technology available to achieve this goal using nondestructive methods.

1: I urge the BOR to not conduct this experiment and instead investigate nondestructive methods of building beaches in the Grand Canyon and to use common sense and sound judgment in dealing with this and all future planned experiments on the Colorado River.

2: I urge the BOR to remove the proposal for low steady flows in September and October from the experiment. I support clean energy and encourage the wise use of power generation from Glen Canyon Dam.

3: I, my 40 employees, and all the businesses in Marble Canyon, strongly support THE NO ACTION ALTERNATIVE.

Terry Gunn
Lees Ferry Anglers Fly Shop, Guides, & Rentals
Cliff Dwellers Lodge
http://www.terrygunn.com
http://www.leesferry.com
http://www.cliffdwellerslodge.com
800-962-9755
Fax 928-355-2271
Hm. 928-355-2220

72

From: "R/C Southwick" <RSouthwick@ShamanProducts.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 2:29 PM
Subject: Comments on Environmental Assessments of the GC Experimental Release propsed

Comments on Environmental Assessment

Date: February 20, 2008

To: Dennis Kubly, Bureau of Reclamation

GCexpReleases@uc.usbr.gov

From: Celia Southwick,

Private Boater

Member of GCRG, RRFW, Adobe Whitewater Club of New Mexico

Re: Comments on Environmental Assessment of High Flow Experiment (HFE).

Comments herein are not necessarily represented by those organizations listed to which I belong but rather I have used the resources to determine my own opinion. Additionally I have been down the Grand Canyon over 25 times since early 1990's and have observed changes and seen loss in beaches and riparian sediment particularly in daily hi-low fluctuation scenarios. I have also participated in Adopt A Beach Program of GCRG which has made me more aware of how the beaches are "going down the river". When the beaches and sand are newly deposited or recently eroded (an even more fragile beach) they are also more susceptible to the human factors and that certainly ramps up with more visitors in the high use season approaching.

I support the increase of beaches through this proposed High Flow in March 2008.

I do NOT SUPPORT a decision to do so for the next 5 years at this time. That decision needs to wait.

It may be that the best conditions for these releases do not occur every year (we are still in the drought cycle) and take time to build up or have weather conditions yielding flashes w/ high deposition throughout the length of the river corridor.

I would say that the Canyon can no longer support EXPERIMENTAL flow regimes as the beaches have already suffered extreme loss due to some of that experimenting! This either works.. or it does NOT. Assessment of the series of factors that you think will contribute to beach building and sediment redistribution MUST happen and not at the whims of the bureaucratic wheels that turn.

Bottom line too is that the sediment that should be on the beaches now is ABOVE the dam and filling up the lake. Hmmm. That is yet another subject and not the one on the immediate horizon.

My understanding of the last high flow release in November 2006 was beaches in the upper reaches of the Canyon were built up and those in the lower reaches were not, in fact even devastated in some places. I have addressed this w/ GCRG and Andre Potochnic and the explanations seemed plausible. Additionally the conditions that now exist w/ much sediment deposited in the river along with current contributions from Paria, Little Colorado and side canyon flashes seem like prudent timing for such a high flow release.

The flow should be downramped at a slower pace allowing for stabilization of the sediment where deposited. In previous years we have been in the canyon on winter trips where the flows of 5-20,000 cfs daily resulted in visible bank-storage drainage that tore down the beaches and created gullies of sand wash every day. A more gradual down ramping of the flow seems prudent to give bank-storage a slower drain time and thus taking with it less sediment. The stabilization of the beaches seems essential with higher flows of the summer season coming up.

* I am not an expert in the subject above and perhaps have used some terminology incorrectly.
* I do support the high flow release w/ the correct sediment conditions as is my understanding current exist in the Canyon.
* But I do hope you consider increasing the rampdown time to help with the stabilization of sediment/beaches.
* I do hope you do not make a definitive decision to do this each year after this unless it works this time and unless the conditions needed are present yet again.
* Mother Nature's storms are not on the calendar so do require flexibility and good logical scientific assessment of the river system if we are going to micro manage it! There has certainly been the science down there to monitor this so collect the data and assess it later - not now!
* It may even make a difference for the endangered fish and other species and the overall health of the river ecosystem. I am sure you have given consideration to how all this impacts the efforts being made w/ the endangered species.

Thanks for taking time to read this and allowing for public input into the process.

I may not be down in the Canyon on the river very many more times in my life time but I do hope that things are still more or less the same (in as dynamic a place as it is) for generations to come and that they too can get all the enjoyment and lessons in life that I have gotten from this place we call the Grand Canyon.

Sincerely,

Celia Ann Southwick

Private Boater

rsouthwick@shamanproducts.com

4022 Anderson Ave SE

Albuquerque, NM 87108

505-266-8518

72

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To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 2:29 PM
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Private Boater

rsouthwick@shamanproducts.com

4022 Anderson Ave SE

Albuquerque, NM 87108

505-266-8518

73

From: Rick Johnson <richard.johnson@npgcable.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 3:32 PM

Greetings;

Please find attached the Grand Canyon Trust's comments on the 2008 Environmental Assessment: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

Please feel free to contact me if you have any questions.

CC: Brenda Burman <brenda_burman@ios.doi.gov>, John Hamill <jhamill@usgs.gov>, Steve Martin <steve_p_martin@nps.gov>, Randy Peterson <rpeterson@uc.usbr.gov>, Dave Sabo <dsabo@uc.usbr.gov>, Steve Spangle <steve_spangle@fws.gov>

GRAND CANYON TRUST

February 22, 2008

Grand Canyon Trust Comments on the 2008 Environmental Assessment: Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

This Environmental Assessment is deficient in many ways. In general, it needs to be better connected with the Grand Canyon Protection Act, as described below. Our specific comments also address violations being committed under the National Environmental Policy Act and Endangered Species Act.

National Environmental Policy Act Issues

We are disappointed in the Bureau of Reclamation's lack of adherence to NEPA in connection with the Proposed Action. The Environmental Assessment is inadequate for several reasons, including the following:

1. The Bureau of Reclamation (Reclamation) failed to provide a Federal Register notice on the availability of the Environmental Assessment (EA) for public comment. 40 C.F.R. § 1506.6 states, "In the case of an action with effects of national concern notice shall include publication in the Federal Register and notice by mail to national organizations reasonably expected to be interested in the matter ...."

2. Reclamation has not allowed sufficient time for a 30-day public comment period between a Finding of No Significant Impact (FONSI) on the EA and the scheduled Beach/Habitat-Building Flow (BHBF). As we noted in our 24 January 2008 letter to Secretary Kempthorne, this EA triggers the NEPA requirement for a 30-day public review for several reasons including: 1) there is substantial scientific and public controversy regarding the timing and duration of the steady flow component of the EA; and 2) the proposed action is similar to one which normally requires preparation of an Environmental Impact Statement (EIS). We believe that a 30-day public review is required following the issuance of a FONSI on any action that includes steady flows.

3. Reclamation has not included the National Park Service (NPS) staff in developing the EA. A 30 January 2002 memo from James Connaughton, the Chairman of the Council on Environmental Quality (CEQ), to the heads of Federal agencies recommends the designation of cooperating agencies in the preparation of EAs. As we advised in our comments on the Long-Term Experimental Plan (LTEP), "[t]he need to comprehensively address park resources and values strongly supports designating the National Park Service as a joint lead agency." If resources under the jurisdiction of the National Park Service, a sister agency in the Department of Interior, are being affected by releases from Glen Canyon Dam, then NPS should be intimately involved in the design and implementation of any experimental releases.

4. Reclamation's action affects the development of the Long-Term Experimental Plan as noted in Reclamation's February 12, 2008 Federal Register notice. Section 1506.1 of the CEQ regulations limits actions during the NEPA process until a Record of Decision is issued.

5. Reclamation fails to provide a range of alternatives in the EA as required under Section 1508.9 of the CEQ regulations. As evidenced in the LTEP EIS (and the LTEP scoping comments), there are several alternative approaches to providing the spawning and rearing conditions in the mainstem that are necessary to remove jeopardy to humpback chub and meet the intent of the GCPA. As we noted in our 24 January 2008 letter to Secretary Kempthorne, "If a decision on an alternative in the LTEP requires multiple alternatives analyzed in an Environmental Impact Statement (EIS) with full public process, how can the same decision now require merely an EA with no analysis of alternatives and insufficient public participation?"

Purpose and Need

The Purpose and Need section of the EA is inadequate. This section should acknowledge that existing operations are not meeting the intent nor the letter of the Grand Canyon Protection Act (GCPA) and the Endangered Species Act (ESA), thereby necessitating the proposed action. The 2005 SCORE ("State of the Colorado River Ecosystem") report is an excellent resource that documents the failings of Reclamation's existing operations.

This section should also describe how the proposed action is intended to meet the intent of the GCPA and the ESA. The GCPA states, "The Secretary shall operate Glen Canyon Dam in accordance with the additional criteria and operating plans specified in section 1804 and exercise other authorities under existing law in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established, including, but not limited to natural and cultural resources and visitor use." The values for which the park units were established (e.g., "... maintain the closest approximation of the natural condition....") are identified in the 2006 NPS Management Policies. The purposes of the ESA "... are to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved...." Consistent with these purposes, the

1994 Biological Opinion (BO) directs the "[a]ttainment of riverine conditions that support all life stages of endangered and native fish species...." Nowhere does Reclamation state how these requirements will be achieved through the proposed action.

Authorizing Actions, Permits, or Licenses

In addition to the permits mentioned, Reclamation must obtain a water quality certification from Arizona under section 401 of the Clean Water Act.

Alternatives

The EA states that under the no-action alternative, "Reclamation would continue to operate the dam as described in prior NEPA analyses (Reclamation 1995, 2007a). No experimental flows or actions would occur from 2008-2012." However, these sentences are not internally consistent. In prior NEPA analyses (e.g., the EIS/ROD on Operation of Glen Canyon Dam), the Secretary made several commitments to experimentation. The no-action alternative is what is legally required by the ROD and the Biological Opinion, not what has actually occurred. The status quo is illegal as set forth in the Biological Opinion.

Steady Flows

No scientific justification exists in the EA for conducting steady flows only in September and October. Reclamation implies that they believe summer steady flows are more beneficial to young-of-year humpback chub than the proposed steady flows by stating, "Recognizing that [increased hydropower costs] would be a significant adverse environmental justice impact, the impact was reduced by proposing a steady flow test during the fall rather than the summer when much higher economic impacts would occur." The lack of scientific justification for September and October steady flows precludes the ability to make a FONSI determination on the steady flow component of the EA.

We find comments in the EA regarding the timing of the steady flows to be misleading. The EA states, "The timing of fall steady flows follows young-of-year emergence of humpback chub from the Little Colorado River into the mainstem." However, to test the effects of steady flows on rearing habitat for young-of-year humpback chub, Reclamation must provide the needed habitat conditions <u>when</u> young-of-year are emerging from the Little Colorado River (LCR), not <u>following</u> their emergence. By September, it is likely that the vast majority of young-of-year from the LCR will have already migrated into the mainstem and perished in the cold, fluctuating water. Because the majority of post-larval humpback chub probably migrate into the mainstem during monsoonal floods in August, a legitimate test of the effects of steady flows on humpback chub rearing must begin by August at the very latest.

The EA incorrectly states that, "The experimental design is fully reflected in the science plan developed by GCMRC [Grand Canyon Monitoring and Research Center]." The GCMRC science plan only addresses the 2008 BHBF.

The September and October steady flows proposed in the EA are invalid as a test of the Seasonally-Adjusted Steady Flows (SASF) analyzed in the 1995 EIS and required in the 1994 Biological Opinion. Steady flows in September and October do not meet the requirement in Element 1 of the Reasonable and Prudent Alternative (RPA) to attain "riverine conditions that support all life stages of endangered and native fish species…."

Another problem with the proposed experiment is that the monthly volumes during September and October are not well specified. The EA states, "if possible, dam operations would be managed so September and October releases would be similar (Table 3), but September releases may be structured to provide a transition between August and October monthly volumes." It is unclear how this would occur and what the potential effect of the different volumes (and thus flows) would be on young-of-year chub.

Another problem with the proposed experiment is that the SASF description in the EIS and BO not only specifies steady flows, but also monthly volumes. The September and October monthly volumes are significantly higher under the EA (~600 kaf) than SASF in the EIS (~500 kaf).

Another problem with the proposed experiment is that allowable daily fluctuations for SASF is ± 1000 cfs/24 hours (see page 32 of the EIS), whereas the EA defines steady as ± 1200 cfs within each hour. Because no information is provided on the likely daily stage variation resulting from AGC during the steady flows, it is not possible to determine the potential impact to nearshore habitats and young-of-year humpback chub.

The only justification that is provided in the EA for conducting steady flows in September and October, as opposed to the SASF requirement in the Biological Opinion, is to meet the intent of Executive Order 12898 regarding Environmental Justice. However, the EA does not provide an analysis demonstrating a "disproportionately high and adverse human health or environmental effects of [the proposed action] on minority populations and low-income populations." It is not clear to us, especially with the costs of replacement power being borne by taxpayers, how the experiment could lead to "rising electric costs."

Beach/Habitat-Building Flow

Testing the effects of a BHBF under the high sediment conditions that currently exist in Grand Canyon is crucial for advancing our knowledge of sediment dynamics in Grand Canyon. However, we believe that research efforts should be focused not only on how BHBFs can be used to rebuild beaches and sediment-related habitats, but also on how to maintain that sediment through time. As stated in the EA, "While Reclamation has conducted two prior high flow tests with initial positive results, sandbars and backwaters reverted back to their previous state…." Reversing the continued decline of sediment in Grand Canyon is essential for meeting the intent of the GCPA and the ESA, and preventing impairment of park resources and values.

We are very concerned about the constraints that the EA suggests in regards to additional BHBFs. We concur with John Hamill, Chief of Grand Canyon Monitoring and Research Center, that additional BHBFs beyond 2008 are required to understand sediment dynamics and how best to use BHBFs to meet the goals for sediment in Grand Canyon. Although the rationale for eliminating additional BHBFs is not stated, we presume this is in response to opposition by water and power interests based on their interpretation of law. However, we believe that the Secretary of Interior has broad discretion to operate Glen Canyon Dam to meet the intent of the ESA and the GCPA. If options for meeting the intent of the ESA and GCPA are being constrained by interpretation of law, then we request a formal Solicitor's Opinion to settle the issue.

We are concerned about shifting the time frame of the BHBF from late March or early April (the optimal timing for a BHBF based on resource considerations) to the first week of March based on the "… public perception of the impacts to fishing success in the Lees Ferry reach." If the issue is an inaccurate public perception, then we suggest that a more reasonable mitigation measure is to educate the public rather than a shift in the timing that is unlikely to benefit the guides, the public, or the resource.

The EA omits discussion of aeolian processes following a BHBF for protecting archaeological sites, even though it is discussed in the GCMRC Science Plan. Protecting archaeological sites is not a trivial issue and must be addressed.

Socioeconomic Assessment

The socioeconomic assessment is deficient. For example: 1) there is no analysis or discussion of non-use values or economic effects other than hydropower; 2) there are no supporting studies cited for assertions regarding hydropower impacts; 3) there is no analysis regarding the hydropower impacts of the fall steady flows; and 4) the "analysis" of hydropower impacts uses the "average annual energy generation" from the Shortage EIS, rather than an actual estimate of generation in 2008 (which is presumably lower).

It is unclear from the text who shoulders the various "costs" of the experiments—is it taxpayers, or are the costs passed down through the utilities to their customers? The unsupported assertions in regard to environmental justice effects are inexcusable.

It would be useful to know the "opportunity cost" of the water that would bypass the generators in the proposed BHBF (92,375 af would be routed through the jet tubes and thus would not be available for generating hydropower) compared to the cost of acquiring replacement power. It also would be useful to know the magnitude of the various costs when compared to a 2008 year without a BHBF. It appears from a table recently provided to the AMWG by Western Area Power Administration (WAPA) that under the current contracts, WAPA will need to acquire over $37 million dollars of replacement power costs in WY 2008 whether or not a BHBF is implemented. WAPA's estimated "cost" of the 2008 BHBF appears to be a reduction in the "surplus revenues" available during the summer of just over $3 million.

The paragraph on carbon emissions is also lacking. There is no support provided for the assumption that replacement power would come from carbon-producing sources, that there would be a reduction of 41 GWHr of energy generation in 2008, or that this would produce additional carbon emissions of 45,800 tons. The "eGRID 2006" citation is not referenced in the literature cited.

Best Scientific Information

Assertions in the EA are not adequately supported, and consequently, they have little credibility. A FONSI on such a poorly documented EA cannot be justified.

The EA also suffers from the lack of an experimental design. It will be virtually impossible to assign a cause-and-effect relationship between any change in the abundance of humpback chub and the steady flows proposed in the EA. Although the EA suggests that non-native control "should begin as soon as possible," it is likely that recruitment by humpback chub in the mainstem is dependent upon several processes including hydrology, predation/competition by non-natives, temperature, turbidity, and availability of stable nearshore habitats. An efficient and effective experimental design would need to consider all of these explanatory variables concurrently.

Conclusion

There have been numerous violations of NEPA process, and the EA itself is incomplete, inaccurate, self-contradictory, and poorly supported. We are surprised at the poor quality of the EA as it is far below both the quality of previous EAs, and the capability of Reclamation's professional staff. We believe it would be inappropriate to issue a FONSI on the steady flow component of the EA.

We encourage the Department of Interior to implement a revised approach that, first and foremost, benefits Grand Canyon resources. We suggest: 1) immediately rectifying violations of NEPA process; 2) immediately developing a new EA focused solely on the 2008 BHBF; and 3) immediately restarting the LTEP process to develop a program of experimental flows and other actions that will meet the intent and letter of the GCPA and the ESA.

Although we are cognizant of the time constraints for the 2008 BHBF, we believe that: 1) implementation of the BHBF could be pushed back to the last week of March or first week of April (and in fact, the delay would probably benefit resources); 2) Reclamation, the National Park Service, and the U.S. Fish and Wildlife Service have the professional staff capability to develop and analyze an EA for a BHBF in this time frame; and 3) it would be negligent, given the high value that the American public places on Grand Canyon, to not take advantage of the large amount of sediment that is currently in the river in a manner consistent with the GCPA and ESA.

This Environmental Assessment is far off the mark for restoring Grand Canyon. It is a piece of an unfortunate political puzzle wherein Reclamation is compromising the health of Grand Canyon for the benefit of water and power interests. Notwithstanding politics, Grand Canyon National Park is deserving of the best care and protection possible.

Sincerely,

Nikolai Lash
Adaptive Management Work Group representative
Grand Canyon Trust

Rick Johnson
Technical Work Group representative
Grand Canyon Trust

Cc: Dirk Kempthorne, Brenda Burman, John Hamill, Steve Martin, Randy Peterson, Dave Sabo, Lynn Scarlett, Steve Spangle

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From: Jane Bird
To: GCexpReleases@uc.usbr.gov
Date: Fri, Feb 22, 2008 3:51 PM
Subject: Comments on Environmental Assessment - Experimental Releases from Glen Canyon Dam

Attached are the comments of the Upper Colorado River Commission on the subject EA.

Jane Bird
Assistant to the Executive Director
and General Counsel
Upper Colorado River Commission
355 South 400 East
Salt Lake City, Utah 84111
TEL: (801) 531-1150
FAX: (801) 531-9705
E-mail: jbird@uc.usbr.gov

CC: Larry Walkoviak; Peterson, Randall; Ryan, Tom

UPPER COLORADO RIVER COMMISSION
355 South 400 East • Salt Lake City • Utah 84111 • 801-531-1150 • FAX 801-531-9705

February 22, 2008

Mr. Larry Walkoviak
Regional Director
Upper Colorado Region
U. S. Bureau of Reclamation

VIA E-MAIL: GCexpReleases@uc.usbr.gov

Re: Environmental Assessment – Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012 (February 8, 2008 "EA")

Dear Mr. Walkoviak:

The Upper Colorado River Commission (Commission), representing its member States (Colorado, New Mexico, Utah and Wyoming) sent a letter to Ms. Brenda Burman dated December 6, 2007. This letter discusses the Commission's concerns regarding a high-flow test from Glen Canyon Dam proposed by the Bureau of Reclamation (Reclamation) for the spring of 2008. A copy of that letter is attached.

Additional consideration of this matter has taken place since the Commission's letter was written. However, the Commission remains concerned about both continuation of high-flow tests and steady flow options without addressing the significant legal and policy issues raised in the Commission's prior letter. At this time, we want to reaffirm the positions we stated previously.

The Commission appreciates the opportunity to provide comments on the EA and related documents and processes. The Commission recognizes the challenges the Department of the Interior faces in balancing competing resource needs with the requirements of the Law of the River. We urge timely completion and implementation of this process but reiterate the concerns we have expressed in the past.

Sincerely,

Jane Bird

for Don A. Ostler, P.E.
Executive Director and Secretary

Cc: Randall V. Peterson
Thomas P. Ryan

UPPER COLORADO RIVER COMMISSION

355 South 400 East • Salt Lake City • Utah 84111 • 801-531-1150 • FAX 801-531-9705

December 6, 2007

Ms. Brenda Burman, MS-6640, MIB
Deputy Assistant Secretary for Water and Science
U. S. Department of Interior
1849 C Street, NW
Washington, D.C. 20240

Dear Ms. Burman:

This letter is written on behalf of the Upper Colorado River Commission representing the states of Colorado, New Mexico, Utah and Wyoming. The Commissioners, including their engineering and legal advisors held a conference call on November 21, 2007 to discuss the decision currently before the Department of Interior on whether to initiate a one-time beach habitat building flow (bhbf) test below Glen Canyon Dam, which will result in a bypass of the power generation facilities. We understand this test might be conducted in early March of 2008 and is intended to demonstrate the effects of periodic, controlled flooding on restoring and maintaining sand beaches below the dam.

The Commissioners unanimously have expressed concern that we believe bypassing the power generating facilities is not supported by the Law of the River or the express language in the current Record of Decision for Glen Canyon Dam. We remain concerned about the financial impact upon the Basin Fund from such bypasses of the power generating facilities and if such occurs, the Bureau must assume responsibility to supplement the Basin Fund if problems arise later. Should the Secretary decide to still proceed with such a test on a one-time experimental basis, the Secretary would also be obligated to insure that adequate and complete scientific information is collected to insure that decisions can be made based upon this and the previous two tests regarding the long-term viability of similar flows being used in the future as a management practice. If such power plant by-passes are determined in the future to be a viable management practice, we believe the law would need to be changed to allow for their regular use and that a mechanism is needed to supplement the Basin Fund to mitigate the adverse financial effects from the management practice.

Thank you for consulting with us on this matter. If you have further questions, please do not hesitate to contact us.

Sincerely,

Don A. Ostler

Don A. Ostler, P.E.
Executive Director and Secretary

cc: Secretary Kempthorne
Commissioner Johnson
Larry Walkoviak
Randal Peterson

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From: John Weisheit <john@livingrivers.org>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 2:51 PM
Subject: EA Comments: Living Rivers and Center for Biological Diversity

February 22, 2008

Mr. Dennis Kubly
Bureau of Reclamation, Upper Colorado Regional Office
125 S. State Street, Salt Lake City, Utah 84138
Fax: (801) 524-3858
GCexpReleases@uc.usbr.gov

Re: Environmental Assessment of Experimental Releases from Glen Canyon Dam, Arizona 2008 through 2012.

Dear Mr. Kubly,

On behalf of Living Rivers and the Center for Biological Diversity, we submit the following comments on the February 08, 2008 Environmental Assessment of Experimental Releases from Glen Canyon Dam, Arizona 2008 through 2012. While we appreciate Reclamation's intentions to potentially aid in the redistribution of sediment, such that it might improve habitat conditions for endangered native fish, we find this action insufficient on its own to offer any lasting benefits toward fulfilling this objective.

1. Sediment Augmentation

Past experience has already illustrated the limited benefits such experimentation can achieve. The 1996 and 2004 high flow experiments have revealed that there is not enough sediment entering the river ecosystem below Glen Canyon Dam to make up for the 44 million tons that would otherwise be entering the system on an annual basis were the dam not in place. In 2005, during the Science Symposium by Grand Canyon Monitoring and Research Center (GCMRC), and again in 2006 during meetings of the Technical Working Group, scientists discussed or recommended that the Adaptive Management Program should consider bringing additional sediment into the system through a mechanical augmentation plan. The public also recommended augmentation during the scoping period for the Long-Term Experimental Plan Environmental Impact Statement. Absent such augmentation, this proposed action will offer no lasting benefits, either to endangered fish or recreational beaches. As noted in the 2005 Score Report by the United States Geological Survey, Grand Canyon is running a sediment deficit, and no amount of experimental flows can fix this problem. Reclamation must explore sediment augmentation as a viable alternative to meeting the objectives of this action.

2. Seasonally Adjusted Steady Flows

As has been stated repeatedly, Reclamation is in violation of the terms set forth in the 1994 Biological Opinion requiring that Seasonally Adjusted Steady Flows be implemented from Glen Canyon Dam for reasons of insufficient progress to remove jeopardy to threatened and endangered species, and during minimal releases of 8.23 million acre feet (maf). Only when such flows are integrated with sediment augmentation, as noted above, will there be any real opportunity for species recovery.

We find it particularly unfortunate that the 2007 Biological Assessment also chose to ignore Seasonally Adjusted Steady Flows (SASF). It's unfortunate that such operating criteria may offer the best opportunity for meeting the objectives of the Grand Canyon Protection Act, but continues to be shunned by the hydropower interests.

3. Declining Reservoir Levels

This action is wholly contingent on there being sufficient water in Lake Powell, such that flood flows greater than 41,500 to 45,000 cfs (cubic feet per second) can be created. However, should the reservoir elevation drop below 3,490 feet msl (mean sea level), this will be impossible. The maximum flow that could be achieved would be less than 15,000 cfs through the bypass tubes alone. While current snow pack indicates that for at least the next two years, there should be sufficient water in Lake Powell to undertake such experiments, there is no guarantee that this will be the case through the completion of the proposed action period in 2012. Lake Powell's present elevation is 3,595 feet, meaning reduced inflows during the experiment period to 2012 of a net -6.8 maf will be sufficient to force the shut down the penstocks, and this proposed action. As you are well aware, in the three years after 2000, Lake Powell's level dropped 11 maf, thus history illustrates that such reductions have occurred, yet the EA assumes, without any justification, that they will not.

While section 3.1.1.1 discusses climate change, it relies on the same limited analysis undertaken by Reclamation for Shortage Criteria—analysis which Reclamation states does not take into account climate change. More importantly, isolating the ISM single traces (index sequential hydrologic modeling) that begin with water years 1950 or 2000, would clearly show the potential for Lake Powell dropping to levels near or below the 3,490 msl threshold. While Reclamation may wish to argue the likelihood of such an occurrence, it cannot ignore the prospect altogether.

4. Water Quality

The continued avoidance by Reclamation to address the likelihood of reservoir levels dropping significantly below their current levels, represents a potentially ticking time bomb for Grand Canyon. The implications are far greater than whether or not GCMRC scientists find more grains of sand near the Little Colorado River six months following a high-flow experiment. The quality of water entering Grand Canyon could become so poor as to pose a serious threat to Grand Canyon's entire river ecosystem.

As the EA points out in section 3.1.3.1, dissolved oxygen levels at the upper portion of the reservoir are far greater than that of the water that is typically released from the penstocks. Even now, the levels flowing into Grand Canyon are higher than prior to the experimentation of 1996. This situation only worsens the lower the surface of the reservoir becomes and with the decreased volume of water generally. This issue has never been addressed by Reclamation, nor a number of other potential water quality impacts to Grand Canyon including: extreme water temperature, increased nutrient concentrations, higher salinity, high hydrogen sulfide, heavy metals such as mercury and selenium, and the pass through of exotic reservoir animals. This EA must therefore evaluate the potential water quality impacts the Grand Canyon ecosystem might face from decreasing reservoir levels during the period of the proposed action. More importantly, Reclamation must immediately undertake a comprehensive assessment of the potential water quality impacts on Grand Canyon should the reservoir drop to dead pool.

5. Archeology

As noted in section 3.2, this action is likely to cause harm to a number of archeology sites, as well as to cultural vegetation. Such a problem would not occur were Reclamation to implement SASF as noted above in combination with sediment augmentation. Reclamation continues to make archeology a low priority, preferring to dig and relocate sites and artifacts than preserve them in situ as is their mandate.

Lastly, we remain frustrated by Reclamation's ongoing policy of unnecessarily limiting public comment periods. This action has been contemplated by Reclamation since December of 2007, yet the Environmental Assessment is offered for public comment less than one month prior to the scheduled date of the proposed action. Additionally, a federal action of this magnitude deserves a proper Federal Register notice, which Reclamation has failed to do.

Whether it's poor management on behalf of the AMP and the GCMRC, an intentional disregard for public participation, or both, Reclamation must correct this problem, beginning with extending the deadline for comments on this EA an additional 15 days.

As evidenced by the ramping up of publicity for the first experimental flow contemplated with this action on March 4, it appears Reclamation is more interested in mobilizing media interest in support of Reclamation's own interpretation of this action, than it is on assuring the public has an opportunity to evaluate it for themselves and draw their own conclusions.

In conclusion, we view this EA as merely one more volume in the unfortunate history the Bureau of Reclamation and the Adaptive Management Program has visited on Grand Canyon. Until such time as Reclamation and the AMP makes a commitment to restoring the natural process that nurtured the evolution of Grand Canyon's river ecosystem, no possibility exists for the ecosystem itself to be restored consistent with intent of the 1992 Grand Canyon Protection Act.

Sincerely,

John Weisheit, Conservation Director, Living Rivers
Michelle Harrington, Rivers Conservation Manager, Center for Biological Diversity

CC: John Weisheit <john@livingrivers.org>, Michelle Harrington <mharrington@biologicaldiversity.org>

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From: "Karen Hevel-Mingo" <khevel-mingo@NPCA.ORG>
To: <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 4:05 PM
Subject: Glen Canyon experimental release EA comments

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National Parks Conservation Association®
Protecting Our National Parks for Future Generations®

Southwest Regional Office

307 West 200 South
Suite 5000
Salt Lake City, UT 84101
801.521.0785 (phone)
801.359.2367 (fax)

February 22, 2008

Mr. Randall Peterson
Bureau of Reclamation
Upper Colorado Region
125 South State Street, Room 6103
Salt Lake City, Utah 84138

Reference: Environmental Assessment Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

Dear Mr. Peterson:

The National Parks Conservation Association (NPCA), a national non-profit corporation with a membership of over 340,000 citizens, whose mission is to preserve and protect our national parks for present and future generations, has significant concerns with the referenced environmental assessment.

We believe that the EA is incomplete and proposes a course of action that is not in compliance with the Grand Canyon Protection Act. From our perspective, it appears that the National Park Service was not included in your deliberations as a cooperating agency and this invalidates your purposes for this proposed series of experimental releases. Moreover, it further appears that the substantial work and recommendations of the USGS Workshop on Scientific Aspects of a Long-term Experimental Plan for the Grand Canyon in April 2007 has not adequately been considered for this EA.

The substantial benefits of the proposed beach/habitat-building flow (BHBF) in March, 2008 is a treatment that we support. We have concerns; however, with locking in a multiple year steady flow each fall through 2012. The scientific consensus suggests that on-going analysis and research representing an environmental triggers approach that can inform and support a seasonally adjusted flow regime, should guide subsequent releases from Glen Canyon Dam. The proposed multiple year steady flow does not appear to acknowledge the best available science and locks in a treatment that is not informed and adaptive. In addition, the EA does not recognize any other potential approaches and in our opinion is incomplete.

As a consequence, we believe that this EA is substantially deficient. We recommend that it be revised to more fully reflect the responsibility to embrace an environmental triggers approach that appears to represent consensus among scientists. By failing to adequately consider the best available science, it is our belief that this EA does not appropriately respond to the Grand Canyon Protection Act and is not in compliance with the 2006 Grand Canyon Management Policies.

In addition, the EA represents that there are significant adverse environmental justice impacts as a consequence from future releases other than fall steady flow. This is not supported with any form of analysis and is therefore unsubstantiated and insufficient.

We recommend that the EA, therefore, de-couple the proposed (BHBF) which we believe has been recognized and validated as a crucial and fundamental adaptive management tool, from the subsequent fall steady flow regime which appears to be incomplete and in conflict with the best available science.

The Grand Canyon is one of the most remarkable units of the national parks system. While we applaud the efforts of the Bureau of Reclamation to consider adaptive management releases from Glen Canyon that can restore riparian ecosystems, it appears to NPCA that this EA is incomplete, deficient and not in compliance with the Grand Canyon Protection Act.

Sincerely,

David Nimkin
Director
Southwest Region

77

From: <emiwegner@aol.com>
To: <dkubly@uc.usbr.gov>, <GCexpReleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 4:55 PM
Subject: Comments on Proposed High-Flow Event at Glen Canyon Dam

Dennis - attached are the Glen Canyon Institute comments on the proposed glen Canyon Dam high flow event in March.? Thank you for your consideration of these comments.? Dave Wegner, citizen

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CC: <kellett@restore.org>, <richi47@COMCAST.NET>, <amy@glencanyon.org>, <EMIWEGNER@aol.com>

Date: February 22, 2008

To: Dennis Kubly, Bureau of Reclamation

From: David Wegner, Glen Canyon Institute

Re: **Comments on Environmental Assessment of High Flow Experiment (HFE).**

1) **We Supports the High Flow Experiment.**

We are fairly certain that an HFE will result in deposition of many new sand bars at higher elevations throughout the river ecosystem. We advocate post-test flow regime that maximizes learning and resource benefits for as long as possible. Our objectives are to solve problems and improve conditions in the downstream river ecosystem, while minimizing impacts to hydropower, the trout fishery, and other ancillary benefits of the dam.

2) **We Do Not Support the Five-year, Sept.-Oct. steady flow experiment.**

The logic presented for the add on Five-year September and October steady flow experiment has not been laid out in a scientifically supportable manner. The overall intent of the steady flow is not in question; it is the lack of presentation of native fish scientific data to support the proposed action.

3) **Stable beach profile for recreation and cultural resources.**

From previous studies in the Grand Canyon and experimental flows that were conducted in 1991 we concluded that the steep down ramp following the high release will create an unstable beach profile, leading to calving-off of water-saturated, newly deposited sand bars. From data collected during the 1991 experimental flow studies we measured the impact of beach retreat created by a too rapid decrease in river flow. Go back; look at the data, video tapes from the Bureau of Reclamation, and the remote cameras to verify this comment. This was a principle scientific conclusion of the Glen Canyon Dam EIS in 1995. A more gradual down ramp may rework the new deposits to a more stable beach profile. This should provide terraces at levels accessible to recreational boaters while leaving large sand areas upslope for wind distribution into the higher pre-dam terraces where archaeological and cultural resources are located. A far better approach would be to step the flows down in a documented manner to build terraces and a more stable beach profile.

4) **Backwater habitats.**

There is no scientific logic presented to support the conclusions that a steep and rapid down ramp will create useable backwater habitats for native fish. Backwaters formed at 41k cfs in 1996 become perched and unusable by native fish. Learn from that scientific approach and ramp the flows down slowly. Look at the data and make a scientifically based decision that is best for the native fish, not one that is based on a scientific desire to leave sediment deposits up higher on the beach profile.

4) **Run the High Flow test as a discrete experiment and Tie to Long-Term Experimental Plan.**

It is unclear what the high flow test and steady flow tests are not part of the ongoing long-term experimental plan evaluation. Separating these critical elements appears to violate the intent of the ongoing NEPA process. This plan should only be for the high flow test, not the other elements.

5) **Impacts to Kanab Ambersnails and Leopard Frogs.**

Other species will be impacted by the high flow test. Specifically the direct impact to the species themselves and their habitat, and the indirect impact associated with changing flow dynamics. Specific studies should be developed and implemented to identify impacts to habitats for these species. The specifics of proposed mitigation efforts are not well defined in the Environmental Assessment.

6) **Impacts to water quality as related to lower reservoir level – distribution of mussels?**

Reservoir Powell is a much lower level than when the 1996 event was run. As a consequence it is likely that different water quality impacts will occur downstream, especially in the nutrient and thermal dynamics. This test flow offers an opportunity to couple specific water quality studies to evaluate future water conditions in the Grand Canyon.

On a similar manner, it is possible that some quagga mussels may be incorporated in the release flows and distributed to the Colorado River downstream. With the current downstream concerns regarding mussels and other exotics impacting water systems, it would seem prudent to implement a review and testing procedure to ensure that no additional distribution of the mussels occurs because of the test flow event.

Summary

The Glen Canyon Institute supports the scientific and ecosystem restoration intent of the High Flow Experiment. As long as the dam is in place it will continue to negatively impact the native species and sediment distribution patterns in the Grand Canyon. The Grand Canyon Protection Act and resulting EIS on the operations of Glen Canyon Dam recognized the impacts that the dam has and instituted protocols in an attempt to mitigate some of the negative impacts. This test flow carries on the intent of the EIS and GCPA. We advocate the process as long as a scientifically credible and supportable approach is utilized.

The EA is long on the logic for the event but short on scientific support. We know you can do better. We recommend that the post event hydrograph be designed to optimize ecosystem goals and protect the resources of the Grand Canyon.

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GCexpReleases GCexpReleases - HFE comments

From: Keith Beck <kbeck999@earthlink.net>
To: <GCexpReleases@uc.usbr.gov>
Date: 2/22/2008 5:35:42 PM
Subject: HFE comments

I am writing to state that I am strongly supportive of the HFE. I would also favor a more gradual downramp rate to maximize the effectiveness and longevity of resource benefits for this experiment. In other words, subsequent flows are every bit as critical as the High Flow Experiment itself.

thank you,

Keith Beck, MD, FACP
Professor of Medicine
David Geffen School of Medicine @ UCLA
Physician Specialist; Divisions of HIV Medicine
& Infectious Diseases
Harbor-UCLA Medical Center
Torrance, CA 90266
310.222.2467; 3#

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February 10, 2008

Dirk Kempthorne, Secretary
United States Department of the Interior
1849 'C' Street NW.
Washington, DC 20240

RE: Proposed High-Volume water release, Glenn Canyon Dam, ~~Arizona~~

Dear Secretary Kempthorne:

You are obviously aware that the Bureau of Reclamation, a sub-agency of Interior, is considering a 41,000 CFS test release of water into the Colorado River below Glen Canyon Dam. Said test release is tentatively scheduled to begin in just a few weeks, in early March, 2008.

A press release dated February 8, 2008 was issued by the B.O.R. Upper Colorado Region Office to inform the public that comments regarding the Environmental Assessment for the proposed test would be accepted until February 22nd,, a total of just fourteen days. Moreover,, no instructions were provided that informed the public where such comments should be directed. It would therefore seem to even a casual observer that public comments regarding the proposed test flow were not welcome and an effort was being made to insure such comments were minimal in number.

In view thereof, the question of motivation for rushing ahead without adequate public input arises. That question becomes even more acute when a cursory observation of a cost/benefit analysis of the proposed test release is undertaken. As evidenced by the Environmental Assessment itself,, an aggregate loss of in excess of $8,000,000 in electrical power generation sales is anticipated, other ancillary costs not withstanding. Moreover,, the necessary shift from lost hydro-electric generated power to coal/gas fired generation is expected to release an added 45,000 plus tons of carbonized pollution into the atmosphere. In addition to these economic factors, there is ample documented evidence that the proposed test flood will have a negative impact on the endangered humpback chub, a native fish species, as well as the Amber Snail.

In consideration of these negatives, among others omitted for brevity, is the hope that sand may be carried in suspension to downstream locals and deposited for the purpose of expanding riverside beaches and campsites, despite the well documented evidence that two prior similar experimental flows were not successful in accomplishing the stated goal.

Why Interior is even considering this obscene squandering of taxpayer funds in the face of ample reason to abandon a questionable experiment is unknown. Why it would rush to do so without an adequate opportunity for public oversight is an even greater unknown and raises the question of agency malfeasance.

If the proposed test releases go forward and are actually conducted, I will insist that a Congressional Investigation into the entire matter is conducted to explain to the public why this example of bureaucratic arrogance should be condoned and accepted.

I will anticipate and expect a written response to this letter over your signature.

Respectfully submitted,

Peter Klocki
11052 Turquoise Circle
Dewey, AZ 86327

CC: Randall Peterson
B.O.R. Upper CO Region
125 S. State Street, Room-6103
Salt Lake City, UT 84138

PSK:kve

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From: "Ron & PJ Slovikoski" <ronnpj@ronnpj.com>
To: <GCexpReleases@uc.usbr.gov>
Date: Sat, Feb 23, 2008 3:17 PM
Subject: Lake Powell Experimental Release

Dennis Kubly,

As a 30 year recreational user of Lake Powell I am continually saddened by the repeated "experimenting" with high flow releases into the Grand Canyon. In my career as a "rocket scientist" the government would never support such shoddy technical rationale for continued failed proposals.

I recognize there are more than rational forces at work here, but if the overwhelming majority of responses to this proposal are negative, I do hope you would vote for the No Action Alternative.

Sincerely,

Dr. Ron Slovikoski

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From: "John Shields" <jshiel@seo.wyo.gov>
To: <gcexpreleases@uc.usbr.gov>
Date: Fri, Feb 22, 2008 10:09 PM
Subject: Comments on Draft Environmental Assessment

Please find attached the Wyoming State Engineer's Office's comments on the draft environmental assessment on the Environmental Assessment Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012

With best regards,

John W. Shields
Interstate Streams Engineer
Wyoming State Engineer's Office
Herschler Building 4th East, Cheyenne, Wyoming 82002-0370
307-777-6151 (office) 307-631-0898 (cell) 307-777-5451 (fax)
jshiel@seo.wyo.gov

CC: <dkubly@uc.usbr.gov>

State Engineer's Office

HERSCHLER BUILDING, 4-E CHEYENNE, WYOMING 82002
(307) 777-7354 FAX (307) 777-5451
seoleg@seo.wyo.gov

DAVE FREUDENTHAL
GOVERNOR

PATRICK T. TYRRELL
STATE ENGINEER

February 22, 2008

Mr. Larry Walkoviak
Regional Director
Upper Colorado River Region
Bureau of Reclamation

VIA EMAIL SENT TO: gcexpreleases@uc.usbr.gov

RE: Comments on Environmental Assessment: *Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012* (February 8, 2008) ("EA")

Dear Mr. Walkoviak:

We offer the following general comment concerning the draft Environmental Assessment released February 8, 2008 in re: *Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012.* The EA notes the proposed action:

> "… consists of two types of experimental flows to be implemented beginning in 2008 and concluding in 2012: 1) an experimental high flow test of approximately 41,500 cfs for a maximum duration of 60 hours beginning March 4, 2008, and 2) steady flows in September and October of each year, 2008 through 2012. The overall concept of the experiment is to determine the effectiveness of sandbar building and backwater formation using a high flow test during highly enriched sediment conditions, and the subsequent impact on humpback chub in those backwaters during fluctuating flows in the spring and summer and steady flows in the fall."

It is our understanding that the proposed experimental high flow test, the subject of this draft EA, to determine the effectiveness of sandbar building and backwater formation during what is identified as a current highly enriched sediment condition, will be considered in combination with the prior iterations of these high flow experiments, to establish the "boundaries " for likely future conditions. Accordingly, we understand this experimental flow test will be the last instance that would be characterized as an experiment, and future high flow actions that exceed the generation capacity of Glen Canyon Dam will be management actions that can only be undertaken to avoid a spill.

The EA correctly observes on page 1:

> "The primary purpose and major function of the dam is water conservation and storage. The dam is specifically managed to regulate releases of water from the

> Upper Colorado River Basin to the Lower Basin to satisfy provisions of the Colorado River Compact and subsequent water delivery commitments, and thereby allow states within the Upper Basin (Wyoming, Utah, Colorado, New Mexico, Arizona) to deplete water from the watershed upstream of Glen Canyon Dam and utilize their apportionments of Colorado River water. In addition to the primary purpose of water delivery, another function of the dam is to generate hydroelectric power as an incident to other purposes of Glen Canyon Dam."

In addition, the EA notes that the Grand Canyon Protection Act of 1992 specifically mandated that the provisions of the Act shall be implemented by the Secretary in a manner "fully consistent with and subject to the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona v. California, and the provisions of the Colorado River Storage Project Act of 1956 and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin. (GCPA § 1802(b))."

As you know, the Upper Colorado River Commission has previously expressed its understanding that this proposed upcoming experiment must be the last instance of this sort of experiment and that future management actions akin to this "experiment" that can only be undertaken to avoid a spill absent changes to as an experiment. In its letter of December 6, 2007 to Deputy Assistant Secretary of the Interior Brenda Burman, the Commission noted its view that bypassing the power plant for any additional future high flow actions that exceed the generation capacity of Glen Canyon Dam will require the law to be changed to allow such high flow actions to be regularly used or routinely occur as "management actions." Further the Commission has expressed its belief that a mechanism is needed to supplement the Upper Colorado River Basin Fund to mitigate the adverse financial impacts associated bypassing the Glen Canyon Dam Power Plant. The Wyoming State Engineer's Office and the State Engineer, in his capacity as the Wyoming Commissioner to the Upper Colorado River Commission, appreciate this opportunity to reiterate the Commission's written views as a part of our comments on the draft EA.

We believe that the proposed federal action analyzed in the subject EA – and as it will be described in the Finding of No Significant Impact (FONSI), must be implemented in its entirety, or else National Environmental Policy Act (NEPA) compliance would need to be reinitiated. Some have suggested that the Bureau should proceed with the high flow experimental test and NOT proceed with the steady flows regime during October and November of 2008 through 2012. We do not agree that this would be appropriate – and doing so would be inconsistent with the proposed federal action.

As others have stated, we in Wyoming recognize the difficult and perplexing challenges the Department of the Interior and the Bureau of Reclamation as the implementing bureau within Interior face in balancing competing resource needs, differing perspectives associated with what those resource needs are and how to best meet them to the extent practicable, and with the requirements of the Law of the River. In conclusion, we urge Reclamation to complete and implement each aspect of the proposed action described in the EA, without delay.

With best regards,

John W. Shields

John W. Shields
Interstate Streams Engineer
Wyoming Member, Glen Canyon Adaptive
Management Work Group

JWS/js

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From: "CREDA" <creda@qwest.net>
To: <gcexpreleases@uc.usbr.gov>, <LWalkoviak@uc.usbr.gov>
Date: Sat, Feb 23, 2008 3:17 PM
Subject: Comments

Please see attached letter.
Leslie James
CREDA

CC: <Brenda_Burman@ios.doi.gov>

CREDA
Colorado River Energy Distributors Association

ARIZONA
Arizona Municipal Power Users Association

Arizona Power Authority

Arizona Power Pooling Association

Irrigation and Electrical Districts Association

Navajo Tribal Utility Authority (also New Mexico, Utah)

Salt River Project

COLORADO
Colorado Springs Utilities

Intermountain Rural Electric Association

Platte River Power Authority

Tri-State Generation & Transmission Association, Inc. (also Nebraska, Wyoming, New Mexico)

Yampa Valley Electric Association, Inc.

NEVADA
Colorado River Commission of Nevada

Silver State Power Association

NEW MEXICO
Farmington Electric Utility System

Los Alamos County

City of Truth or Consequences

UTAH
City of Provo

City of St. George

South Utah Valley Electric Service District

Utah Associated Municipal Power Systems

Utah Municipal Power Agency

WYOMING
Wyoming Municipal Power Agency

Leslie James
Executive Director
CREDA
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Website: www.creda.org

February 22, 2008

Mr. Larry Walkoviak
Regional Director
Upper Colorado River Region
Bureau of Reclamation

VIA EMAIL: GCExpreleases@uc.usbr.gov

RE: Biological Assessment on the Operation of Glen Canyon Dam and Proposed Experimental Flows for the Colorado River Below Glen Canyon Dam During the Years 2008-2012 ("BA"), December 2007

RE: Long-Term Experimental Plan for the Operation of Glen Canyon Dam and Other Associated Management Activities (73 FR 29, p. 8062)

RE: Environmental Assessment Experimental Releases from Glen Canyon Dam, Arizona, 2008 through 2012 (February 8, 2008) ("EA")

Dear Mr. Walkoviak:

The Colorado River Energy Distributors (CREDA) is a non-profit organization of firm power customers of the Colorado River Storage Project (CRSP). CREDA members are all non-profit entities, including political subdivisions, irrigation and electrical districts, state agencies, tribal utilities and rural electric cooperatives. CREDA members serve over four million electric consumers in six western states. Power generation from the Glen Canyon Dam represents the largest generating resource of the CRSP; CREDA members have a direct interest in the above referenced proposals and associated processes.

CREDA offers the following initial comments on the BA and EA. In addition, we have restated under separate cover our January 11, 2008 comments and questions to the Grand Canyon Monitoring and Research Center on their draft high flow experiment science plan. Given the timeframe provided for comment on the EA, the majority of the specific references below are to the BA, but are applicable as well to the EA.

GENERAL COMMENTS (Unless otherwise noted page numbers are references in the BA).

1) P. 18: Reference to AMWG constituencies should be consistent with the ROD, i.e., "contractors for the purchase of Federal power produced at Glen Canyon Dam" as opposed to "hydroelectric power marketers." To some, the term "marketers" implies profiteers or profit-making entities. By law, such contractors are not-for-profit entities.

2) P. 46: Please elaborate on the reference to "several" Beach Habitat Building Science Plans. It is CREDA's understanding that a *single* plan is still under development. Additionally, P. 7 of the EA states that *(t)he Department does not propose through this Proposed Action to undertake any further experimental high-flow testing until the information from this element of the Proposed Action is fully*

analyzed, presented to the Adaptive Management Work Group and the general public and can be integrated into an appropriate analytical framework based on predictive models and other analytical tools. CREDA understands Interior's desire to perform the high flow experiment in 2008 in order to "book-end" the results from the previous beach habitat building flow experiments. Following synthesis of the results of the proposed high flow experiment, together with the results from the 1996 and 2004 experiments, Interior should have the learning necessary to make decisions regarding the future use of high flows. Because this experiment, when combined with prior experiments, will "bound" the likely future conditions, this is the last time that an action of this nature can be characterized as an experiment, and future high flow actions that exceed the generation capacity of Glen Canyon Dam will be management actions that can only be undertaken to avoid a spill.

3) EA, P. 4: Please clarify that Reclamation "collaborated" with the Adaptive Management Program regarding experimental releases, but that Adaptive Management "collaborators" themselves did not conduct experimental releases.

4) EA, P. 34: The estimated cost for the high flow experiment for water year 2008 is about $8 million. The steady flow five-year experiment is approximately $815,000 annually. The use of power revenues for funding the Glen Canyon Dam Adaptive Management Program, as well as the requirements of the Biological Opinion on the Operation of Glen Canyon Dam and activities required by the Programmatic Agreement on Cultural and Historic Properties is capped at an annual level (currently approximately $9.4 million), subject to escalation. In other words, costs associated with the BA and EA as well as purchased power required as a result thereof are nonreimbursable, and will have to be funded by appropriations or other sources given the cap on power revenue funding.

5) CREDA recognizes the challenges Interior faces in balancing the resource impacts with the costs associated with the Proposed Action. For example, limiting the steady flow timeframe to September and October takes into consideration the current abundance of the humpback chub, as well as the impacts to the hydropower purpose and resource. Any extension of that timeframe would have significant implications to the hydropower resource.

BIOLOGICAL RESOURCE COMMENTS (Unless otherwise notes, page numbers are references in the BA)

1) P. 48: Did the September-October 2005 experiment monitor the effects of daily fluctuations on humpback chub as well as "water quality parameters and biotic constituents?" If so, how are those findings incorporated into the flow recommendations in this BA?

2) P. 82: Non-native cold water fish, like trout, prefer higher velocity habitats than their warm water counterparts so saying that non-native fish will experience negative impacts of high flow tests due to their preference for low water velocities is not complete. Also, earlier studies showed numbers of warm water non-natives to rebound soon after high flows. Displacement does not equate to death so assuming negative impacts merely because the fish is displaced is not correct. Typically, fish are displaced from a high velocity habitat to a low velocity habitat, which is the same habitat type sought and occupied by native fish. Commingling native and non-native fish in low velocity habitats resulting from high flow tests should be viewed as a negative impact to native fish.

3) P. 82: There must be an assessment of the response of non-native fish to steady flows since they most likely would have a similar, positive response to the steady flow portion of the experiment. Also, since many of the current non-native warm water fish have a short life cycle, they may be able to respond quicker and in larger numbers than the longer-lived humpback chub. What is the current state of work related to non-native control and what triggers will be established to reverse the steady flow portion of the experiment if the non-native population proliferates?

4) P. 87: Growth rates are governed by many factors, including, but not limited to, temperature.

These may include fish species, food supply, conversion rates, age, bioenergetic costs, etc. Flows that inundate backwaters and change the temperature may affect growth rate but higher flows also may bring additional food supply offsetting temperature effects. The argument is not complete when limited solely to temperature; in other words, there appears to be an inherent bias against fluctuating flows if the beneficial aspects to the food supply are not appropriately monitored and factored into the consideration.

5) PP. 88-89: The dynamics of the Colorado River immediately below Glen Canyon Dam have historically resulted in more productivity than in the pre-dam era as a result of the creation of clear water conditions. The Lees Ferry reach is believed to be far more productive today than pre-dam due to clear water. River reaches downstream have progressively less productivity due to more turbid conditions. This means the Lees Ferry reach provides a very high percent of the biomass food for river reaches downstream. Higher fluctuating flows result in more transport of this biomass and likewise, a high flow experiment will result in a large amount of biomass transported downstream. Conversely, during steady flows as proposed for September-October, this should result in less downstream transport of this biomass. Humpback chub not residing in the 5% of shoreline habitat called backwaters may have reduced invertebrate supply but for those chub in the remaining 95% of shoreline habitat, more food is available with fluctuating flows than under steady flows. Arguing that more backwaters should be created to thereby produce more invertebrate food works *if* the remaining 95% of shoreline habitat and the increased drift that occurs when flows are not steady is ignored. In other words, why should there be a benefit provided to 5% of the habitat at the detriment of the remaining 95%?

6) P. 90: A large assumption footnoted in Table 10 is development and implementation of a successful non-native fish control program. This is an optimistic assumption, especially as it relates to control of warm water non-native fish. Second, steady flows, or at least lower fluctuating flows, could result in proliferation of non-native fish thereby exacerbating the already difficult control effort. Steady flows, or at least lower fluctuating flows, are believed responsible for an explosion of rainbow trout and this explosion may be in part responsible for the decline in humpback chub recruitment witnessed in the early 1990's. Suggesting that steady flows may be beneficial to humpback chub may not ignore the past trend or the best available science but it does add a significant risk factor.

7) EA Section 3.1.7 (P. 24): "*The razorback suckers in Grand Canyon are old and no reproduction has been documented. Razorback suckers evolved under a water regime featuring high spring flows, and adult suckers would be able to locate refuge areas during the proposed flow and would suffer no adverse effects. There is no indication that young razorback suckers occur in Grand Canyon today.*" This statement appears to imply that there are razorback suckers known to exist; but it is our understanding the last recorded razorback, young OR old, was well over 12 years ago and none have been seen since, despite repeated monitoring by GCMRC.

SEDIMENT RESOURCE COMMENTS

According to the BA (P. 5), the high-flow experiment is intended to create and improve eddy complexes, including backwater habitats and beaches, and three specific hypotheses are to be tested in this regard:

1. Widespread beach building will result from controlled releases from the dam under sediment-enriched conditions in Grand Canyon.

2. High releases from the dam will increase sandbar crest height, while increasing return channel depth through scouring.

3. If the above geomorphic changes occur as a result of the high-flow test, greater and more persistent backwaters could be created, which may benefit conservation of the humpback chub and other native fish species.

Two additional hypotheses are to be tested with the fall steady flows:

1. Backwater and other near shore habitat used by young native and endangered fish will become more hydraulically stable, with potentially warmer water temperatures than would exist under regular MLFF

operations.

2. These changes could create conditions for improved young-of-year humpback chub survival and growth rates, more persistent suitable habitat (depth and velocity over preferred substrates), and increased productivity of algal invertebrate prey items for use by humpback chub.

CREDA has not seen a Science Plan for the 5-year fall steady flow portion of the EA, but we have reviewed the Science Plan for the high flow experiment portion of the EA, as well as the cited literature, and find:

1. While the upper part of Marble Canyon appears to be sediment enriched, sufficient information has not been provided to assess whether the lower part of Marble Canyon and Grand Canyon are also sediment enriched. In fact, the available information indicates that these lower reaches may not be sediment enriched, in which case the proposed high flow experiment may actually be detrimental to the objective of widespread beach building.
2. Section 4.1.2 of the BA supports the hypothesis that high flows will improve backwater habitat. However, the literature cited concluded that *(d)espite the...qualitative evidence linking floods and backwater area, there is little evidence that floods increase the number of backwaters and the absence of floods leads to decreased numbers of backwaters.* Further, they conclude that *(t)here is no evidence of a progressive trend in backwater availability, based on the time series of backwater area and number between 1935 and 2000.* If backwaters are a key habitat component for the humpback chub, the high flow experiment may not be effective in improving or protecting this aspect of its habitat needs.
3. Section 4.1.3 of the BA presents results from a 2-D hydrodynamic model to support the hypothesis that the proposed high flow experiment and subsequent September and October steady flows will create more persistent suitable habitat conditions. However, there is little or no discussion of *how* they support the hypothesis.

CREDA recommends the following:

1) A reasonable alternative hypothesis be included which states: "The transport capacity of the mainstem Colorado River in the lower half of Marble Canyon and Grand Canyon exceeds the amount that can be delivered under sediment-enriched conditions resulting from large sand inputs from the Paria and Little Colorado Rivers. As a result, sufficient sand storage cannot be developed to enlarge and maintain eddy sandbars or substantially improve backwater habitat throughout these reaches."
2) The previous tests in 1996 and 2004 indicate high flows can be effective in building beaches and sand bars in areas that are sediment enriched, but high flows cause net erosion of sand bars in the absence of sediment enriched conditions. If beach building and maintenance throughout the Canyon, rather than only the upper part of Marble Canyon, is an objective, the 2008 plan should be modified to include more detailed data collection and analysis at specific locations in the lower half of Marble Canyon and Grand Canyon to assess their response. It should also consider the potential adverse consequences of additional erosion of sandbars in the downstream portion of Marble and Grand Canyons.
3) The available information does not clearly demonstrate how habitat maintenance flows (HMFs) within powerplant capacity are inadequate to enhance and maintain eddy sandbars and humpback chub habitat. Data from the 2000 flows that included both low, steady flows and at least one HMF release should be assessed in more detail to determine whether HMFs can be used to meet the management objectives of the Glen Canyon Dam Adaptive Management Program.

CREDA has submitted previous comments related to the "aeolian transport" portion of the high flow experiment and will not restate those comments here. However, the Science Advisors January 13, 2008 Review of the Science Plan is consistent with CREDA's previous comments in that: "*The part of the study relating to the cultural sites does not appear to be a legitimate scientific matter, at least as stated in Section*

1.C. It is, rather, an ethical archaeological issue (Fowler, Jolie and Salter 2008; Green 2008)."

SOCIO-ECONOMIC RESOURCE COMMENTS

EA, Section 3.3.1.2: The EA indicates that the "*baseline against which effects of the proposal may be compared*" is the 2007 Shortage EIS, which establishes a present value of $7.634 billion for energy generation from 2008-2026 (which is a 19-year period). The EA then estimates the cost of the high flow experiment as $4.1 million (in 1 year). Rather than comparing the $4.1 million to the $7.634 billion, CREDA believes it is more appropriate to compare the $4.1 million to what Western Area Power Administration estimates in their power repayment study to represent their purchase power obligation for 2008 WITHOUT the high flow experiment, which is $43.5 million. In other words, the high flow experiment is slightly over a 9% increase in what is anticipated for operations without the experiment. This comparison would also impact the Environmental Justice analysis contained in the EA. In addition, CREDA believes the increase in additional carbon emissions of about 45,800 tons (P. 34) should be a significant consideration in analyzing the impacts of the high flow experiment and in balancing resource benefits with economic impacts, since over 50 Indian tribes are the recipients of the benefits of CRSP hydropower. Many of these CRSP contractors are included among the low-income households analyzed in Section 3.3.6 of the EA and as shown on Figure 2 (P. 33).

CREDA appreciates the opportunity of providing comments on the BA, EA and related documents and processes and looks forward to receiving responses to these questions and comments. We appreciate the challenges Interior faces in balancing the competing resource needs with the requirements of the Law of the River. We urge timely completion and implementation of this process.

Sincerely,

/s/ Leslie James

Leslie James
Executive Director

Cc: CREDA Board
Brenda Burman

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Government-to-Government Consultation Re: BHBF EA, GCDAMP Treatment Plan for FY08 and Glen Canyon NAGPRA Affiliation Study.

Pipe Springs, AZ February 21, 2008

Participants:

Mike Berry	Reclamation	801-524-3816
Charley Bulletts	Southern Paiute Consortium	928-645-8313
LeAnn Skrzynski	Kaibab Paiute Environmental Director	928-643-8311
Selena Benson	Kaibab Paiute Tribal Member	928-643-7245
Gale Stanfield	Kaibab Paiute Tribal Council Member	928-643-7245
Valencia Castro	Kaibab Paiute Tribal Council Treasurer	928-643-7245
Teyawanna Pickayviett	Kaibab Paiute Tribal Council Member	928-643-7245
Laura Rae Savala	Kaibab Paiute Tribal Council Member	928-643-7245
LeAnn Shearer	Kaibab Paiute Tribal Council Member	928-643-7245

Approximately a dozen tribal audience members were present for parts of the presentation.

EA Issues

I submitted a copy of the EA to the Council's secretary and summarized the action.

What will be the impact on the Hopi salt mine? Kaibab and Moapa Paiute gathered salt samples during the Tribal Consultation river trip and consider the salt source a sacred site. 1

What will be the effect on critical resources in the Palisades area?

Council and audience members expressed concern that Reclamation did not consult earlier in the process. They expressed the belief that, at this point, the high flow is a done deal regardless of tribal concerns. Charley Bullets will be leading a monitoring river trip on March 6 but probably will not be involved in the March 5 ceremony. One audience member asked why any tribal member would participate in the ceremony since the high flow could damage sacred sites. 2

Valencia Castro wanted to know what kind of monitoring was planned. I explained that monitoring would be accomplished by GCMRC and I had no details on what would be monitored. I noted that the GCMRC science plan made no reference to cultural monitoring and suggested that significant tribal resources will best be monitored by the tribes using the GCDAMP participation funding.

V. Castro asked how long Reclamation had known about the high flow and, again, why Reclamation was only now requesting consultation. Audience members expressed the same concerns. I apologized for the delay and said I would do my utmost to see that it didn't happen in the future. I requested that V. Castro submit a written summary of the Council's concerns and she agreed.

Treatment Plan Issues

I submitted a copy of the FY08 work plan to the Council's secretary and summarized the data recovery plan.

The Council agreed with the concept that data recovery was appropriate in cases where sites would be destroyed by erosion.

However, some audience members wanted to know why we had to excavate and especially why White people were "grave robbers." I explained that we didn't believe there would be any burials encountered at the FY08 sites but that we likely would discover human remains in the future. I explained that the treatment and disposition of human remains would be done in compliance with NAGPRA and that NPS, as land managing agency, would have compliance responsibility. This information was not well-received.

The Council raised the issue of tribal monitoring of excavations. I indicated that the RFP specifically noted that tribes had indicated an interest in data recovery monitoring and that the cultural consultants should expect to have Native Americans visit the sites during excavation. I further noted that Native American perspectives were to be incorporated in the site report interpretive sections where appropriate. However, I also noted that no funds had been specifically allocated for this task. I suggested two funding sources. The first was the commitment made by NPS at a multi-tribe consultation meeting at the Grand Canyon south rim facility. V. Castro attended that meeting and recalled the NPS commitment. The second was the $27+K line item in the GCDAMP budget for implementation of the tribal monitoring protocols that were developed under contract last year. I recommended that Kaibab Paiute build data recovery monitoring into the scope of work. Charley Bullets is working on the SOW and will get it to me soon. The Council had been unaware of this funding source.

V. Castro asked for the Glen Canyon site number and why we had to excavate prior to the high flow. I gave her a brief history of high flow damage to the site and also noted that it was being excavated now. She asked if there would be any tribal monitoring at the site. I told her that Hualapai and Hopi had expressed an interest but I did not know if they were actually going to visit the site. It would be possible because NPS is shuttling the crews to the site on a daily basis and could accommodate visitors.

Glen Canyon NAGPRA Issues

I submitted a copy of the four available lines-of-evidence studies to the Council's secretary. I also distributed a summary of the studies' tentative conclusions and a dendrogram of Southwestern modern and archaeological mtDNA.

I asked the Council to verify the status of their claim to the human remains and associated funerary objects from the 1950s, 1960s Glen Canyon excavations. I noted that they had expressed an interest several years ago and asked V. Castro to discuss this issue with the tribal chair and tribal elders and send us written confirmation of the claim. She agreed.

I explained the difference between pre- and post-1990 NAGPRA and then summarized the current lines-of-evidence recommendations, noting that the archaeological line of evidence was not yet available. I indicated that a Kaibab Paiute affiliation had not yet been rejected but was classified as inclusive due to lack of evidence,

Council member Pickayviett asked why Kaibab Paiute was not represented in the dendrogram. I indicated that we had no modern Kaibab Paiute samples to include in the analysis and described that such data were typically recovered through cheek swabs. I explained that I did not know if Kaibab Paiute had been approached for samples and also that we had no data for Uintah Ouray, Ute Mountain or Southern Ute populations. I suggested Reclamation could assist in the analysis if Kaibab Paiute was interested.

An audience member asked why we couldn't just put the human remains back where we found them. I explained that most of them were recovered from what is now Lake Powell. He said that if we could put a man on the moon, we could figure out a way to put the bodies under water. Another audience member asked why if White people dug the bodies up, why should we make it the responsibility of Indians to rebury them. Another member of the audience said that he didn't understand why White people were "grave robbers." He offered that he was going to be cremated so that my grand children couldn't dig him up. There was some humor in all this, but clearly an underlying feeling of mistrust.

Summary

I concluded with a brief question-and-answer session and promised to keep the tribe informed on the progress of all studies, actions and undertakings. Council member Shearer asked why she should believe me given the late notification on the EA. I apologized for the agency again and indicated I would do everything within my power to keep them informed. The Council and several audience members acknowledged that they understood I was merely the messenger of bad news and probably not the perpetrator.

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From: "Brandon Jolley" <bjolley@cox.net>
To: <GCexpReleases@uc.usbr.gov>
Date: Mon, Feb 25, 2008 7:53 PM
Subject: Lees Ferry Flood

To Whom it may concern:

I am curious how we can make the same mistake again. The Ferry is finally rebounding from the last experimental flood and we are deciding to do it once again? I sometimes wonder if the powers that be, give these ideas any thought whatsoever! I have friends that are finally starting to go there again after a several year hiatus, the guides and lodges are starting to make a little money again, this will be the death knoll for most of the businesses in the area. Is this the master plan? Are we trying to destroy the fishing and the fishing industry once again? I know many of the past and present guides on the river and in talking with most of them, a big downturn in the fishing will end their livelihood on the Colorado River.

Brandon Jolley

Late 85

From: Doug Hendrix
To: Coulam, Nancy; Kelleher, Jayne
Date: 2/27/2008 2:02:33 PM
Subject: Fwd: Fw: March, 2008 High Flows below Glen Canyon

fyi...

>>> <nbryant@usgs.gov> 02/27/08 12:22 PM >>>
Gentlemen

Could you respond please.

Nora Bryant
Secretary
SBSC-GCMRC
2255 N. Gemini Dr.
Flagstaff, AZ 86001
(928) 556-7217
(928) 556-7092 (FAX)
nbryant@usgs.gov

----- Forwarded by Nora Bryant/BRD/USGS/DOI on 02/27/2008 12:20 PM -----

"Dick Hile" <dhile@enterprise-lakepowell.com>
02/27/2008 12:12 PM

To
<nbryant@usgs.gov>
cc

Subject
March, 2008 High Flows below Glen Canyon

Not having found am address for public comment, I would appreciate it if
you
could forward my comments to the appropriate authority.

I do not feel that the high flows scheduled are in anyone's lasting
benefit.
You may push some sand around but you are not replacing it. I believe
BuRec
should seriously undertake efforts to re-introduce up-lake sand to the
Colorado below Glen Canyon and initiate a program to direct surface water
through the penstocks to raise the temperature of the water.

The high flow should be abandoned. It's a waste of water, power, time and
money.

Regards,

Dick Hile
Page, AZ

Upper Colorado Region
Salt Lake City, Utah

Media Contact: Doug Hendrix (801) 524-3837 Dennis Kubly (801) 524-3715

Released On: February 29, 2008

Reclamation Releases Final EA and FONSI Authorizing High-Flow and Steady Flow Experiments on the Colorado River

Salt Lake City - The Bureau of Reclamation today released a final environmental assessment (FEA) and a Finding of No Significant Impact (FONSI) that authorizes the initiation of an early-March 2008 high-flow test and fall steady flow experiment from Glen Canyon Dam downstream through the Grand Canyon. The FEA provides an evaluation of the environmental effects of the proposed action and no action, in compliance with the National Environmental Policy Act of 1969.

The FEA evaluates the impact of the proposed experimental flows on a wide range of environmental and socioeconomic resources. Following release of these documents, the high-flow experiment and associated research activities will be undertaken on March 4th cooperatively by scientists and resource managers from Interior's U.S. Geological Survey (USGS), Reclamation, National Park Service, U.S. Fish and Wildlife Service, and Bureau of Indian Affairs.

The 2008 high flow test will be similar to the previous high flow experiments conducted by the joint Interior agencies in 2004, but the amount of sediment available for the 2008 experiment is considerably larger. Based on the previous experiments, scientists have concluded that more sand is needed to rebuild sandbars throughout the 277-mile reach of Grand Canyon National Park than was available in 1996 or 2004. Currently, sand supplies in the river are at a 10-year high with a volume about three times greater than in 2004 due to tributary inflows below the dam over the past 16 months.

During the high-flow experiment, Reclamation will release water through Glen Canyon Dam's powerplant and bypass tubes to a maximum amount of approximately 41,500 cubic feet per second (cfs) for about 60 hours. Current operational plans call for the experimental flows to begin increasing in the evening on March 4th, with powerplant bypass flows to begin on March 5th.

From February 8-22, 2008, Reclamation solicited public comments on the environmental assessment. The final environmental assessment and FONSI conclude that implementation of the preferred alternative - the March 2008 high-flow test and fall steady flow experiment from Glen Canyon Dam - would have no significant impacts on the quality of the human environment or the natural resources below the dam.

The FEA and FONSI are available for review at:
www.usbr.gov/uc/envdocs/ea/gc/2008hfe/index.html

# # #

Reclamation is the largest wholesale water supplier and the second largest producer of hydroelectric power in the United States, with operations and facilities in the 17 Western States. Its facilities also provide substantial flood control, recreation, and fish and wildlife benefits. Visit our website at www.usbr.gov.