



— BUREAU OF —
RECLAMATION

Report to Congress on the Operations of Glen Canyon Dam Pursuant to the Grand Canyon Protection Act of 1992

Water Years 2018 (Observed) to 2019 (Projected)



EXECUTIVE SUMMARY

This report by the Department of the Interior (Interior) is submitted pursuant to the Grand Canyon Protection Act (GCPA) of 1992. Pub. L. No. 102-575, which provides:

Each year after the date of the adoption of criteria and operating plans pursuant to paragraph (1), the Secretary shall transmit to the Congress and to the Governors of the Colorado River Basin States a report, separate from and in addition to the report specified in section 602(b) of the Colorado River Basin Project Act of 1968 on the preceding year and the projected year operations undertaken pursuant to this Act.

GCPA § 1804(c)(2). This report provides an update from the last report, which was submitted on July 12, 2019 by Interior for years 2017 (observed) and 2018 (projected). The current report covers dam operations and other activities undertaken pursuant to the GCPA for 2018 (observed) and 2019 (projected). In this report, the timeframe for water and fiscal years is identical, October 1 through September 30.¹

INTRODUCTION

Glen Canyon Dam was authorized for construction by the Colorado River Storage Project Act of 1956. See 43 U.S.C. § 620. The dam was completed in 1963 and is operated by the Bureau of Reclamation (Reclamation). In 1992, Congress enacted the GCPA, which requires the Secretary of the Department of the Interior (Secretary) to 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.

See GCPA § 1802(a). Congress also directed that such operations be undertaken

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). In 1997, the Secretary established the Glen Canyon Dam Adaptive Management Program (AMP) to carry out the requirements of the GCPA. As part of the AMP,

¹ This report was initially prepared during the 2018 water year and finalized during the 2020 water year. Notwithstanding the timing of finalization of this report, the format follows the direction of GCPA Section 1804(c)(2) and describes the 2019 operations as “projected.”

the Secretary also established the Adaptive Management Work Group (AMWG), a 25-member federal advisory committee that operates pursuant to the provisions of the Federal Advisory Committee Act, 5 U.S.C. § App. 2. The Secretary's Designee is the Assistant Secretary for Water and Science who serves as the Chair of the AMWG.

STATUS REPORT

Five agencies within Interior have responsibilities under the GCPA and undertake operations pursuant to the GCPA; the: (1) Bureau of Indian Affairs (BIA); (2) Reclamation; (3) National Park Service (NPS); (4) United States Fish and Wildlife Service (FWS); and (5) United States Geological Survey (USGS). Collectively these five agencies fund five American Indian Tribes (Hopi, Hualapai, Pueblo of Zuni, Kaibab Paiute, and the Navajo Nation) to participate in the AMP and two Tribal Liaison positions within Interior that assist in coordination between Interior and the tribes. The Western Area Power Administration (WAPA) also has statutory responsibilities pursuant to the Department of Energy Organization Act, Flood Control Act, Reclamation Project Act, Colorado River Storage Project Act, and the GCPA. The role of each responsible Interior agency under the GCPA is briefly addressed below.

Bureau of Indian Affairs

The BIA's mission, among other objectives, includes enhancing quality of life, promoting economic opportunity, and protecting and improving trust assets of Indian Tribes and individual American Indians. This is accomplished within the framework of a government-to-government relationship in which the spirit of Indian self-determination is paramount. As part of the AMWG, the BIA works hand-in-hand with interested tribes and other participating agencies to ensure that this fragile, unique, and traditionally important landscape is preserved and protected.

Bureau of Reclamation

Reclamation operates Glen Canyon Dam in accordance with and subject to interstate compacts, an international treaty, federal laws, court decisions and decrees, contracts, and regulatory guidelines collectively known as the "Law of the River," additional criteria and operating plans specified in section 1804 of the GCPA, and approved experimental plans. Reclamation also provides support to the Secretary's Designee in administering the AMP, including coordinating logistics for the AMWG and the Technical Work Group (TWG).

National Park Service

The NPS manages units of the national park system and administers resource-related programs under the authority of various federal statutes, regulations, and executive orders, and in accordance with written policies set forth by the Secretary and the Director of the NPS, including the NPS Management Policies 2006 and the NPS Director's Orders. The NPS manages Grand Canyon National Park and Glen Canyon National Recreation Area under the NPS Organic Act, 16 U.S.C. §§ 1 and 2-4, as amended; other acts of Congress applicable generally to units of the national park system; and the legislation specifically establishing those park units. See 16 U.S.C. §§ 221-228j and 16 U.S.C. §§ 460dd through 460dd-9 (2006). The NPS Organic Act directs the

NPS to “promote and regulate the use of . . . national parks . . . in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.” The NPS helps the Secretary achieve the goals outlined in the GCPA through its resource management and resource monitoring activities.

United States Fish and Wildlife Service

The FWS provides Endangered Species Act (ESA) conservation and associated consultation and recovery leadership with various stakeholders primarily to benefit five listed species located in the Colorado River: the humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), southwestern willow flycatcher (*Empidonax trailii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), and Kanab ambersnail (*Oxyloma haydeni kanabensi*), as well as other relevant resource issues.

United States Geological Survey

The Grand Canyon Monitoring and Research Center (GCMRC) of the USGS was created to fulfill the mandate in the GCPA for the establishment and implementation of a long-term monitoring and research program for natural, cultural, and recreational resources of Grand Canyon National Park and Glen Canyon National Recreation Area. GCMRC provides independent, policy-neutral scientific information to the AMP on (1) the effects of the operation of Glen Canyon Dam and other related factors on resources of the Colorado River ecosystem using an ecosystem approach, and (2) the flow and non-flow measures to mitigate adverse effects. The GCMRC’s activities are focused on (1) monitoring the status and trends in natural, cultural, and recreational resources that are affected by dam operations, and (2) working with land and resource management agencies in an adaptive management framework to carry out and evaluate the effectiveness of alternative dam operations and other resource conservation actions described in this report.

I. 2018 Operations (Observed)

Bureau of Indian Affairs

In water year 2018, the BIA participated in consultation meetings with the tribes regarding the Tribal Consultation Plan, conducted pre-meetings with tribal representatives prior to the AMWG meetings, met with the Interior Tribal Liaisons in person and via monthly telephone calls to discuss tribal concerns, and participated in meetings regarding cultural and natural resources issues and concerns. Principal among tribal concerns for 2018 remains the importance of traditional cultural values. The tribes remain concerned with the mechanical removal of non-native fish in the Colorado River and were opposed to trout stocking at Lees Ferry by the Arizona Game and Fish Department (AGFD). The BIA continued to provide its portion of funding to tribes for their participation in the AMP. Other activities included continued coordination of efforts for tribal participation in the AMP, coordinating with other agencies on whether or not to conduct a fall high-flow experiment (HFE) and a spring Macroinvertebrate

Production Flow experiment, reviewing annual tribal monitoring reports, and continuing to work with the Interior Tribal Liaisons to maximize tribal consultation and involvement.

Bureau of Reclamation

Water Operations

The August 2017 24-Month Study projected the January 1, 2018, elevations of Lake Powell and Lake Mead to determine the water year 2018 operating tier for Lake Powell. Using the most probable inflow scenario, and with an 8.23 million acre-feet (MAF) annual release pattern for Lake Powell, the January 1, 2018, reservoir elevations of Lake Powell and Lake Mead were projected to be 3,627.34 feet and 1,083.46 feet, respectively. Given these projections, the annual release volume from Lake Powell during water year 2018 was consistent with the Upper Elevation Balancing Tier (section 6.B of the 2007 Interim Guidelines) and under section 6.B.1, the annual release would be 8.23 MAF.

The Upper Elevation Balancing Tier provides for the possibility of adjustments to the operation of Lake Powell based on the projected end of water year condition of Lake Powell and Lake Mead from the April 2018 24-Month Study. The April 2018 24-Month Study was run with an 8.23 MAF annual release volume to project the September 30, 2018, elevations of Lake Powell and Lake Mead. Under the most probable inflow scenario, and with an 8.23 MAF annual release volume, the projected end of water year elevation at Lake Powell was 3,646.82 feet and Lake Mead was 1,070.07 feet. Since the projected end of water year elevation at Lake Powell was below the 2018 Equalization elevation of 3,652 feet and above 3,655 feet, and the projected Lake Mead elevation was below 1,075 feet, section 6.B.4 of the 2007 Interim Guidelines governed for the remainder of water year 2018. Under section 6.B.4, the Secretary shall balance the contents of Lake Mead and Lake Powell but shall release not more than 9.00 MAF and not less than 8.23 MAF from Lake Powell. The annual release volume during water year 2018 was 9.00 MAF.

Under the Long-Term Experimental and Management Plan (LTEMP), the first macroinvertebrate production flows (also commonly referred to as “bug flows”) experiment was designed and conducted during May-August 2018. Information on the background and benefits of the bug flow experiments can be found in the U.S. Geological Survey section of the document. Bug flows are intended to increase the diversity and abundance of aquatic insects by improving egg laying conditions for these aquatic insects. Hydropower peaking releases were held steady during Saturday and Sunday in an attempt to increase production of aquatic insects. The second bug flow experiment is scheduled to be completed in water year 2019.

The first High-Flow Experimental release under the LTEMP was successfully conducted during November 2018 (water year 2019). Reclamation released the maximum available capacity, 38,100 cubic feet per second, during the experiment, which began on November 5 and ended on November 8, 2018. Preliminary findings suggest that this HFE and the previous four HFE releases (under the High-Flow Experimental Protocol) have been very successful in transporting sediment accumulated near the confluence of the Colorado and Paria rivers to beaches and sandbars where sediment replenishment was needed. Though erosion occurs at most monitored sandbars as a result of normal dam operations in the months following an HFE, the most recent

topographic surveys of long-term monitoring sites indicate sandbars increased in size following these HFEs. Reports from the Grand Canyon white water rafting community have been positive on the improvement of beaches in Grand Canyon over this period as well.

The total annual release from Glen Canyon Dam in water year 2018 did not change as a result of the HFE. The monthly release volumes for water year 2018 are displayed in Table 1. The end of water year 2018 elevation for Lake Powell was 3,592.28 feet.

**Table 1. Lake Powell Monthly Release Volumes
Water Year 2018**

Month	Monthly Release Volumes (MAF)
October 2017	0.640
November 2017	0.630
December 2017	0.740
January 2018	0.860
February 2018	0.730
March 2018	0.800
April 2018	0.705
May 2018	0.705
June 2018	0.760
July 2018	0.860
August 2018	0.900
September 2018	0.670
Total Releases	9.000

The ten-year total flow of the Colorado River at Lees Ferry² for water years 2008 through 2018 was 91.65 maf (USGS stream flows, Lees Ferry plus Paria River gage data). This total is computed as the sum of the flow of the Colorado River at Lees Ferry, Arizona, and the Paria River at Lees Ferry, Arizona, surface water discharge stations which are operated and maintained by the USGS.

Long-Term Experimental and Management Plan (LTEMP) Environmental Impact Statement (EIS) and Record of Decision (ROD)

Interior, through Reclamation and the NPS, jointly published the final LTEMP EIS on October 7, 2016, and a Record of Decision (ROD) was signed on December 15, 2016. The purpose of the LTEMP is to increase scientific understanding of the ecosystem downstream from Glen Canyon Dam and to improve and protect important downstream resources, while maintaining compliance with relevant laws including the GCPA, “Law of the River,” and ESA. The EIS had 15 cooperating agencies (including six tribes). A primary function of the implementation of the LTEMP EIS and ROD is to continue the successful experiments completed under the AMP.

² A point in the mainstream of the Colorado River one mile below the mouth of the Paria River.

Conservation Measures for Humpback Chub and Razorback Sucker

From fiscal years 2009 through 2018, Reclamation has funded the NPS to remove non-native trout and intermittently translocate humpback chub into two tributaries: Shinumo Creek and Havasu Creek. In 2018, scientists determined that a five-year adaptive management action to remove non-native trout was adequately successful in Bright Angel Creek, and thus humpback chub were translocated there. These actions were implemented to fulfill: (1) conservation measures from two biological opinions (BO) on the operations of Glen Canyon Dam, and (2) recovery goals as defined by the FWS for establishing additional reproducing populations of humpback chub. These efforts are to provide additional refuge populations that minimize the effects of predation and competition from non-native fish, contribute to mainstem populations of humpback chub, and may eventually establish new spawning populations.

Although the 2016 LTEMP BO replaced the 2011 BO, many of the conservation measures in the 2011 BO were continued in the 2016 BO, with some adjustments based on emerging science. New actions are mostly in anticipation of potential hydrological conditions that could result in non-native fish establishment. Further planning and compliance may be needed to implement components of the new conservation measures.

Translocations into Shinumo Creek that occurred from 2009 to 2013 were discontinued following a lightning-caused fire that burned 6,100 acres in the drainage and led to a series of ash-laden floods. These events flushed and scoured the aquatic fauna from the creek and greatly altered habitat conditions making the lower portion temporarily unsuitable for fish. Monitoring of Shinumo Creek has continued to determine the recovery and suitability of the habitat. Surveys indicate that the habitat has improved, and humpback chub translocations may resume in 2020.

Juvenile humpback chub have been translocated to Havasu Creek periodically since 2011. Two monitoring trips per year are conducted to determine abundance, annual survival, and growth estimates for the translocated humpback chub. Data indicates that the objectives of the translocations are being met and in addition, non-translocated humpback chub and chub less than 150 millimeters have also been captured. The occurrence of the smaller chub indicates that there are naturally occurring humpback chub in Havasu Creek and they are reproducing. Evidence of reproduction has been consistently demonstrated since 2012. Consequently, a spawning population may be present and translocations will likely occur in the future only to assure the genetic diversity of the population.

Monitoring has shown that abundance of adult chub in the mainstem has significantly increased at all aggregations since 2006, and at some non-aggregation sites. Humpback chub adults are currently abundant (more than 12,000 adults) and expanding in range. Humpback chub translocations to Shinumo Creek and Havasu Creek have also contributed to the mainstem aggregations located at the tributary mouths. Past mainstem aggregation sampling indicated that humpback chub translocated into Shinumo and Havasu tributaries are approximately 70% and 35% of the total aggregation, respectively. Other areas not associated with known aggregations were sampled the last several years and results indicate that humpback chub are more widely distributed in the mainstem than had been detected previously. This is likely a result of

emerging habitat below Diamond Creek as Lake Mead recedes, warmer water temperatures, and low predator burden.

The razorback sucker was thought to be extirpated from the Grand Canyon reach of the Colorado River. However, in 2013, two razorbacks were captured downstream of Diamond Creek (RM 225), more than 50 miles upstream from Pearce Ferry near the inflow of the Colorado River to Lake Mead and the termination of Grand Canyon. Consequently, Reclamation continued financial and staff support of a monitoring project for razorback sucker aimed at better understanding the use and life history needs of the species in Lake Mead and western Grand Canyon.

While researchers have known since the 1900s that razorback sucker occupy and are able to reproduce and recruit in Lake Mead, recent monitoring projects found that the species also uses the Colorado River in western Grand Canyon much farther upstream. Other findings include the presence of juvenile fish in the Lake Mead inflow area indicating recruitment, larval fish above Lava Falls indicating spawning and possible recruitment in the river reach, and long-distance movement of adult razorback suckers throughout Lake Mead and western Grand Canyon.

Because the capture of larval fishes helps to identify where spawning takes place, the duration of spawning activities, habitat use, and availability and fish community dynamics, Reclamation funded additional research for larval fish surveys in the lower reaches of Grand Canyon. For the last five years, biologists have sonic-tagged adult razorback suckers to track movements and possibly locate spawning aggregations. Evidence indicates razorback sucker had migrated upstream from Lake Mead and had spawned in Grand Canyon during February and March of each year. Larvae were found above Lava Falls, which suggests that spawning is occurring somewhere above that point in the river. This is encouraging news for native fish restoration because the detection of these larval fish indicates that razorback suckers may be naturally reproducing in an area where the species had not been detected in more than 20 years.

Tribal Activities

Reclamation continued to fund five American Indian Tribes (Hopi, Hualapai, Pueblo of Zuni, Kaibab Paiute, and the Navajo Nation) to participate in and provide their perspectives to the AMP. They identify and monitor traditional cultural properties and provide annual reports detailing their activities, findings, and monitoring of data.

In addition to the high-flow experimental release and consultations per the LTEMP ROD, Reclamation continues to conduct government-to-government consultations with American Indian Tribes as part of the AMP on operations of Glen Canyon Dam and activities of the AMP in services of its responsibilities, including those under Section 106 of the National Historic Preservation Act, Executive Order 13175, Secretarial Order 3206, and the November 5, 2009, Presidential Memorandum on Tribal Consultation.

Reclamation continued implementation of two memoranda of agreement (MOA) to mitigate for adverse effects under Section 106 of the National Historic Preservation Act for the High-Flow Experimental Protocol and non-native fish management described above. The consultation process

leading to execution of these two MOAs included consensus determination of eligibility of the Grand Canyon as a traditional cultural property for several tribes, at their request. Reclamation, in collaboration with other stakeholders, completed a new Programmatic Agreement (May 9, 2017) for the operation of Glen Canyon Dam pursuant to the GCPA that is consistent with the LTEMP. Reclamation also completed a Historic Preservation Plan (November 5, 2018) as required by the LTEMP Programmatic Agreement in fiscal year 2018. Reclamation has begun consultation to replace the two existing MOAs.

Other Activities

Grand Canyon National Park employs a permitting specialist and staff who review all proposals for projects to be completed in the park. Reclamation funds these positions to offset the park's administrative burden from AMP activities. Permitting activities completed in 2018 are described by the NPS in the following section of this report.

National Park Service

Three units of the NPS (Glen Canyon National Recreation Area, Grand Canyon National Park, and Lake Mead National Recreation Area) provide support for various AMP operations and activities. In 2018, staff from the Intermountain Regional Office, along with staff from both Glen Canyon National Recreation Area and Grand Canyon National Park, continued working with Reclamation and the other AMP agencies on reviewing information for a potential HFE. Based upon agency recommendations, the decision was made by the Secretary to go forward with a fall HFE in 2018 to address the protection of sediment-related resources through the Grand Canyon. Staff from the NPS continued to work with Reclamation on implementation of the LTEMP ROD, including processing agreements and conducting planning to address environmental commitments for cultural resources, endangered species, avifauna, and vegetation management.

LTEMP EIS and Record of Decision (ROD)

Since the completion of the LTEMP EIS and ROD in late 2016, the NPS, working with Reclamation and other Interior partners, has continued to work on implementation of the action and specific resource management recommendations. NPS worked with Reclamation on agreements for fisheries, archaeological monitoring and mitigation, vegetation monitoring and mitigation, and avifauna monitoring to pursue parts of the triennial work plan and budget that were priorities for 2018. For the LTEMP vegetation project, NPS held several meetings with the GCMRC and tribes to work through the scientific recommendations and the aspects of these projects important to tribes.

Archaeological/Cultural Resources

Grand Canyon National Park: No field work occurred in 2018. Staff completed work with Reclamation and other signatories on Stipulation IV of the LTEMP Programmatic Agreement and a Historic Preservation Plan has been finalized and approved by Reclamation's Upper Colorado Regional Director.

Glen Canyon National Recreation Area: Staff from Glen Canyon National Recreation Area implemented the first year of a new long-term monitoring and protection plan for the cultural resources found in the Glen Canyon reach. Important components of the finalized LTEMP Historic Preservation Plan will be added to the plan in fiscal year 2019. The NPS scheduled and hosted boat trips as requested by tribes in the Glen Canyon reach, including a final trip by the Navajo Nation as they finished their ethnographic report on the Glen Canyon reach. Glen Canyon National Recreation Area staff also continued to support the GCMRC's monitoring of dam related topographic changes at select cultural sites and tested a helium filled balloon to better access some sites and newly acquired photogrammetry equipment as possible monitoring tools.

Tribal Consultation

In 2018, the NPS continued to participate in consultation meetings with the various tribes who are directly involved in the AMP and other Colorado River related programs. The NPS's Grand Canyon National Park and Glen Canyon National Recreation Area continued discussions with tribes and incorporated tribal perspectives into implementation of the NPS's Comprehensive Fisheries Management Plan, the LTEMP, and initiation of the Expanded Non-Native Aquatic Species Management Plan. The NPS worked extensively together with Reclamation and tribes on the draft Historic Preservation Plan, the implementing document of the 2016 Programmatic Agreement associated with the final LTEMP EIS and ROD.

In late summer and fall of 2018, Glen Canyon National Recreation Area and Grand Canyon National Park initiated discussions and made a decision to use a Programmatic Agreement as the best pathway forward for addressing the Section 106 concerns from the nearly finalized Expanded Non-Native Aquatic Species Management Plan/Environmental Assessment (EA) and its adaptive management approach to addressing new and ongoing issues. NPS prepared a draft document which was provided to representatives at the Arizona State Historic Preservation Office, Advisory Council on Historic Preservation, and the tribes who had expressed an interest in participating including the Hopi Tribe, Hualapai Tribe, Kaibab and San Juan Paiute Tribes, Navajo Nation, and the Pueblo of Zuni. Notifications were also sent out regarding a fourth green sunfish invasion in the Upper Slough of Glen Canyon National Recreation Area which was removed in September 2018. The NPS also proposed combining the memorandum of agreement for the Comprehensive Fisheries Management Plan (2013) into the new Programmatic Agreement document, as well as combining the annual project proposals and reports from both planning documents and both NPS park units into one joint effort. The tribes suggested this streamlining would benefit all.

Glen Canyon National Recreation Area staff traveled to and engaged in consultation with the Pueblo of Zuni to discuss next steps during the public review of the draft Expanded Non-Native Aquatic Species Management Plan/EA. The insights and concerns of each tribe (primarily from written comments) provided valuable information on making some additional adjustments and changes to the Plan/EA.

Humpback Chub Translocation and Fisheries Management

In 2018, Grand Canyon National Park continued implementation of the Comprehensive Fisheries Management Plan for native fish within Grand Canyon National Park and sport fish in the Lees Ferry area of the Glen Canyon National Recreation Area. These efforts included an evaluation of the status and habitat use of endangered razorback sucker (thought to have been extirpated until 2014), translocations and/or monitoring of endangered humpback chub to Havasu and Bright Angel creeks, and the removal of non-native fishes threatening endangered and native fish in Bright Angel Creek. Translocations to Bright Angel Creek followed successful suppression of invasive brown and rainbow trout. The recovery of habitat in Shinumo Creek following a fire and flood was also monitored.

Monitoring of humpback chub translocation efforts in 2018 allowed the NPS to document the successful establishment of a reproducing population of the endangered species in Havasu Creek through translocations. Humpback chub that were produced as a result of spawning in Havasu Creek were found to have grown to maturity.

Invasive species monitoring continued in 2018 in Glen Canyon with emphasis on invasive fish and quagga mussels. Quagga mussel colonization in the river within Glen Canyon is increasing, but remains very patchy. The non-native brown trout population in Glen Canyon continued to increase; brown trout are a high-risk non-native predator that may threaten the rainbow trout fishery in Glen Canyon and humpback chub populations in Grand Canyon. There were numerous public comments from angling groups and guides, AGFD, and the tribes expressing concerns about large scale and extensive mechanical harvest efforts to remove brown trout from the Glen Canyon reach. NPS researched and proposed incentivized harvest strategies resulting in much more favorable support from all of the parties. NPS continued to monitor brown trout using sonic tags and also authorized additional pit tagging of brown trout by GCMRC and AGFD research teams.

The angler catch rate of rainbow trout within Glen Canyon began to improve in the lower 2.5 miles of the Colorado River above the mouth of the Paria River which is accessible by walk-in anglers. The AGFD, in coordination with the FWS, completed one stocking of triploid (sterile) rainbow trout at this location after the HFE in November of 2018. The stocking was consistent with the NPS's Comprehensive Fisheries Management Plan, including the development of an implementation plan for stocking that would minimize risk to endangered species in Grand Canyon and allow for AGFD to restore a rainbow trout fishery should a catastrophic event occur that impacted the entire rainbow trout population.

Wildlife Surveys and Monitoring

Grand Canyon National Park: In 2018, Grand Canyon National Park continued wildlife monitoring and surveys of several species. Those efforts included the continuation of a multi-year bat baseline and white-nose syndrome project, monitoring and surveys for ESA listed Mexican spotted owls and California condors, and monitoring the movements of elk and bison using global positioning system (GPS) collars. Collaborative efforts between Grand Canyon and AGFD continued to collect baseline data on bat diversity, seasonal activity patterns, cave

hibernacula, and perform surveillance for white-nose syndrome (which has not arrived yet to Grand Canyon). Surveys for Mexican spotted owls continued to document the presence of breeding pairs and refine the numbers and locations of protected activity centers. Collaborative efforts between Grand Canyon and the Peregrine Fund continued to track breeding success and survival rates of California condors. An elk management project was implemented that fitted seven elk with GPS collars to track their movement in the South Rim village area. Staff continued to monitor the movements of seven bison on the North Rim.

Glen Canyon National Recreation Area: In 2018, Glen Canyon National Recreation Area staff and partners worked on great blue heron, waterfowl, and raptor surveys along the 16-mile reach below Glen Canyon Dam. Work continued on monitoring aquatic/riparian invertebrates and terrestrial vertebrate populations utilizing the open water habitat at Leopard Frog Marsh.

Continuing bat monitoring efforts were completed both above and below the dam in order to identify the bat species using the Colorado River corridor and as a monitoring effort for white-nose syndrome.

Monitoring for impacts from quagga mussels both above and below the dam and for invasive fish, especially green sunfish, brown trout, walleye, and smallmouth bass, and other invasive species is ongoing.

Vegetation Management/Exotic Species Removal

Grand Canyon National Park: In 2018, the NPS continued to implement exotic plant species removal at priority sites, expand understanding of plant collection and propagation efforts needs in preparation for future watershed restoration projects, and provide hands-on stewardship opportunities. The NPS also maintained native plants and removed exotic species at Granite Camp and Cardenas Camp as part of the second phase of a pilot riparian restoration project. Specific accomplishments along the river corridor in Grand Canyon National Park were:

- Continued the first riparian project and implemented a second restoration project in the river corridor at Granite Camp (RM 94) and Cardenas Camp (RM 71) with exotic species removal and planting of native stock through site maintenance and outreach to collaboration with Cooperative Ecosystem Studies Units project partners.
- Continued collection and propagation of riparian plant species for mortality replacement plantings at Granite Camp and other future riparian restoration projects. Began a genetics study of mainstem woody species to determine best practices for propagation.
- Removed over 350 tamarisk (*Tamarix sp.*) plants at the Cardenas restoration site and 727 camelthorn (*Alhagi pseudalhagi*) plants from the Granite Camp restoration site.
- Initiated planning with The Arboretum at Flagstaff for the second riparian restoration project at Cardenas Camp. Tested methods for removal of invasive arrowweed at 21 campsites and removed over 2100 camelthorn and Russian thistle plants at those sites.
- Joined tribal partners at a series of three planning meetings related to implementation of the LTEMP non-flow mitigation project work.

Glen Canyon National Recreation Area: In 2018, the NPS, partners, and volunteers continued invasive plant management efforts, native plant restoration activities, and vegetation monitoring efforts along the Colorado and Paria rivers below Glen Canyon Dam. Specific accomplishments in Glen Canyon National Recreation Area were:

- Continued to water and restore native upland plants at a number of sites along the roadways into Lees Ferry.
- Continued native seed collection and plant propagation planning efforts to begin riparian plant restoration in important habitat areas in the Glen Canyon reach.
- Tribal youth and other crews helped to remove a stand of dead tamarisk at RM 7 in preparation for riparian restoration plantings in 2019 and 2020.

Expanded Non-Native Aquatic Species Management Plan

In 2018, NPS conducted planning for an EA related to non-native fish and other aquatic species below Glen Canyon Dam entitled the Expanded Non-Native Aquatic Species Management Plan. The NPS held public scoping meetings, solicited input from cooperators and AMP stakeholders on the development of alternatives, consulted with tribes, and then released a public EA in September 2018. The work with partners provided NPS with the opportunity to develop an adaptive, tiered approach to non-native aquatic species management that allows for the use of many tools, but addresses concerns by using less management intensive approaches first. The selected alternative allows for a proactive approach to non-native removal that allows anglers and tribal youth and elders to get involved with removing non-native fish through an incentivized harvest program. NPS anticipates a Finding of No Significant Impact (FONSI) in the spring of 2019 after consultations with the tribes are complete.

Research Review and Permitting

The Grand Canyon's Research Office continues to have one of the largest research and collection permitting programs within the NPS. There are more than 200 researchers that are listed as either principal or co-principal investigators presiding over current studies. In 2018, GRCA's Research Office received 11 Scientific Research and Collection Permit applications from GCMRC, and accordingly issued all 11 research permits. Additionally, 18 administrative river launch permits were issued, totaling 4,095 river user days for the 2018 calendar year, to fulfill the mission of these research projects and obligations under the AMP. Each project requiring administrative river access must go through requisite compliance prior to park approval. The permits correlate with the projects outlined in the GCDAMP Triennial Budget and Work Plan: Fiscal Years 2018-2020. Additionally, five tribes requested renewal research permits with corresponding river trips this year: Hopi, Hualapai, Navajo, Zuni, and Paiute Tribes, totaling 1,003 user days. The tribes utilized GCMRC as their outfitter for these river trips. Overall, 5,098 user days were spent on the river conducting AMP related research.

For each GCMRC and tribal permit, an interdisciplinary team of technical experts reviewed and provided comments on the research proposal or logistics and assistance was given to the principal investigator in completing the minimum requirement analysis and related compliance documents.

Additionally in 2018, Grand Canyon science and resource management staff participated in AMP related meetings and river trips; attended and participated in GCMRC's annual reporting meeting; and attended Glen Canyon Dam TWG meetings, knowledge assessment workshops, and other meetings with the GCMRC and TWG. These discussions are integral to future collaborations and allow for shared input and an increase in NPS involvement in the AMP.

Outside of the AMP, the research office continued to review proposals, coordinate efforts, and provide permitting guidance as needed for all GCPA projects in 2018. An additional 50 research permits were issued to independent or university researchers and logistical planning was provided to various disciplines including vegetation baseline monitoring, geomorphology, terrestrial remote sensing, and soundscape monitoring. Grand Canyon National Park currently has 101 active research permits and anticipates continuation of research and permitting activities in 2019 at similar levels as 2018.

The Glen Canyon National Recreation Area continued administration of nearly 15 research permits associated with the AMP between Glen Canyon Dam and the Paria River. The NPS anticipates continuation of research and permitting activities in 2019 at similar levels as 2018.

Resource Monitoring and Mitigation

In 2018, Grand Canyon National Park continued integrating monitoring of Colorado River campsites with all backcountry campsite monitoring. The opportunity presented itself when the strategic pause in Grand Canyon NPS river operations allowed staff to review and revise Colorado River Management Plan methods and create a final, written protocols document. At the same time, a plan for adaptive management of day and overnight use in the Grand Canyon backcountry, tied to drafts of the Backcountry Management Plan, was in development. Methods for monitoring backcountry campsites were aligned with Colorado River Management Plan campsite monitoring in ways that allowed integration of the two into a single database with shared fields.

The Glen Canyon National Recreation Area continued spreading the Clean, Drain, Dry message in partnership with the State of Arizona to prevent aquatic invasive species transport to and from Lake Powell and Lees Ferry. Aquatic invasive species (including New Zealand mudsnails, didymo, quagga mussels, brown trout, and green sunfish) present extreme potential impacts to a wide range of Glen Canyon National Recreation Area associated resources. The NPS funded and installed new boot cleaning stations at Lees Ferry which include educational information on the importance of not spreading aquatic invasive species. Cultural resource staff conducted the annual monitoring of cultural sites and eroding banks in order to track and document any new threats to the known archeological sites in the reach.

United States Fish and Wildlife Service

The FWS has participated in the LTEMP as a cooperating agency and has transitioned efforts to supporting implementation of the plan pursuant to the LTEMP ROD.

The FWS continued to cooperate with the NPS regarding the Comprehensive Fisheries

Management Plan, which guides NPS activities for native and non-native fish in Grand Canyon National Park and Glen Canyon National Recreation Area. Additionally, the FWS was a cooperating agency on the NPS's Expanded Aquatic Non-Native Plan and completed Section 7 consultation with the NPS for this plan in the spring of 2019. The FWS also cooperates with the AGFD regarding recreational angling in the same area. The FWS will continue to participate in the AMWG, TWG, and various ad hoc groups and other related assignments.

In 2018, the FWS conducted four monitoring trips on the Little Colorado River to generate population estimates for humpback chub and to monitor trends of other native fishes. Since 2006, the Little Colorado River population of humpback chub in Grand Canyon has significantly increased in size. Population estimates in 2018 were similar to 2017 and continue a reversal of declines seen in 2015 and 2016. The FWS conducted one trip on the Little Colorado River to monitor the success of upstream translocations of humpback chub within the Little Colorado River. These translocation efforts have been successful with humpback chub experiencing high growth rates and high survival in this upper portion of the river. In 2017, the FWS continued this translocation effort, but due to low reproduction, only 49 humpback chub were translocated upstream of Chute Falls.

The FWS worked collaboratively with Grand Canyon National Park to translocate humpback chub into Bright Angel Creek. The fish were removed from the Little Colorado River as larvae in 2015 and grown to adult size at the FWS's Southwest Native Aquatic Research and Recovery Center. In 2018, 116 humpback chub were stocked into Bright Angel Creek.

The FWS has continued to work collaboratively with the GCMRC and Grand Canyon National Park in the collection and transport of young humpback chub for translocation into Havasu Creek. Due to low recruitment numbers, no larval humpback chub were collected in 2018 for grow-out and translocations.

The FWS, in collaboration with the GCMRC and NPS, continues to develop and refine a monitoring program to effectively sample mainstem aggregations of humpback chub in the Colorado River in Grand Canyon. In 2018, the FWS and GCMRC conducted one sampling trip to assess population size of humpback chub in these aggregations. Large numbers of juvenile and adult humpback chub and detection of sexually mature individuals provide evidence of an expanding population comprised largely of in-situ spawning and recruitment in West Grand Canyon.

The AGFD specified needs for management of the Lees Ferry rainbow trout fishery that included the need to stock triploid (non-reproductive) rainbow trout into walk-in portions of the fishery. The AGFD requested funding and regulatory support from the FWS's Wildlife and Sport Fish Restoration Program and the Ecological Services Office for this action. The FWS provided support for this plan, which included grant funding, ESA compliance, and tribal consultation compliance. Section 7 consultation (ESA) was completed in the fall and resulted in the issuance of a biological opinion that included avoidance and conservation measures that promoted the protection of humpback chub from impacts of this action. Tribal consultation was completed in this same timeframe with various tribal participant groups, AGFD, NPS, Advisory Council on Historic Preservation, and the Arizona State Historic Preservation Office. After completion of

the grant package, funding was provided to AGFD for this action on November 1, 2018. A total of 525 triploid rainbow trout were stocked into Lees Ferry on November 14, 2018, and AGFD plans to stock an additional 6,000 fish throughout the spring of 2019. With the assistance and support of multiple partners, monitoring and reporting of the impacts and efficacy of this action are ongoing.

United States Geological Survey

In 2018, the GCMRC continued to serve in its role as the primary science provider to the AMP. The GCMRC's primary activities during 2018 were: (1) collaborating with Reclamation and WAPA to develop the experimental bug flows hydrograph and then monitoring ecosystem response to this flow experiment during its implementation; (2) conducting an annual reporting meeting that summarized findings from the previous year's research and monitoring activities and summarized knowledge-to-date concerning the Colorado River ecosystem; (3) implementing the first year of a three-year Budget and Work Plan encompassing fiscal years 2018-2020; (4) maintaining a stream flow and sediment transport measurement and internet-based real-time reporting program that was the foundation for planning and implementing a November 2018 HFE; (5) analysis of those data so as to inform dam and river management activities in the months immediately before the HFE; (6) collection and reporting of data describing resource conditions following the November 2016 HFE; (7) collection and reporting of native and non-native fish population data in support of management decisions regarding recovery of humpback chub, maintaining the Lees Ferry sport fishery, and non-native fish control; (8) monitoring key cultural resources and geomorphic processes that may affect them; and (9) providing science support for experimental riparian vegetation management. Additionally, the GCMRC conducted numerous field and laboratory studies and provided logistical support for river trips and other field activities and provided scientific support for implementation of the LTEMP EIS and ROD.

Bug Flows Implementation and Monitoring

In 2018, GCMRC monitored ecosystem response to experimental bug flow releases from Glen Canyon Dam and assisted with the design and implementation of the flow experiment. Aquatic insects are an important prey item that fuels growth of fish, birds, bats, and countless other wildlife living in and along the Colorado River. However, prior studies by GCMRC demonstrated that the low diversity and abundance of aquatic insects in the Colorado River was limiting the growth and condition of native and desired non-native fish populations. A 2016 paper by GCMRC scientists demonstrated that the hourly variation in flows arising from hydropower production was limiting aquatic insect abundance and diversity by causing desiccation and mortality of insect eggs laid along unstable river shorelines. Bug flows (also known as macroinvertebrate production flows) are intended to increase the diversity and abundance of aquatic insects by improving egg laying conditions for these aquatic insects.

GCMRC collaborated with WAPA and Reclamation staff to design and implement experimental bug flow releases from Glen Canyon Dam. This included deciding the appropriate flow level for weekend steady flows for each month of the experiment and routing these flows throughout Grand Canyon to predict how aquatic insects would respond at various locations of management interest. In 2018, bug flows occurred from May through August. These experimental releases

involved low, steady flows on weekends to enhance egg laying conditions for aquatic insects while minimizing impacts to hydropower production. Fluctuating flows for hydropower

production occurred during weekdays and included slightly higher peaks than normal to compensate for the lower weekend flows.

GCMRC monitored ecosystem response to the 2018 bug flow experiment by launching river trips in spring and fall, through continuation of long-term citizen science insect monitoring in Grand Canyon, through continuation of insect drift and emergence monitoring in Glen Canyon, and by using time-lapse cameras to quantify egg laying activity at different flow levels. Monitoring data indicate that the 2018 bug flows were successful at enhancing egg laying conditions for aquatic insects and improving aquatic insect populations, as predicted. For example, monitoring data showed that the number of adult aquatic insects emerging from the Colorado River on weekends when flows were steady was > 30% higher than the number of aquatic insects emerging during weekdays with fluctuating flows for hydropower production.

Time lapse photos taken throughout the experiment also showed that large numbers of aquatic insect eggs were being laid each weekend during bug flows, as predicted, and these eggs were staying wet and were therefore likely to hatch and contribute to insect populations. In contrast, time-lapse photos during weekday fluctuating flows for hydropower production showed that many insect eggs were laid at high water levels and then exposed, desiccated, and likely died within hours when flows were lowered. Finally, the average number of caddisflies, an aquatic insect that is sensitive to disturbance, captured in citizen science light traps increased four-fold throughout the Grand Canyon in 2018 compared to yearly average light trap catches from 2012-2017. This large increase in the abundance of sensitive caddisflies in 2018 compared to six prior years of baseline data is another indication that bug flows are improving the diversity and abundance of aquatic insects in the Colorado River.

Knowledge Synthesis

In March 2018, the GCMRC conducted an annual reporting meeting with AMP stakeholders during which results from research and monitoring in key resource areas in Glen and Grand canyons from the previous year were presented by scientists from the GCMRC and cooperating agencies as well as tribal representatives. The foci of the March meeting were biology, ecology, hydrology, sediment transport, geomorphology, cultural resources, and recreation resources. All materials presented at the meeting were made available in electronic postings at the GCMRC and Reclamation websites.

Implementation of Stream Flow and Sediment Measurement Program in Support of the LTEMP ROD

The periods from December 1, 2017, to June 30, 2018, and July 1 to November 30, 2018, mark the “sediment accumulation periods” for spring and fall HFEs, respectively, as defined under the High-Flow Experimental Protocol that was initially adopted by the Secretary in 2012 and carried forward into the 2016 LTEMP EIS ROD. The HFE Protocol necessitates the estimation in real time of sand delivery from the Paria River and sand retention in Marble Canyon in the months

immediately prior to the HFE. The GCMRC worked in collaboration with the Arizona and Utah Water Science Centers of the USGS to measure suspended-sediment transport and to process field samples in the GCMRC sediment lab. Telemetered data from remotely deployed instruments were shared in real time on the GCMRC website while data from physical samples were shared with Reclamation via the GCMRC website on a bi-weekly basis in an effort to provide sediment data in a near real-time format for HFE planning purposes.

The GCMRC measurements indicated that between 18,900 and 23,100 metric tons of sand were supplied to the Colorado River by the Paria River between December 1, 2017, and June 30, 2018, and that between 238,000 and 263,000 metric tons of sand were exported from Marble Canyon during this same period. The GCMRC measurements also indicated that between 699,000 and 855,000 metric tons of sand were supplied to the Colorado River by the Paria River between July 1 and November 30, 2018, and that between 290,000 and 320,000 metric tons of sand were exported from Marble Canyon during this same period. Thus, during the spring accumulation period (December 1, 2017, through June 30, 2018) net erosion of sand from Marble Canyon occurred, whereas during the fall accumulation period (July 1 through November 30, 2018) substantial net sand accumulation in Marble Canyon occurred. Therefore, although the amount of newly delivered sand retained in Marble Canyon during the spring 2018 sediment accumulation period was insufficient to trigger an HFE, the amount of newly delivered sand retained in Marble Canyon during the fall 2018 sediment accumulation period was sufficient to trigger an HFE.

Analyses of Sediment Transport Data to Inform HFE Planning and Design

GCMRC scientists evaluated sediment transport and sediment mass balance data and made recommendations to Reclamation concerning whether or not to conduct an HFE with sediment inputs from the Paria River. Because there were sufficient inputs of sediment during the fall accounting period in 2018, an HFE was recommended to Interior and implemented in November 2018.

Implementation of a Plan to Evaluate HFE Effects

The GCMRC utilizes annual topographic surveys and a network of field time-lapse cameras to evaluate the effects of HFEs and other flows on sandbars throughout the Colorado River ecosystem. Scientists were sent into the field in February 2018 to collect photographic data and recover gaging station data. Preliminary results indicate that there was favorable bar building in Marble and Grand canyons caused by each of the fall HFEs conducted in November of 2012, 2013, 2014, 2016, and 2018 (water years 2013, 2014, 2015, 2017, and 2019). Sandbar size at a majority of sites (> 88%) either increased or was maintained in response to each HFE. No HFE occurred in fall 2015 or fall 2017 (water years 2016 and 2018) and preliminary results indicate erosion occurred at most monitored sandbars as a result of normal dam operations (e.g., daily variation due to hydropower load-following flows) in water years 2016 and 2018. The most recent topographic surveys of long-term monitoring sites from fall 2018 (water year 2019) indicate that most sandbars continued to increase in size since implementation of the HFE Protocol in 2012.

GCMRC scientists completed and published several journal articles in 2018 that quantify effects of the HFE Protocol (which began in 2012) on source-bordering aeolian dunefields that contain archaeological sites within Grand Canyon National Park. Those publications show that there are 57 large, source-bordering aeolian dunefields along the Colorado River in Grand Canyon and another 60 similarly large areas of unvegetated sand located at high elevations outside of the active river channel. Many of those dunefields and high elevation sand areas contain archaeological sites. While HFEs do not directly inundate most of these areas, they do resupply them with river sand by rebuilding upwind sandbars.

The LTEMP EIS predicted that conditions for achieving the goal of preservation of cultural resources, termed “preservation in place,” will be enhanced as a result of implementing the selected alternative. HFEs are one component of the selected alternative that will be used to resupply sediment to sandbars in Marble and Grand Canyons, which in conjunction with targeted vegetation removal, is expected to resupply more sediment via wind transport from HFE-deposited sandbars to dunefields and archaeological sites. While HFEs have been shown to directly erode terraces that contain archaeological sites in Glen Canyon National Recreation Area, HFEs have also been shown to rebuild or maintain sandbars that provide sand to resupply aeolian dunefields containing archaeological sites throughout Marble and Grand Canyons.

GCMRC characterized the response of source-bordering dunefields during four HFEs in 2012, 2013, 2014, and 2016 and found that aeolian sediment resupply unambiguously occurred in half of the instances (eight of 16). GCMRC infers that the relative success of HFEs as a regulated-river management tool for resupplying sediment to dunefields that contain archaeological sites, is analogous to the frequency of resupply observed for river sandbars, in that sediment resupply at sandbars monitored by GCMRC was estimated to have occurred in roughly half of the instances. Importantly, GCMRC determined that dunefield sediment storage increased cumulatively when HFEs were conducted consistently on an annual basis, whereas sediment storage decreased at three of the four dunefields during the one-year hiatus from HFE in 2015. GCMRC scientists specifically determined that sediment storage increased at each of the individual archaeological sites within the four monitored dunefields owing to resupply from 2012-2016 HFE sand. GCMRC used these results to help design experimental vegetation removal treatments that will be implemented by the NPS in 2019 in Grand Canyon to increase aeolian sediment supply from HFE sandbars to several dunefields that host archaeological sites (see Other Science Activities and Findings below for more detail).

In addition, rainbow trout populations and the aquatic food base in Glen Canyon were sampled before and after each of the November 2012, 2013, 2014, 2016, and 2018 HFEs to evaluate any effects on the aquatic ecosystem. Results indicate that fall HFEs do not trigger downstream movement of rainbow trout or affect rainbow trout growth rates. Rainbow trout abundance in Glen Canyon did decline substantially over the period that included the November 2012, 2013, and 2014 HFEs and also through 2015. These changes appear to be related to an overabundance of young trout produced in water year 2011 and a limited aquatic food base rather than any effect of fall HFEs. The abundance of young rainbow trout increased dramatically in 2016 and remained high in 2017 and 2018 suggesting a recovery of the Glen Canyon rainbow trout population is underway. Catches of non-native brown trout have been increasing in Glen Canyon coincident with the implementation of the HFE Protocol with evidence of spawning in

2015 and 2016 and recruitment into larger size classes in 2017 and 2018. The influence of fall HFEs on increases in this fish-eating predator are unknown, but is a topic of ongoing discussion among scientists and managers.

Results from monitoring also suggest that the aquatic food base only responds weakly to fall HFEs. Sampling before and after these fall HFEs demonstrates that the invertebrate assemblage is still dominated by New Zealand mudsnail, an invasive species, and tubificid worms and amphipods. These observations concerning fall HFEs stand in stark contrast to the dramatic change in the aquatic food base observed following the March 2008 HFE when unpalatable tubificid worms and New Zealand mudsnails declined sharply and abundance of high-quality aquatic insect prey increased dramatically.

Presentations concerning the effects of the 2012-2014 and 2016 HFEs were given at GCMRC's March 2018 annual reporting meeting. Additional information about the effects of these HFEs was also presented at the AMP meeting in March 2018.

Fisheries Information in Support of the LTEMP ROD

The GCMRC conducted monitoring of native and non-native fish populations in support of the LTEMP ROD and its associated BO for endangered humpback chub. The BO identifies several triggers which, if met, require management actions to be taken to protect humpback chub. The BO includes two tiers of possible actions to protect humpback chub. The first specifies actions to benefit humpback chub directly and the second looks to reduce non-native fish populations. Information provided by the GCMRC for specific triggers included the abundance of juvenile, sub-adult, and adult humpback chub and the abundance of non-native rainbow trout and brown trout in the Colorado River near the Little Colorado River confluence.

The GCMRC and its cooperators generated estimates of the abundance of several life stages of humpback chub in the Little Colorado River itself and near its confluence with the Colorado River, as well as survival rates of juvenile humpback chub in this latter area. None of the triggering criteria for humpback chub or trout were reached in 2018. Overall, adult and sub-adult humpback chub abundance in both the Little Colorado River and near its confluence with the Colorado River were above levels identified in the BO that would trigger action. Non-native trout abundance also remained below levels that would trigger action. Therefore, no additional actions to benefit humpback chub or control non-native fish abundance were required or implemented.

As in 2015-2017, green sunfish were detected in Glen Canyon downstream of Glen Canyon Dam in the summer of 2018. Similar to 2016 and 2017, distribution was limited with these fish found only in a small pond. Green sunfish have rapid invasion and expansion potential and prey upon and compete with native fishes. Given these concerns and the fact that the pond would be inundated by HFE flows, it was determined that green sunfish should be eradicated from the area. In October 2016 and 2017, in cooperation with the NPS and AGFD, the backwater was successfully treated with ammonia as an experimental piscicide to remove green sunfish. In October 2018, NPS with GCMRC assistance experimentally pumped water out of the pond until only a few small pools remained. These were spot treated with ammonia to remove the small

number of remaining green sunfish. These actions successfully eradicated green sunfish from this area ahead of the decision deadline for a potential HFE.

Cultural Resource Monitoring in Support of the LTEMP ROD and AMP

In 2018, GCMRC scientists continued to implement the plan for monitoring effects of dam operations, as well as non-flow actions of the LTEMP, on the geomorphic condition of archaeological sites. The plan was prepared in 2015 in consultation with Reclamation, the NPS, and American Indian Tribes affiliated with the AMP and initially implemented in fiscal year 2016. In May 2018, GCMRC scientists continued to map and monitor archaeological sites in Grand Canyon using terrestrial LIDAR and other methods as described in the monitoring plan.

In addition, GCMRC compiled and summarized 30 years of research and monitoring of archaeological sites in the river corridor to aid in the development of a new Historic Preservation Plan and GCRMC scientists continued to compile repeat photographs of historical images from the river corridor to assess changes in the distribution and abundance of riparian plant species that were traditionally valued and utilized by American Indian Tribes affiliated with the AMP.

Science Support for Experimental Riparian Vegetation Management

In fiscal year 2018, GCRMC also worked with NPS staff and tribal partners to design and implement experimental vegetation removal at several locations along the river. GCMRC helped NPS organize and lead two in-person meetings and one web-based meeting among all the project partners for the LTEMP experimental riparian vegetation management project. Project partners included NPS, GCMRC, Hopi Tribe, Hualapai Tribe, Navajo Nation, Southern Paiute Consortium, and Pueblo of Zuni. GCMRC helped to develop pilot studies that will be implemented by the project partners in 2019 for vegetation management treatments in Glen Canyon National Recreation Area and Grand Canyon National Park.

The purpose of the experimental vegetation removal effort is to create more camping space for recreational visitors and to improve connectivity between near shore sandbars and aeolian dunefields and associated archaeological sites that are located farther from the river. GCMRC scientists will be monitoring these sites in the future to determine whether vegetation removal results in more sediment transport to archaeological sites, thereby helping to preserve these cultural sites in situ. As a project partner, GCMRC's roles and responsibilities are to: (1) provide input to NPS and tribal partners on project design, site selection, and methods for implementation and monitoring; (2) provide scientific support via monitoring and research to evaluate vegetation management treatment outcomes, effectiveness, and success; (3) provide objective advice on project efficiency and adaptive management; and (4) help manage project data while respecting tribal data sensitivity.

Other Science Activities and Findings

In the course of its regular and mandated science monitoring and research activities, the GCMRC and its cooperators provided stakeholders and the AMP with other information including: (1) critical data concerning the status and trends of endangered humpback chub populations in the

Colorado River downstream of Glen Canyon Dam as well as key tributaries; (2) status and trends of rainbow trout in Glen Canyon, Marble Canyon, and near the Little Colorado River confluence; (3) distribution and relative abundance of potentially harmful non-native aquatic species between Glen Canyon Dam and Lake Mead reservoir; (4) status and trends of the aquatic food base in the Colorado River ecosystem; and (5) status and trends of riparian vegetation. Of note in 2018 was the observation of adult quagga mussels on fixed equipment at the USGS stream gages at 30-mile and Grand Canyon.

The GCMRC was permitted for and provided logistics support for 23 mainstem river trips downstream of Lees Ferry in 2018. Trips in 2018 included 15 AMP approved research and monitoring trips led by GCMRC or cooperating agency scientists that launched from Lees Ferry (three of these trips launched from Diamond Creek, one each by FWS and AGFD to monitor fish populations and one by GCMRC to monitor riparian vegetation); five tribal-led monitoring trips; and two youth “Partners-in Science” trips that launched from Lees Ferry. The GCMRC was also permitted for and provided logistics support for seven trips upstream of Lees Ferry in Glen Canyon to conduct AMP-funded projects. These included six trips to monitor trout populations (four led by GCMRC and two led by AGFD), and one trip led by GCMRC to monitor riparian vegetation. Logistics support, including helicopter transport, was also provided for AMP-funded projects in the Little Colorado River conducted by the FWS, AGFD, and GCMRC. Five Little Colorado River trips were conducted in 2018 (same as in 2017) with each trip requiring two flight days, one to take crews into field camps along the river and one to retrieve them.

Tribal Activities

GCMRC staff and collaborators met with tribal leadership and representatives to the AMP on several occasions in 2018 to discuss implementation of a socioeconomic study that is being developed with tribal involvement. In 2018, the GCMRC economist participated in meetings with three Navajo Nation Agency Councils, the Navajo Nation Human Research Review Board, and the Hualapai Tribe Council, receiving support for implementation of tribal surveys with the Navajo Nation and Hualapai Tribe. In addition, GCMRC and NPS organized two meetings with representatives from the Hopi, Hualapai, Navajo, Southern Paiute consortium, and Zuni Tribes to discuss a proposed vegetation management project and to seek tribal input on the locations and implementation of this project in 2019. In 2019, USGS continues to provide appropriate funding for tribal participation in the AMP.

II. 2019 Operations (Projected)

Bureau of Indian Affairs

In water year 2019, the BIA will continue to take an active role in supporting stakeholder tribes related to the AMP. The BIA will participate in meetings concerning the Tribal Consultation Plan, the LTEMP Programmatic Agreement, pre-meetings with tribal representatives prior to AMWG meetings, and continue to participate in various ad hoc groups regarding tribal, cultural, and natural resource issues and concerns. The BIA will continue to be involved with any future HFE or experimental releases from Glen Canyon Dam as staffing permits. The BIA will

coordinate with, and if necessary meet with Interior’s Tribal Liaisons to facilitate stakeholder tribe participation in various aspects of the AMP.

Bureau of Reclamation

Water Operations

The operation of Glen Canyon Dam is described in a set of documents relating to the use of the waters of the Colorado River, which are commonly and collectively known as the “Law of the River.” The 2007 Interim Guidelines (Guidelines) became part of this collection, which set the operations of Lake Powell and Lake Mead according to the strategy set forth in section 6 of the Guidelines. On December 15, 2016, the ROD for the Glen Canyon Dam LTEMP was signed by the Secretary. The LTEMP provides alternative operating hydrographs developed for different hydrological year classes. These monthly release volumes are found in Attachment B to the ROD. The LTEMP monthly release volumes will be used in conjunction with Guidelines operations between October 1, 2018, and September 30, 2019 (water year 2019).

Releases from Lake Powell in water year 2019 reflect consideration of the uses and purposes identified in the authorizing legislation for Glen Canyon Dam and will be consistent with the 2016 LTEMP ROD. As of May 30, 2019, the observed and projected monthly release volumes for water year 2019 are displayed in Table 2, and the end of water year 2019 elevation for Lake Powell is projected to be 3,610.33 feet.

**Table 2. Lake Powell Monthly Release Volumes
Water Year 2019**

Month	Monthly Release Volumes (MAF)
October 2018	0.625
November 2018	0.585
December 2018	0.740
January 2019	0.804
February 2019	0.730
March 2019	0.790
April 2019	0.720
May 2019	0.720
June 2019	0.765
July 20189	0.860
August 2019**	0.900
September 2019**	0.683
Total Releases**	9.000

** = projected release

Under the LTEMP HFE Protocol, high-flow experimental releases from Glen Canyon Dam are timed to occur following sediment inputs to the Colorado River from downstream tributaries to maintain and improve beaches and sandbars and associated habitat. HFEs may be conducted in the fall or the spring³ when conditions warrant. GCMRC scientists and Reclamation modelers considered cumulative sediment inputs from July 1 through midnight October 9, 2018. Based on these data it was determined that there was sufficient sediment to support implementing an HFE at Glen Canyon Dam during the fall 2018 planning window. The HFE release included a peak flow of approximately 38,100 cubic feet per second for 60 hours (four days including ramping from baseflows to peak releases) to move accumulated sediment downstream to help rebuild beaches and sandbars. This HFE release was the first to be conducted under the 2016 Long-Term Experimental and Management Plan HFE Protocol.

Under the LTEMP, the second bug flow (also known as macroinvertebrate production flows) experiment is being conducted during May-August 2019. Information on the background and benefits of the bug flow experiments can be found in the USGS section of this document. Hydropower peaking releases were held steady during Saturday and Sunday in an attempt to increase production of aquatic insects. Bug flows are intended to increase the diversity and abundance of aquatic insects by improving egg laying conditions for these aquatic insects.

Reclamation will continue planning for high-flow experimental releases from Glen Canyon Dam in accordance with the LTEMP High-Flow Experimental Protocol.

LTEMP EIS and ROD

The LTEMP EIS and ROD provide a comprehensive framework for adaptively managing Glen Canyon Dam over the next 20 years consistent with the GCPA and other provisions of applicable federal law. The LTEMP includes a communication and consultation process that ensures input and consultation with stakeholders throughout the 20-year implementation. In 2019, Reclamation will continue a phased implementation of the LTEMP. Ongoing communication and coordination with stakeholders will continue. Reclamation is also funding an AMWG stakeholder river trip in July 2019.

Conservation Measures for Humpback Chub and Razorback Sucker

In 2019, ongoing conservation measures will continue as described above for 2018, and consistent with the prescriptions set forth under the LTEMP implementation. Reclamation will continue to provide funding to the GCMRC for aquatic and sediment research.

Tribal Activities

In 2019, Reclamation plans to continue to provide funding to the GCMRC and NPS for cultural resources research and monitoring will also continue to fund participation and monitoring for the five American Indian Tribes associated with the AMP (as described above for 2018). Reclamation will continue with National Historic Preservation activities associated with the

³ Under the LTEMP HFE Protocol, spring HFEs will be considered after September 30, 2019. No spring HFEs will occur prior to water year 2020.

LTEMP Programmatic Agreement and the Historic Preservation Plan. This plan will ensure continued consultation with interested parties including the tribes, identify mitigation measures to address any adverse effects to historic properties, and develop a cultural sensitivity training for all researchers conducting work in the canyons below the dam.

Other Activities

In 2019, Reclamation plans to continue to provide funding to Grand Canyon National Park for a permitting specialist and staff to review all proposals for projects to be completed in the park. Reclamation funds these positions to offset the park's administrative burden from AMP activities. Reclamation also plans to continue to provide funding to Grand Canyon National Park to conduct management actions that fulfill ESA compliance for the LTEMP EIS.

National Park Service

LTEMP EIS and ROD

LTEMP implementation of various components will continue in 2019. Budgeting, coordination, and experimental planning continue in collaboration with Reclamation, GCMRC, tribes, and other stakeholders and partners.

NPS staff will continue to work on implementation of the National Historic Preservation Act Section 106 compliance program, working with all interested parties on updating plans and developing field review strategies. This work will be guided by the finalization of a Historic Preservation Plan.

Archaeological/Cultural Resources

Grand Canyon National Park: In 2019, NPS Archaeological Sites Management Information System condition assessments will be conducted at 50 sites as part of the monitoring for the Grand Canyon Colorado River Management Plan. The NPS is proposing to conduct assessments to a selection of 50 high priority locations identified in previous Reclamation treatment documents as recommended for mitigations. The assessments will be conducted jointly with Reclamation as part of the planning process outlined in the Historic Preservation Plan.

Glen Canyon National Recreation Area: In 2019, work will include additional development and evaluation of monitoring protocols for terrestrial and non-native fish resources to evaluate potential effects resulting from dam operations. The Expanded Non-Native Aquatic Species Management Plan EA is scheduled to be completed in 2019 and initial efforts to implement an incentivized harvest program for brown trout control will be initiated. Staff will also continue to monitor for and manage any new populations of green sunfish in the RM 12 backwater sloughs. The site preparation efforts for riparian habitat restoration plantings at RM 7 will occur. Glen Canyon will continue research into photogrammetry monitoring at select cultural sites. Staff will also continue opportunistic cultural and natural resource monitoring around planned HFEs.

Tribal Consultation

In 2019, the NPS anticipates continued participation in consultation meetings with the various tribes who are directly involved in the AMP and other Colorado River related programs. Grand Canyon National Park and Glen Canyon National Recreation Area will continue discussions with tribes to incorporate tribal perspectives into implementation of the NPS's Comprehensive Fisheries Management Plan, the new Expanded Non-Native Aquatic Species Management Plan, as well as the combined Programmatic Agreement for both plans. Tribal advisors will continue to be consulted on specific monitoring and mitigation protocols.

The Grand Canyon National Park anticipates working with the Pueblo of Zuni and external partners on projects to better protect important resources along the Colorado River. Specific efforts will be made with the Pueblo of Zuni relative to creating a "buffer" zone near the confluence of Bright Angel Creek and Ribbon Falls Creek. This zone will incorporate specific removal techniques including use of nets and elimination of electrofishing in that area. Additional crew training will occur with representatives from Zuni to discuss specific concerns.

Park staff anticipates working with representatives from Traditionally Associated Tribes to gather information on the salt mines located along the river downstream of the Little Colorado River confluence. The NPS will continue to work with Reclamation to consult with interested tribes involved in the LTEMP.

In continuance of the 2016-2018 efforts with the Hopi Tribe, Hualapai Tribe, Kaibab Paiute, Navajo Nation, and the Pueblo of Zuni, Glen Canyon National Recreation Area anticipates compiling the tribal ethnographic reports for the Glen Canyon reach into one final report that will facilitate contextualization of the archaeological sites in the Glen Canyon reach. As stated above, the purpose of that work will be to help inform mitigation of sites adversely affected by dam operations and to provide the federal land manager with an understanding of tribal histories in that stretch of the river to facilitate informed and culturally sensitive land management.

Further, Glen Canyon National Recreation Area, in partnership with Grand Canyon National Park and the NPS Intermountain Region, will conduct ongoing consultations relative to the

Programmatic Agreement meeting National Historic Preservation Act Section 106 requirements for implementing the Expanded Non-Native Aquatic Species Management Plan/EA.

Humpback Chub Translocation and Fisheries Management

In Grand Canyon, implementation of the Comprehensive Fisheries Management Plan will continue into 2019. These efforts will include monitoring of translocated endangered humpback chub in and around Havasu and Shinumo creeks, and the continued removal of non-native fishes threatening endangered and native fish in Bright Angel Creek and the Bright Angel Creek inflow area of the Colorado River. Following the first translocation of humpback chub to Bright Angel Creek in 2018, additional monitoring of that population will take place in the spring and fall. The recovery of Shinumo Creek will continue to be monitored for the suitability of humpback

chub translocation in the future. Collaboration with Reclamation, the FWS, GCMRC, and others will continue on all fisheries projects leading to well integrated projects.

In Glen Canyon, monitoring for invasive species, especially invasive fish, will continue with partners in 2019. Quagga mussel colonization monitoring above and below Glen Canyon Dam will continue. Continuing the 2017-2018 effort, the NPS will finalize an expanded non-native fisheries management plan that includes a suite of management tools that will be implemented in an adaptive management, tiered approach. The tiers include trigger points for when additional or higher level tools may need to be implemented. The plan and Programmatic Agreement are expected to be finalized in 2019.

Green sunfish populations, especially in the backwater areas, will be monitored carefully with partners in 2019 while annual pump out and fish removal actions are implemented. A series of metal fish screens were installed immediately after the November 2018 HFE to prevent sunfish from accessing, and thereby reproducing in the Upper Slough backwater area. Portable high volume pumps and mechanical removal will be used prior to green sunfish being able to reproduce. These solutions are an acceptable alternative to regular chemical treatments and an engineered channel that would greatly disrupt the aquatic and wetland ecosystems at RM 12.

Wildlife Surveys and Monitoring

Grand Canyon National Park: In 2019, Grand Canyon National Park surveys and monitoring for ESA listed California condors and Mexican spotted owls will continue, as well as ESA surveys for Ridgway's clapper rails, Southwestern willow flycatchers, and Yellow-billed cuckoos as identified in the LTEMP ROD. The long-term bat study will continue in 2019, focusing on captures (acoustically and mist netting) and white-nose syndrome surveillance in new areas of the park, including the addition of doing bat work on a river mission. Baseline data collection on select herpetofauna species will begin in the summer of 2019 to inform a graduate study beginning in the fall of 2019. Three more elk will have GPS collars placed on them and the park will attempt to corral and remove bison from the North Rim this fall.

Glen Canyon National Recreation Area: In 2019, Glen Canyon National Recreation Area plans to continue programs related to aquatic/riparian invertebrates, bats, other terrestrial vertebrate populations, and northern leopard frog habitat enhancements.

Vegetation Management/Exotic Species Removal

In 2019, NPS staff will continue site maintenance and monitoring at Granite and Cardenas camps. Working with the GCMRC, NPS staff will continue integrating long-term monitoring data into future mitigation efforts including creating a detailed species list and planting plans, plant material collection, monitoring transect establishment, ground water monitoring well installation, and site mapping. NPS staff will implement the Colorado River Monitoring Program campsite monitoring and mitigation river mission in spring 2019. Work on this river mission will include campsite monitoring using the Colorado River Management Plan rapid assessment tool, tamarisk beetle monitoring, invasive species removal, and vegetation removal/pruning.

In 2019, the NPS (both Grand Canyon National Park and Glen Canyon National Recreation Area), partners, and volunteers will continue invasive plant management, native plant restoration, and vegetation monitoring activities along the Colorado and Paria rivers below Glen Canyon Dam. Both parks will also initiate riparian habitat restoration projects associated with the LTEMP EIS.

Expanded Non-Native Aquatic Species Management Plan

NPS anticipates a FONSI in the spring of 2019 after consultations with tribes are complete. Once the FONSI is complete, NPS will begin implementation starting with setting up an incentivized harvest program for non-native fish in the Glen Canyon National Recreation Area below the dam.

Research Review and Permitting

The NPS (both Grand Canyon National Park and Glen Canyon National Recreation Area) anticipates continuation of research and permitting activities in 2019 at similar levels as 2018. For each of the research projects in support of the GCPA, peer review of the proposals, evaluation of the need for National Environmental Policy Act compliance, and completion of minimum requirement analysis will be completed. Updating of annual investigator reports will be done for each research permit and coordination with Reclamation will continue.

Resource Monitoring and Mitigation

In 2019, fieldwork will resume with the resumption of NPS and contracted river operations. One springtime monitoring and campsite mitigation trip is planned. In addition, a cooperative monitoring and mitigation program is in development which will use monitoring done by the GCMRC to inform NPS mitigation work where flow-related changes in vegetation and geomorphology degrade campsite conditions. Discussions were also begun with the Northern Arizona University Environmental Genetics and Genomics lab to determine the feasibility of combining future mitigation projects with field tests to address questions related to conservation genetics and community genetics.

Greater Grand Canyon Landscape Assessment

The report has been completed and is available through various online NPS outlets (<https://irma.nps.gov/DataStore/Reference/Profile/2253268>).

United States Fish and Wildlife Service

In 2019, the FWS will conduct four monitoring trips on the Little Colorado River to generate population estimates for humpback chub and other native fishes, and to also monitor the success of upstream translocations. The FWS will continue to work cooperatively with the NPS and Havasupai Tribe on monitoring Havasu Creek and collecting larval fish for additional translocations of humpback chub in the summer of 2019. Fish will be collected for translocations from the Little Colorado River and held at the Southwest Native Aquatic

Resources and Recovery Center until they are large enough to be marked with a small tag. The FWS will continue to take the lead on refining and implementing a monitoring protocol for effectively sampling the mainstem aggregations of humpback chub and will conduct two sampling trips in 2019.

United States Geological Survey

The major focus of the GCMRC's activities in 2019 is to continue to serve in its role as the primary science provider to the AMP by conducting the field and laboratory studies described in the fiscal years 2018-2020 Budget and Work Plan. Additionally, the GCMRC plans to continue providing real-time scientific data needed to implement the LTEMP. Specifically, the GCMRC will maintain its internet-based real-time reporting of stream flow, water quality, and sediment storage and transport in Marble and Grand canyons as well as continue providing estimates of the mass of sand, silt, and clay supplied to the Colorado River by the Paria and Little Colorado rivers and the mass of fine sediment stored in various parts of Marble and Grand canyons. Native and non-native fish population data will continue to be collected and reported on in support of management decisions regarding recovery of humpback chub, maintaining the Lees Ferry sport fishery, and control of non-native fish and aquatic invasive species. The GCMRC economist and collaborators will begin implementation of focus groups with Navajo Nation tribal members at chapter houses in 2019. The GCMRC will continue monitoring and reporting on the condition of resources identified in the LTEMP before and after HFEs as well as in response to bug flows and any other flow experiments. The GCMRC will also work with Reclamation in refining experimental planning protocols.