Grand Adaptation: A Dammed River and a Confluence of Interests

By Jennifer Sweeney and Paul Hirt

When the diversion tunnels closed at the newly constructed Glen Canyon Dam in March 1963, the formidable Colorado River and the ecological processes it supported in Grand Canyon changed forever. The volume of water downstream of the dam was reduced to a fraction of its normal flow as the barricaded river began to inundate the canyon behind it. Lake Powell, the second largest reservoir in the country, was so enormous that it took seventeen years to fill. When hydropower generation began in the mid-1960s, variations in the river's flow changed from the relatively predictable pre-dam rhythms based on seasonal temperatures and precipitation to correspond instead to the sharp peaks and valleys of electricity demand as the U.S. Bureau of Reclamation timed water releases from the dam to optimize hydropower generation. The water level in the river often fluctuated fifteen feet in a single day.

Hydropower interests appreciated the new river management regime, but river runners and environmental advocates grew increasingly troubled by the impact of dam operations on river recreation

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Glen Canyon Dam site, looking upstream in August 1959. Photograph by A. E. Turner, U.S. Bureau of Reclamation. PC1000, Box 16, Glen Canyon Dam, Arizona Historical Society–Tucson Collections.

and on the natural and cultural resources that made Grand Canyon exceptional: sandy beaches along the river, archaeological sites and sacred places, fish, birds, mammals, and insects. Often working in tandem with concerned scientists, environmental advocates worked for decades to mitigate the impacts of the dam and protect natural conditions in Grand Canyon's inner gorge. Their efforts eventually led to passage of the 1992 Grand Canyon Protection Act, which required a science-based, collaborative decision-making process to determine how best to modify dam operations to protect natural and cultural resources in Grand Canyon.

Four years later, the federal government completed a landmark environmental impact statement (EIS) on Glen Canyon Dam operations that was mandated by the Grand Canyon Protection Act. It documented the dam's impacts on downstream resources and delineated a program of adaptive management. The resulting Glen Canyon Dam Adaptive Management Program (GCDAMP) has brought diverse stakeholders together for over twenty years in an attempt to make research-based decisions that balance Glen Canyon Dam hydropower operations with the protection of resources in Grand Canyon. It is a complex and sometimes contentious confluence of competing interests forced to work together to recommend to the secretary of the interior how best to modify dam operations to comply with the goals of the Grand Canyon Protection Act. It is just one of many focal points where contending interests struggle over the Colorado River. Other struggles include water allocations among the seven basin states, unresolved tribal water rights claims, regional electric-power marketing, and climate change–induced drought contingency plans—all of which intersect in important ways to influence river and dam management in the Southwest. As Grand Canyon scientist and river runner Larry Stevens has noted, "There is more politics than water in the Colorado River."[1]

The Problem and the Players

Before adaptive management was formally implemented in 1997, regular daily releases through Glen Canyon Dam were dictated by hydropower demand. The resulting fluctuations in river level might

[1] Larry Stevens, interview by Paul Hirt, February 6, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 5.

have been the most noticeable effect of dam operations, but they were far from the only one. The river became much colder because the water that came through the dam was drawn from the shady depths below the surface of the reservoir. Colder water altered fish habitats. Water chemistry and sediment loads shifted dramatically, too, as the dam blocked the transport of organic matter and silt, which settled and accumulated in Lake Powell. These and other changes profoundly altered riverine ecosystems and impacted fish, plants, animals, people, and archaeological sites along the river.

Some people saw these changes as acceptable trade-offs for the flood control, water storage, and hydropower benefits provided by Glen Canyon Dam and Lake Powell. Others saw the alterations of the natural river as an unacceptable degradation of nature within a national park. There are hundreds of large dams in the United States impacting rivers and their ecosystems in similar ways. What makes this particular conflict different is its impact on Grand Canyon National Park, one of the nation's most famous and prized wilderness parks, lying just a few miles downstream of Glen Canyon Dam. National parks are supposed to protect nature and preserve natural ecological processes permanently for the benefit of present and future generations. As one Grand Canyon National Park administrator put it, the National Park Service (NPS) is "in the *forever* business. We're stewards of this place and we need to pass it on in at least as good, if not better condition than we found it."[2]

While the voices defending Glen Canyon Dam and its economic benefits to the region carried great weight in the public debate, so too did those voices defending the sanctity of Grand Canyon National Park. Throughout the 1970s, as the impacts of the dam grew increasingly consequential, the debate over the dam spread wider and grew more energetic, getting attention in Washington, D.C. The first people to raise alarms about Glen Canyon Dam's impact on the river through Grand Canyon were whitewater rafters and environmentalists in the 1970s.[3] Because the Bureau of Reclamation managed the daily operation of the dam to meet electric power needs in the greater Southwest, summer water flows in the river below the dam increased steeply in the

[2] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 34.

[3] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, p. 2; Larry Stevens, interview by Paul Hirt, February 6, 2017, pp. 5, 8.

afternoon to meet air-conditioning loads, then dropped back to a relative trickle in the overnight and early morning hours. This high daily fluctuation of river flows created unnatural and problematic conditions for river runners.[4] Groups might land at a beach for the night, leaving their rafts afloat but tethered to shore, then wake up in the morning with the water level fifteen feet lower and their rafts stranded far from the river, requiring the party to unload the boats, drag them to the water, then reload everything. Farther downriver, the opposite problem could occur. A group might stop and set up camp on a riverbank sandbar in the afternoon, then find their boats floating into camp in the evening as the water levels rose, requiring everyone to hastily disassemble and move camp to higher ground. Sometimes boats and equipment washed away in the high water.[5]

The loss of sand beaches for camping plagued river runners in another way. Because the vast majority of the river's sediment was now trapped behind Glen Canyon Dam, every high-water event was now an opportunity for the Colorado River to remove sand rather than deposit it. Year by year, many favored camping beaches grew smaller.[6] Additionally, because the Bureau of Reclamation stored most of the spring snowmelt in Lake Powell, allowing only as much water past the dam as needed for hydropower generation, the downstream river stopped getting the cleansing, runoff-fed annual floods that formerly washed away much of the vegetation colonizing the sand beaches. Shrinking and covered in shrubby vegetation, the beaches' utility for campers was sharply reduced.[7]

Only a small number of people rafted through Grand Canyon in the first years after Glen Canyon Dam was completed, so few were directly affected by the fluctuating water levels. Thanks largely to the pioneering work of early commercial river runners like Martin Litton and Georgie White, who started guiding paying passengers through Grand Canyon in wooden dories and rubber rafts in the 1950s, whitewater rafting in the canyon became a big business by

[4] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, p. 2.
[5] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, November 29, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 46.
[6] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, November 29, 2017, p. 29.
[7] Mike Yeatts, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 19–20.

the late 1960s, leading to a sustained boom in river-based recreation.[8] No more than seventy people traveled down the Colorado River in 1955, but by 1972 the number of people floating through Grand Canyon topped 16,400.[9] This whitewater-rafting boom spread throughout the United States in the 1960s and 1970s, spurred in part by the rise of the modern environmental movement heralded by the nation's first Earth Day celebration in April 1970. Americans clamored to experience the outdoors by the tens of millions. Many of them joined organizations like the Sierra Club, the Wilderness Society, and the Nature Conservancy.[10] This provided an effective constituency for professional and amateur river guides who encouraged clients, many of them wealthy and influential, to express their concerns to elected officials about the radically fluctuating flow and the shrinking beaches of the newly engineered river in Grand Canyon. In fact, river runners sued the Bureau of Reclamation in 1974, claiming Glen Canyon Dam operations interfered with their ability to conduct river trips.[11]

Arizona political luminaries Senator Barry Goldwater and Governor Bruce Babbitt were among the outdoors enthusiasts who took river trips through Grand Canyon in these early years. In fact, legendary river runner Norm Nevills took Goldwater whitewater rafting from Green River, Utah, to Hoover Dam in 1940, commemorating a bit of the original John Wesley Powell expedition and making Goldwater among the first hundred people to raft Grand Canyon! In 1970, the Arizona Historical Foundation published Goldwater's diary from that trip in a book titled *Delightful Journey.*[12] Goldwater then ran the Glen and Grand Canyons again with his family in 1964. In an oral history interview with Grand Canyon River Guides late in his life, Goldwater reflected on those trips and other matters related to the river and Grand Canyon.[13]

[8] For brief sketches of the rise of river running through Grand Canyon and its early commercial guides, see "Nature, Culture, and History at the Grand Canyon" website, http://grcahistory.org/history/colorado-river/running-the-river/; and also "Canyoneers" website https://canyoneers.com/about-us/canyoneers-story/ (accessed September 17, 2019).

[9] Richard E. Westwood, *Woman of the River: Georgie White Clark, White Water Pioneer* (Logan, Utah, 1997), 189.

[10] Adam Rome, *The Genius of Earth Day* (New York, 2013), 47–56.

[11] *Grand Canyon Dories v. Walker*, 1974, available online at http://www.riversimulator.org/Resources/Legal/GCD/GCDoriesComplaint.pdf (accessed September 17, 2019).

[12] Barry M. Goldwater, *Delightful Journey Down the Green & Colorado Rivers* (Tempe, Ariz., 1970).

[13] Barry Goldwater, interview by Grand Canyon River Guides, May 5, 1994, transcript,

Bruce Babbitt, who has taken dozens of rafting trips through Grand Canyon in his lifetime, explained in a 2018 oral history interview that he "started awakening" to changes along the river by the 1970s. "From trip to trip, you could see the way the sand was being totally stripped away," he recalled. On one journey, trip leader Martin Litton had to delay the group's run of Hance Rapid to avoid running aground and being stranded on rocks because the river level had dropped so low. "That was kind of the point at which I really sort of viscerally started to make the connection between . . . [the] river being manipulated for hydro demand," Babbitt recalls, and "[w]hat it was doing in terms of all the downstream ecology." Two decades after that experience, Babbitt was appointed secretary of the interior during the Clinton Administration. In that position he was instrumental in implementing adaptive management in Grand Canyon, a concept essential to the Grand Canyon Protection Act and the decisions that would successfully reduce high fluctuating flows to mitigate the impact on both the river and recreationists.[14]

The next set of key players in the GCDAMP are the federal and state agencies responsible for the management of land, water, infrastructure, and hydropower in the region. There are five of them, each with a unique mandate and set of responsibilities. The two main agencies are the U.S. Bureau of Reclamation and the National Park Service. The Bureau of Reclamation manages Glen Canyon Dam, including its hydropower generation. The National Park Service manages both Grand Canyon National Park and the Glen Canyon National Recreation Area surrounding Lake Powell. Responsibility for protecting and recovering endangered species in the river, the reservoir, and the canyon falls under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS). While tribal interests (discussed more fully below) are key players in the GCDAMP, the federal Bureau of Indian Affairs (BIA) also plays a role, though recently it has become somewhat secondary to the tribes. The Bureau of Reclamation, the National Park Service, the U.S. Fish and Wildlife Service, and the Bureau of Indian Affairs are all agencies within the Department of the Interior. They operate under different agency directors and fulfill different mandates

Grand Canyon River Guides Oral History Collection, http://archive.library.nau.edu/digital/collection/cpa/id/110428 (accessed September 19, 2019).

[14] Bruce Babbitt, interview by Paul Hirt, September 21, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 3–5.

but are ostensibly united under one cabinet secretary: the secretary of the interior. All these agencies have a role and representation in the GCDAMP established in 1997, although they have not always spoken with one voice.

The complexity does not end there, however. Management of the federal hydropower system in the Southwest, comprising a whole suite of federal dams in the Colorado River Basin and its tributaries, is coordinated through the Western Area Power Administration (WAPA), which is part of the U.S. Department of Energy (DOE). Finally, management of sport fishing (seasons, limits, and licenses) below Glen Canyon Dam but outside Grand Canyon National Park is the responsibility of a state agency—the Arizona Game and Fish Department (AZGFD). Recreational fishing interests (e.g., Trout Unlimited) are also among the important stakeholders involved in the GCDAMP. They are sometimes allied with environmental groups and sometimes not, depending on the issue. For example, non-native rainbow trout were stocked in the Colorado River below Glen Canyon Dam to support a thriving sport fishery in its newly clear and cold waters. But those and other introduced fish are seen by some as "invasive" species that displace native fish, some of which are endangered, like the humpback chub.[15] In practice, the larger group of conservationists is actually a diverse coalition with sometimes conflicting goals.[16]

Among the two most important federal agencies, the National Park Service has a preservation mission with a focus on human engagement with the natural environment while the Bureau of Reclamation has a water resource development mission, with a focus on water supplies for irrigation, municipal, and industrial uses. Over the years, Reclamation has emphasized hydropower generation at its dams to pay for the large water-supply infrastructure costs. Clearly, there is tension between the preservation and development missions of these two agencies. At the inception of the GCDAMP and for some years thereafter, Bureau of Reclamation leaders evinced the somewhat chauvinistic attitude that they were engaged in more important work than the preservationists, and

[15] Mike Yeatts, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, pp. 24–25.

[16] Anne Castle, interview by Paul Hirt, March 26, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, Part Two, 12; Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, December 4, 2017, pp. 11–12.

that their engineering expertise justified more closed and insular decision-making regarding management of the dam. One of the long-term accomplishments of the GCDAMP was to change that attitude and open up decision-making to a broader array of stakeholders and values.[17]

Regional tribes and their consulting archaeologists are another category of major players in the GCDAMP. Tribal interests had to push hard to get to the table and to get their interests and values respected.[18] The National Park Service now recognizes eleven tribes with cultural and historical ties to Grand Canyon, although in the 1980s only five were involved directly in consultations with the park: the Navajo, Hopi, Zuni, Havasupai, and Hualapai.[19] Although some tribes were consulting with the National Park Service about Grand Canyon matters, none were involved in the studies of Glen Canyon Dam's impact on the Colorado River until 1990.[20] In a 2018 interview, Grand Canyon National Park archaeologist Jan Balsom acknowledged with a little embarrassment that professional archaeologists were still not working much with the tribes as recently as the early 1990s. Balsom says the tribes willingly engaged in the formal Glen Canyon Dam environmental impact statement process after 1990 to ensure their interests were represented, admitting this was unusual at the time but served as a good precedent for the GCDAMP.[21]

State water interests and regional hydropower interests also have representation on the GCDAMP. Each of the seven basin states has a representative, usually someone from a state water agency, to ensure that their water interests are protected in the adaptive management negotiations. Organizations that market hydropower from federal dams are also represented on the GCDAMP. The two groups with permanent representation are the Colorado River Energy Distributors Association (CREDA) and Utah Associated Municipal Power (UAMP). They seek to minimize the impact

[17] Bruce Babbitt, interview by Paul Hirt, September 21, 2018, p. 4.

[18] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 4–6. This is a recurring theme in Kuwanwisiwma's interview and is also a primary topic in oral history interviews with Jan Balsom, Kurt Dongoske, Larry Stevens, and Mike Yeatts.

[19] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, p. 8.

[20] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, pp. 1–2.

[21] Jan Balsom, interview by Paul Hirt, September 7, 2018, pp. 7, 10.

adaptive management decisions have on hydropower availability and price.

The final group of key players in the development and implementation of the adaptive management program are the biological and physical scientists who provide the foundational research regarding the dam's impacts and evaluate the likely outcomes of proposed management actions. Interestingly, people in this group sometimes overlap with other stakeholder groups like river runners and fisheries advocates. As Babbitt noted in his oral history interview, the early river trips he took through Grand Canyon fulfilled his joint interest in recreation *and* science. Babbitt studied geology in college and was particularly interested in fluvial geomorphology—the study of how rivers change over time and interact with sediment to shape the riverine environment. Likewise, many early Grand Canyon river runners were scientists, and even those who were not scientists often appreciated and studied science in order to become lay experts on the landscape they loved. Larry Stevens, who is one of the longest-serving members of the GCDAMP, began doing research on Glen Canyon Dam's effects on riparian vegetation in 1980 as a graduate student at Prescott College and has been involved in Grand Canyon research ever since. He now serves as director of the Springs Stewardship Institute at the Museum of Northern Arizona. Stevens is a well-known river runner in his own right, who wrote one of the most popular river guidebooks available for Grand Canyon.[22]

Despite the close connection between those who study natural ecosystems and those who seek to preserve them, many scientists, especially those associated with the "science provider" for GCDAMP, the Grand Canyon Monitoring and Research Center (GCMRC), have sought to claim a separate status from the formal "stakeholders" who represent a particular interest group or set of values. There is consequently some recurring tension between scientists and environmentalists. Environmental representatives on the GCDAMP are unapologetic "advocates" for environmental goals and values. They represent an interest group focused on protecting natural resources and ecological processes, endangered species, and wilderness. Science, in contrast, is about data collection,

[22] Larry Stevens, *The Colorado River in the Grand Canyon: A River Runner's Map and Guide to Its Natural History and Human History* (Flagstaff, Ariz., 2013).

hypothesis testing, cause and effect evaluation, and analytical-tools development. It seeks knowledge and understanding, not necessarily values and policies. As Larry Stevens emphasized in his oral history interview: "As scientists, we are not advocates . . . except for advocates for good science."[23] While an advocate's job is to articulate a policy preference—defend a set of values or biases—a scientist is supposed to constantly question his or her biases.[24] But that can be a tightrope to walk, since no one is really free of personal and cultural biases.[25]

All these major players have been arrayed in a shifting and contentious political environment, attempting to understand and address the impacts of Glen Canyon Dam on the downstream environment through Grand Canyon. Some wanted to defend the status quo, others to change it. Some wanted years of research conducted prior to taking action, others wanted action right away. Some claimed to speak for an interest group, others called only for good science and a fair decision-making process. Yet everyone agreed on the immediate need for better information on the dam's impact on the river. And that is where the formal process started.

Glen Canyon Environmental Studies Phases I and II

Under pressure from river runners, environmentalists, and members of Congress, Secretary of the Interior James Watt in December 1982 authorized the Bureau of Reclamation to begin a study of Glen Canyon Dam's impact on downstream resources. Part of the impetus for the study resulted from Reclamation's desire to "rewind" the generators at Glen Canyon Dam to increase their power-generating capability. Environmentalists claimed this was a major federal action that required a time-consuming environmental impact statement. James Watt assiduously wanted to avoid doing this kind of study, so he authorized an alternative: Glen Canyon Environmental Studies (GCES).[26] Watt hoped the science program would calm the waters, so to speak, but did not expect it to last more than a

[23] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 3.
[24] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 14.
[25] Kurt Dongoske, interview by Paul Hirt and Jennifer Sweeney, August 15, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 23.
[26] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, Part One, 2–3.

few years and did not favor making any significant changes in dam operations. By 1982, Watt had made a name for himself as one of the most anti-environmental interior secretaries in United States history. His controversial tenure lasted less than one term of the Reagan Administration before he resigned under a cloud of acrimony in 1983.[27]

The Bureau of Reclamation hired a young scientist named Dave Wegner to run Glen Canyon Environmental Studies. Wegner had worked for Reclamation since 1975, doing aquatic ecology and engineering studies for the Central Utah Project. In 1977, he went back to school for a master's degree in river engineering (fluvial geomorphology), funding his studies with contract work for the U.S. Fish and Wildlife Service. In 1980, degree in hand, he returned to the Bureau of Reclamation, working on water-quality issues for the Upper Colorado River Regional Office in Salt Lake City. Hiring Wegner in 1983 to run Glen Canyon Environmental Studies proved to be a consequential decision for Reclamation. He remained in charge until 1996, overseeing two distinct phases of the program and laying down institutional groundwork that has endured to the present day. Larry Stevens, who worked on Glen Canyon Environmental Studies under Wegner's tenure, claimed Wegner "pretty much single-handedly turned the battleship of the Bureau of Reclamation ninety degrees to bring it into an open social process, active science, tribal engagement, and a dialogue about how to manage, rather than a monolithic, in-house kind of effort."[28]

The period from 1982 to 1989 came to be known as Glen Canyon Environmental Studies Phase I, in which research primarily focused on the effects of the dam on downstream resources. According to Larry Stevens, scientific studies during this first phase took a "shotgun approach" at first because so little was known.[29] Quality fieldwork took a long time and results were often inconclusive. There were so many questions to ask, data to collect, research protocols to develop and test in the field, measurement tools to invent and improve. The first years of the program mainly tried to lay down a baseline of knowledge about the system and sketch out initial hypotheses about which ecosystem changes might be

[27] David Hoffman, "Watt Submits Resignation as Interior Secretary," *Washington Post*, October 10, 1983.
[28] Larry Stevens, interview by Paul Hirt and Jennifer Sweeney, February 6, 2017, p. 12.
[29] Larry Stevens, interview by Paul Hirt and Jennifer Sweeney, February 6, 2017, p. 3.

attributed to the dam's operation versus other factors. Uncertainty ruled the roost. This was understandable but also frustrating to environmentalists and river runners, who wanted quicker action to fix the problems, and policymakers, who wanted scientists to pinpoint causation and settle debates with some degree of certainty.

Ironically, Glen Canyon Environmental Studies I launched during a year in which river flows were entirely unlike any since the Bureau of Reclamation closed the dam gates in 1963. A wet El Niño year, exacerbated by a volcanic eruption, precipitated near record snowpack in the Rocky Mountains, the headwaters of the Colorado and Green Rivers.[30] Extremely high flows had to be released from Glen Canyon Dam in 1983 to maintain the integrity of the structure. Bureau of Reclamation administrators were sweating bullets, desperately hoping the dam's spillways would hold.[31] In the middle of the flood stage a daring (or crazy) group of river runners decided to raft the floodwater to break the Guinness record for the fastest run through Grand Canyon. The experience was immortalized in Kevin Fedarko's riveting book, *The Emerald Mile*.[32] This was quite a contrast to the previous two decades, as Reclamation had been holding back significant amounts of annual flow in order to fill Lake Powell right up until 1980. In 1983 and 1984, the region's floodwaters were being released for months straight through a river corridor that had not seen such flows for decades.[33] Now everyone was paying attention to Glen Canyon Dam and the Colorado River through Grand Canyon.

In May 1988, the U.S. Department of the Interior published its Glen Canyon Environmental Studies Final Report. The report concluded that: (1) more studies were needed, especially on the impact of fluctuating flows on beaches, sediment, and endangered species; (2) dam operations should be modified to reduce daily flow fluctuations, limiting high flows to 31,500 cubic feet per second (cfs) and maintaining a minimum flow of 3,000–5,000 cfs; (3) a coordinating committee should be set up to formalize cooperation among the Bureau of Reclamation, the National Park Service, the U.S. Fish and

[30] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 8.

[31] Cliff Barrett, interview by Paul Hirt, Joshua MacFadyen, and Jennifer Sweeney, May 15, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 27.

[32] Kevin Fedarko, *The Emerald Mile: The Epic Story of the Fastest Ride in History through the Heart of the Grand Canyon* (New York, 2013).

[33] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, pp. 1–2.

Wildlife Service, and the Western Area Power Administration; and (4) a formal National Environmental Policy Act (NEPA) process should be initiated to develop a full environmental impact statement.[34]

This 1988 Glen Canyon Environmental Studies "final report" provided no real resolution of problems or satisfaction for stakeholders, so debate continued, along with the threat of litigation and congressional legislation. In 1989, following the recommendations of the final report, George H. W. Bush's interior secretary, Manuel Lujan, agreed to launch a full environmental impact statement to comply with the National Environmental Policy Act and get more clarity on a recommended program of action to modify dam operations.[35] This more formal and comprehensive environmental analysis launched Glen Canyon Environmental Studies Phase II, which lasted until October 1996 and resulted in the environmental impact statement mentioned earlier that established the GCDAMP. Looking back on this period, Larry Stevens observed that "Glen Canyon Environmental Studies Phase I pointed to the dam as having a large impact on the system. The Department of the Interior came back and said, 'Ok, so if it's having an effect, what are the effects and can we modify them by modifying dam operations?' So Phase II was about pursuing those questions."[36]

In the middle of that second phase of Glen Canyon Environmental Studies, Congress debated and passed the Grand Canyon Protection Act (Public Law 102-575), which had five key components. First, it directed the secretary of the interior to modify the operation of Glen Canyon Dam in such a way as to "mitigate adverse impacts to and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established" (Sec. 1802). Second, it required the secretary of the interior to complete the environmental impact statement process and publish a record of decision (ROD) by 1996, meaning the Bureau of Reclamation could not "slow ball" the study in its

[34] U.S. Department of the Interior, "Glen Canyon Environmental Studies Executive Review Committee Final Report" (May 1988), available online at http://archive.library.nau.edu/utils/getfile/collection/cpa/id/61166/filename/61167.pdf (accessed September 18, 2019).

[35] U.S. Bureau of Reclamation, "Record of Decision, Operation of Glen Canyon Dam Final Environmental Impact Statement" (October 1996), 2, available online at https://azmemory.azlibrary.gov/digital/collection/p17220coll7/id/781/ (accessed September 18, 2019).

[36] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 9.

reluctance to implement changes to the dam's historic operations (Sec. 1804).[37] These two components of the law pleased environmental interests.

But, like most legislation, the Grand Canyon Protection Act was a compromise that included language designed to appease those who felt threatened by the environmental protection language in the law. Accordingly, the third major component of the Grand Canyon Protection Act stipulated that any changes to the operation of Glen Canyon Dam would be fully consistent with and subject to what is commonly referred to as the Law of the River: 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 (Sec. 1802, 1803, 1806).[38] Essentially, Congress told the secretary of the interior to modify dam operations to mitigate negative impacts on the river in Grand Canyon, but not to do anything contrary to the existing Law of the River. That gave each side something to bank on but left a lot of room for continued disagreement over the degree to which dam operations could or should be modified.

The fourth key feature of the Grand Canyon Protection Act was the requirement to set up a collaborative stakeholder decision-making process, designed in part to prevent river management from falling into litigation by giving stakeholders a voice and facilitating communication and compromise. It expanded on the recommendation in the Glen Canyon Environmental Studies Phase I Final Report to establish a more formal consultation process between the federal agencies by mandating that federal agencies also collaborate with tribes, representatives from the basin states, environmental groups, recreation and fishing interests, power interests, and other stakeholders (Sec. 1805). This signaled a significant shift from standard operating procedure in which the Bureau of Reclamation

[37] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part One, p. 13. Wegner refers to the potential for USBR to "slow ball" the EIS study.

[38] "The Law of the River," U.S. Bureau of Reclamation website, https://www.usbr.gov/lc/region/g1000/lawofrvr.html (accessed September 18, 2019).

typically made decisions about dam operations without consulting with environmental groups, tribes, or other stakeholders beyond the traditional water and power interests.

The final feature of lasting significance in the Grand Canyon Protection Act was the requirement to engage in adaptive management by maintaining a program of long-term research and monitoring of the environmental effects of modifications to dam operations, to learn whether actions were effective in accomplishing the objectives of the law (Sec. 1805). All of these elements laid out a roadmap for what in 1997 would become the Glen Canyon Dam Adaptive Management Program.

Moving Toward Adaptive Management in Grand Canyon

Carl Walters, University of British Columbia professor emeritus, is one of the architects of the modern adaptive management concept. Walters's resource-management philosophy embraces experimentation, anticipates uncertain outcomes, and prioritizes "learning by doing."[39] He began implementing his ideas on a large scale in Canada and the United States in the 1970s, sometimes working under contract to the U.S. Fish and Wildlife Service.[40] By the time Walters got involved with Glen Canyon Dam issues in 1996, his work was familiar to most scientists involved with Grand Canyon research.

As early as 1987, scientists explored the adaptive management concept as a strategy for dealing with the complexity of resource pressures in Grand Canyon. That year, Dave Wegner made a presentation on adaptive management to the Glen Canyon Environmental Studies Executive Review Committee, describing programs in other parts of the country. He pushed the idea to legislators and policymakers that scientific research on the Grand Canyon ecosystem and Glen Canyon Dam operations had to emphasize monitoring because so little was known about how ecosystems might respond to management actions and modified dam operations: "we're not gonna be able to know everything going into this."[41]

[39] Carl J. Walters and C. S. Holling, "Large-Scale Management Experiments and Learning by Doing," *Ecology* 71 (Dec. 1990): 2060–68.

[40] Carl Walters, interview by Paul Hirt and Jennifer Sweeney, August 8, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 2.

[41] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part One, p. 16.

Wegner's frequent collaborator on environmental protection issues, U.S. Representative George Miller of California, shepherded inclusion of the adaptive management concept into the Grand Canyon Protection Act and, subsequently, into the 1995 environmental impact statement. Carl Walters recalls the Bureau of Reclamation's fondness for using the Law of the River as an "excuse for inaction" with regard to modifying Glen Canyon Dam operations.[42] "Decisive action generally has immediate and obvious costs" for federal agencies, Walters observed, "ranging from loud outcries from affected economic interest groups to the risk of embarrassment if the policy does not perform as expected. On the other hand, the costs of inaction are seldom so immediate," encouraging agencies to sit back and see if contentious issues resolve on their own. "It should not surprise us at all to see a remarkable range of excuses used to delay the difficult decisions needed to implement a significant program of experimental management."[43]

During the preparation of the environmental impact statement, the secretary of the interior designated the Bureau of Reclamation as the lead agency, in cooperation with the Bureau of Indian Affairs, the National Park Service, the U.S. Fish and Wildlife Service, the Western Area Power Administration, and the Arizona Department of Game and Fish. In 1990, these "cooperating agencies," along with representatives of non-governmental interests, convened at a workshop to deliberate the issues of concern unearthed by public scoping meetings conducted earlier in the year, which had yielded over seventeen thousand comments. An environmental impact statement team consisting of individuals from some of the cooperating agencies, in consultation with Glen Canyon Environmental Studies scientists and other experts, was tasked with devising feasible dam operation alternatives to address public concerns. They considered eight water flow alternatives to the historic dam operations baseline, with resource protection objectives in mind that they termed "common elements." These included maintaining water quality, bolstering humpback chub numbers, building or maintaining beaches and riverine

[42] Carl Walters, interview by Paul Hirt and Jennifer Sweeney, August 8, 2018, p. 19. Walters believes that both the Bureau of Reclamation and the National Park Service are still extremely conservative in their management policy choices.

[43] Carl Walters, "Challenges in Adaptive Management of Riparian and Coastal Ecosystems," *Conservation Ecology* 1 (Dec. 1997): 13.

habitats, preserving cultural resources, and reducing unscheduled high-water releases.[44]

To propose and monitor specific alterations to Glen Canyon Dam's operations, the environmental impact statement called for the creation of an Adaptive Management Work Group (AMWG) to include the cooperating agencies, a representative from each of the Colorado River Basin states, and representatives from hydropower contractors, recreational groups, and environmental organizations.[45] The 1997 AMWG charter laid out the purpose, structure, and responsibilities of the group of stakeholders entrusted with facilitating the GCDAMP.[46] AMWG reports to the secretary of the interior through the secretary's designee, who chairs the group, and it functions as a Federal Advisory Committee. Such bodies, authorized by the 1972 Federal Advisory Committee Act, are intended "to bring together various experts—often with divergent opinions and political backgrounds—to examine an issue and recommend statutory, regulatory, or other actions."[47] Their proceedings are open to the public. Larry Stevens describes GCDAMP's AMWG as a stool with three legs: policy, recommended to and implemented by agencies; science, guided by AMWG and conducted in large part by the Grand Canyon Monitoring and Research Center; and social process, played out among the stakeholders in the adaptive management program.[48]

Despite their obvious connections to Grand Canyon, Indigenous groups were not invited to participate in the Glen Canyon Environmental Studies program nor in the early development of the environmental impact statement process. Instead, a Bureau of Indian Affairs representative had been designated to stand in for all the tribes that nurtured a connection to Grand

[44] U.S. Bureau of Reclamation, "An Assessment of the Environmental Impact Statement on the Operations of the Glen Canyon Dam" (October 1996), 23.

[45] U.S. Bureau of Reclamation, "Operation of Glen Canyon Dam Colorado River Storage Project, Arizona, Final Environmental Impact Statement" (March 1995), 36.

[46] "Charter, Adaptive Management Work Group," filed February 4, 1997, in "Glen Canyon Dam Adaptive Management Program: Roles, Responsibilities, Schedules and Process Integration," appendix 9, p. 97, available online at http://www.riversimulator.org/Resources/GCMRC/AdaptiveManagement/GCAMWG1998.pdf (accessed September 19, 2019). FACA requires committees to produce a charter.

[47] Wendy R. Ginsberg, "Federal Advisory Committees: An Overview" (Congressional Research Service, April 16, 2009), 1.

[48] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 13.

Canyon.[49] Leigh Kuwanwisiwma, Hopi cultural preservation officer from 1988 to 2018, recalled reading a newspaper notice in 1990 for an upcoming meeting in Flagstaff on Glen Canyon Dam. Curious, Kuwanwisiwma attended the meeting and realized that it was about the environmental impact statement process. "That was how I got a whiff of something happening" in Grand Canyon, he says. "Nobody came to the Hopi" or any of the surrounding Indigenous communities.[50] Kuwanwisiwma was the only Native person at the meeting, and once he returned to Hopituskwa he convinced fellow tribal members to lobby for participation in the environmental impact statement process. Not until the passage of the Grand Canyon Protection Act in 1992 did tribal involvement become formalized. Initially the Hopi Tribe, Hualapai Tribe, and Navajo Nation were included as cooperating agencies and added to the environmental impact statement team. Later in the process, the Pueblo of Zuni, San Juan Southern Paiute Tribe, and Southern Paiute Consortium also joined the group of cooperating agencies. The final environmental impact statement report is clear on the government's obligation to include Native connections to significant sites on federal lands in its decision-making processes, although tribal representatives have found it consistently difficult to convey the validity of the Indigenous traditional ecological knowledge base to the Grand Canyon research establishment.[51]

Establishment of the Grand Canyon Monitoring and Research Center

The 1995 final environmental impact statement acknowledged long-term research and monitoring as the core of the adaptive management program and proposed a science center to coordinate that research. Founded in November 1996, the Grand Canyon Monitoring and Research Center in Flagstaff is commonly called the "science provider" for GCDAMP. Because the Grand Canyon

[49] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, pp. 1–2.

[50] Leigh Kuwanwisiwma, interview by Paul Hirt, September 8, 2018, p. 1.

[51] Kurt E. Dongoske, Loretta Jackson-Kelly, and Charley Bulletts, "Confluence of Values: The Role of Science and Native Americans in the Glen Canyon Dam Adaptive Management Program," in Theodore Melis et al., "Proceedings of the Colorado River Basin Science and Resource Management Symposium, November 18–20, 2008, Scottsdale, Arizona" (Grand Canyon Monitoring and Research Center, 2010), 135.

Protection Act stipulated that funding for research and monitoring would come from the Bureau of Reclamation's hydropower revenues, the initial research programs were coordinated by Reclamation and the Grand Canyon Monitoring and Research Center was originally a subdivision of that agency. Bruce Babbitt wanted the GCDAMP science center to be independent rather than subject to the Bureau of Reclamation's institutional perspectives and priorities. In 1995, he tapped longtime professional acquaintance Dave Garrett, a proponent of adaptive management, to delay his planned retirement and help implement Babbitt's vision. Garrett had a background in forestry and a penchant for bringing underrepresented groups into resource-management processes. He was named chief of the Grand Canyon Monitoring and Research Center at the center's inauguration. Garrett took on the parallel task of leading an informal Transition Work Group, comprised of a selection of future AMWG stakeholders, in an attempt to transfer the Glen Canyon Environmental Studies body of knowledge and experience into the adaptive management program. This "proved to be challenging" because Glen Canyon Environmental Studies Phase II Program director Dave Wegner decided not to stay on during the transition to GCDAMP.[52]

Challenges continued as the complexities of implementing a new program model, managing a compromised ecosystem, and working with a diverse group of stakeholders bubbled to the surface. Effecting a democratic process to determine what research would be funded was "difficult, because many people wanted to do things the way they'd always done. Cut deals on the side," Garrett recalls. Although it stopped after the first three years, "I had people coming to me and wanting to influence me."[53] Within the program, research and funding discussions between the Grand Canyon Monitoring and Research Center and AMWG often devolved into fruitless arguments. The Technical Work Group (TWG) was devised as an intermediary between the science director of the Grand Canyon Monitoring and Research Center and the "policy people" in AMWG, smoothing contentious interactions and presenting a

[52] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, December 4, 2017, p. 3.

[53] Dave Garrett, interview by Paul Hirt and Jennifer Sweeney, August 9, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 23.

united GCDAMP front to the secretary of the interior.[54] Garrett resigned from the Grand Canyon Monitoring and Research Center in 1998. In 2000, the Department of the Interior finally moved the center from the Bureau of Reclamation into a more independent science agency, the U.S. Geological Survey (USGS), a decision in which Babbitt was not involved.[55]

Conflict and Consensus: AMWG Meets on the Colorado River

Much of the research that underpins GCDAMP happens on Colorado River boat trips. In order to secure funding and to cement their participation in the environmental impact statement and adaptive-management processes, Hopi representatives drafted their own scientific study plan in the early 1990s, centered on river research trips. The study trips continue to this day, fostering camaraderie among the Hopi research crews and agency scientists and reinforcing the tribe's intimate connection with the canyon. On one trip, tribal members found and collected culturally significant plant materials, and on another cooked and shared "armfuls" of wild spinach harvested from the canyon walls. Leigh Kuwanwisiwma found that the river trips enhanced the nuance with which Hopis viewed the canyon, as when one team observed native birds' dependence on tamarisk, commonly derided as an invasive species.[56]

In the mid-1990s, the kind of companionable open-mindedness that marked the Hopi research trips was notably absent among the larger group of AMWG participants. Mary Orton worked as a mediator and facilitator for GCDAMP starting in late 1999 but had become aware of the program in 1997 as Southwest Regional Director for American Rivers.[57] She officially joined AMWG as representative

[54] Dave Garrett, interview by Paul Hirt and Jennifer Sweeney, August 9, 2018, p. 14.

[55] "Glen Canyon Adaptive Management Work Group (AMWG), Meeting Minutes July 6–7, 2000," p. 2, available online at http://www.riversimulator.org/Resources/GCDAMP/AMP1999toPresent/AMWG/2000/2000_07/Final_Minutes.pdf (accessed September 18, 2019); "Glen Canyon Adaptive Management Work Group (AMWG), Minutes of July 21–22, 1999 Meeting," available online at https://www.usbr.gov/uc/progact/amp/amwg/1998-07-21-amwg-meeting/Minutes_98jul21.pdf (accessed September 18, 2019); Dave Garrett, interview by Paul Hirt and Jennifer Sweeney, August 9, 2018, p. 10.

[56] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, p. 9.

[57] Mary Orton, "Glen Canyon Dam Adaptive Management Program Assessment Report" (Bureau of Reclamation, February 9, 2016), 2.

for American Rivers by early 1999.[58] At that time, she said, "there was quite a bit of conflict in the group." Although most of the disagreements were valid and civil, Orton recalls more heated interactions as well. "Almost name-calling. Ad hominem attacks. Really unproductive kinds of communication."[59] Larry Stevens remembers that around the same time, "we actually had one of the stakeholders banging his shoe on the table" in frustration.[60]

The Bureau of Reclamation's solution to this prickly atmosphere was to "put everyone on the river" for a floating AMWG meeting. One of the three vessels on the river trip was designated "the vision boat." Its passengers were responsible for drafting a vision statement for AMWG guidance. At camp one evening, the vision boat passengers presented to the group their vision statement. But Orton, who had executive experience and facilitation training, pointed out that the group had actually come up with a mission statement rather than a vision statement. She explained to the group that a mission is "what you do," while a vision is "what you want to see in the future." The interior secretary's designee, who was on the river trip, announced, "She's right." So the group asked Orton to facilitate the visioning process over the next several days, which she expanded to include all of the trip participants.[61]

Tribal representatives on the river trip wished to ask permission from Grand Canyon for their presence within it each morning. Leigh Kuwanwisiwma describes Hopi regard for the area simply, but with awe: "It is different looking down, when you see the little river, and then being down there, and seeing how massive the canyon is."[62] Tribal members led daily prayers to express their respect, inviting other AMWG travelers to participate. The experience deeply affected many in the group. "The word 'spiritual' actually ended up in the vision-mission statement," Orton recalls, adding that such language "is pretty unusual for a government group."[63]

[58] Mary Orton, interview by Paul Hirt, February 14, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 1.
[59] Mary Orton, interview by Paul Hirt, February 14, 2017, p. 8.
[60] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 5.
[61] Mary Orton, interview by Paul Hirt, February 14, 2017, p. 3.
[62] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, p. 7.
[63] Mary Orton, interview by Paul Hirt, February 14, 2017, p. 6.

"We came off that river trip with a common vision," says Andre Potochnik.[64] Because AMWG was a Federal Advisory Committee, though, the vision and mission language formulated on the trip had to be taken up again in a publicly accessible forum. With the help of detailed notes from fellow passenger Larry Stevens, Orton "developed a presentation for that [public] meeting that showed how every single person on that river trip actually contributed to the consensus language."[65] The river trip and the subsequent AMWG follow-up informally marked the beginning of Orton's seventeen-year tenure as facilitator and mediator for GCDAMP.[66]

The final draft of the combined mission and vision statement hit group members' desks in June 1999. The statement, published as part of the GCDAMP Strategic Plan in 2001, acknowledged the legal obligations and management goals inherent to the program but emphasized the intangible cultural values associated with Grand Canyon and the Colorado River.

> The Grand Canyon is a homeland for some, sacred to many, and a national treasure for all. In honor of past generations, and on behalf of those of the present and future, we envision an ecosystem where the resources and natural processes are in harmony under a stewardship worthy of the Grand Canyon. We advise the Secretary of the Interior on how best to protect, mitigate adverse impacts to, and improve the integrity of the Colorado River ecosystem affected by Glen Canyon Dam, including natural biological diversity (emphasizing native biodiversity), traditional cultural properties' spiritual values, and cultural, physical, and recreational resources through the operation of Glen Canyon Dam and other means. We do so in keeping with the federal trust responsibilities to Indian tribes, in compliance with applicable federal, state, and tribal laws, including the water delivery obligations of the Law of the River, and with due consideration to the economic value of power resources. This will be accomplished through our long-term partnership utilizing the best available scientific and other information through an adaptive ecosystem management process.[67]

[64] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, December 4, 2017, p. 5.

[65] Mary Orton, interview by Paul Hirt, February 14, 2017, p. 4.

[66] Orton, "Glen Canyon Dam Adaptive Management Program Assessment Report," 1–2.

[67] Glen Canyon Dam Adaptive Management Program, "Strategic Plan Final Draft," (GCDAMP, August 17, 2001), available online at http://www.riversimulator.org/Resources/GCDAMP/GCDAMPchronicle/StrategicPlanGCDamp2001.pdf (accessed September 18, 2019).

While the AMWG vote to approve the statement was unanimous, some members still had misgivings about the document. The Hopi Tribe was concerned that the visioning language did not adequately account for the mitigation of threats to resources, such as archaeological sites, nor did it include the tribe's centuries of traditional ecological knowledge of the canyon in its concept of scientific research. State of Colorado representative Peter Evans commented that "there did not seem to be a lot of room for humans in the Grand Canyon ecosystem." He worried that the only human needs addressed in the vision statement, and in GCDAMP overall, were recreational and spiritual.[68]

The next step—formulating the principles, goals, and detailed management objectives to support the vision/mission statement—was a laborious process because all of the diverse stakeholders involved with AMWG had to be in general agreement.[69] The process foreshadowed AMWG's subsequent focus on consensus rather than the rule of the majority. Mary Orton reports that consensus is not always achieved, "nor should it be. There are times when it's important not to agree."[70]

Making Decisions Under Uncertainty

Managers and policymakers want to make decisions based on a reliable understanding of the likely effects of their actions on natural and social systems. But scientific knowledge is usually tentative and subject to revision. Ecosystem responses to natural and human-caused disturbances are unpredictable. Climate conditions are erratic and changing. Moreover, people and their institutions are as variable and capricious as nature. Uncertainty is a ubiquitous condition of life. According to Carl Walters, adaptive managers must "recognize that any time you go out there and do an experiment in nature, there's almost certain to be serendipity, there's almost certain to be surprises. Things you hadn't expected at all that turn out to be things that can turn into opportunities for

[68] "Glen Canyon Adaptive Management Work Group (AMWG), Minutes of July 21–22, 1999 Meeting" (quotation from p. 2).
[69] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, December 4, 2017, p. 6.
[70] Mary Orton, interview by Paul Hirt, February 14, 2017, p. 10.

improving management."[71] But while uncertainty is a core concept of adaptive management, it tends to make resource managers nervous. As Walters pointed out, "agency staff commonly say that they must present options with confidence and certitude to maintain credibility with political decision makers and players from other agencies. That is, many agency people apparently view admission of uncertainty as admission of weakness, and assume that the outcome of admitting weakness will be inaction or ineffective compromise policy."[72]

Collaboration rather than command and control structures are a key feature of the GCDAMP, which exacerbates uncertainty and can slow down decision-making. While collaborative multi-stakeholder decision-making is not required for adaptive management, it can enhance its effectiveness. But too much attention to collaborative processes can also divert from the central mission of adaptive management, according to Carl Walters, by obscuring the core concept of uncertainty and focusing on the politics of compromise rather than learning and adaptation.[73]

Uncertainty and the need to find consensus among a large, diverse group of stakeholders stymied the effort to address the problem of beach erosion. Larry Stevens claims the Colorado is the best-managed river in the world as far as understanding the sediment-flow relationship.[74] Still, the body of research in that vein is relatively recent. The first scientific article examining beach erosion below the dam came out in 1974.[75] Before 1983, scientists knew Grand Canyon sandbar beaches were getting smaller but had no specific data on their diminishment. The 1983 flooding event was a revelation to researchers and others who were intimate with the river. The enormous flows redistributed sediment, churning it up from the Colorado River bottom and building large beaches—some of which could even accommodate landing airplanes.[76]

[71] Carl Walters, interview by Paul Hirt and Jennifer Sweeney, August 8, 2018, p. 10.
[72] Carl Walters, "Challenges in Adaptive Management of Riparian and Coastal Ecosystems," 11–12.
[73] Carl Walters, interview by Paul Hirt and Jennifer Sweeney, August 8, 2018, p. 8.
[74] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 4.
[75] Robert Dolan, Alan Howard, and Arthur Gallenson, "Man's Impact on the Colorado River in the Grand Canyon," *American Scientist*, July-August 1974, pp. 392–401.
[76] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part One, p. 20.

In the early 1990s, scientists began excitedly debating the merits and hazards of replicating the flood flows of 1983 on a smaller, ostensibly controllable scale. One such group of researchers consisted of Ned Andrews, Dick Marzolf, Jim Smith, Dave Rubin—all affiliated with the U.S. Geological Survey—and Jack Schmidt, who would later become chief of the Grand Canyon Monitoring and Research Center, serving from 2011 to 2014. Rubin and Schmidt were skeptical about the potential efficacy of artificial flooding events; Andrews, Marzolf, and Smith were advocates of the idea.[77] They speculated that releasing controlled high flows through Glen Canyon Dam after tributaries like the Paria and Little Colorado Rivers had deposited their seasonal loads of sediment into the Colorado River mainstem would distribute that sediment to areas farther downstream. The environmental impact statement ultimately proposed experimental high flows (High Flow Experiments or HFEs, originally called Beach/Habitat Building Flows) "to rebuild high-elevation sandbars, recycle nutrients, restore backwater channels, and provide some of the dynamics of a natural system"—issues that none of the flow regimes considered in the environmental assessment process could completely address.[78] The first High Flow Experiment in March 1996 was "the first full-scale national experiment for adaptive management," Dave Wegner says. "It was a great time to be a scientist, because we didn't know what to expect."[79] Bruce Babbitt fondly remembers watching water cascade through the dam's spillways and into the river during the first controlled flood, an event he calls a keystone of the adaptive approach.

The 1996 High Flow Experiment lent GCDAMP scientific credibility, Dave Wegner contends.[80] As was the case before the experiments were implemented, though, some people with ties to the adaptive management program disagreed on the advisability of the High Flow Experiment protocol. Cultural resources in Grand Canyon are caught in a double bind of uncertainty. Before Glen Canyon Dam was closed, seasonal flooding covered archaeological

[77] Jack Schmidt, interview by Paul Hirt and Jennifer Sweeney, June 11, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 6–7.

[78] U.S. Bureau of Reclamation, "An Assessment of the Environmental Impact Statement on the Operations of the Glen Canyon Dam" (October 1996), 28.

[79] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part One, p. 23.

[80] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part Two, p. 11.

sites in a new layer of sediment every year. Cultural resources below the high-water mark on the canyon's walls used to be hidden to such a degree that a 1958 archaeological inventory found almost no evidence of the generations of Indigenous people who had lived their everyday lives along the river.[81] But after 1963, with the loss of sediment-laden floods, archaeological sites became increasingly exposed as beaches eroded. Unexpectedly, the post-dam High Flow Experiments sometimes contributed to that loss at certain sites rather than consistently adding protective layers of new sand and silt, which caused further erosion and damage to culturally significant sites. This realization generated some consternation and uncomfortable conversations at AMWG meetings, especially among tribal representatives. Cultural differences between tribal participants and other AMWG members shape Indigenous communities' participation in GCDAMP: why culturally significant sites matter, the nature of scientific knowledge, even how people communicate at AMWG meetings.[82] Worry about the loss of cultural resources, regardless of why a management action is taken, exacerbates feelings of alienation from the adaptive-management process among tribes.

Uncertainty in Management of Endangered Species

Carl Walters believes that, as impressive and highly publicized as they are, high flows are not the most important experimental procedures conducted within the GCDAMP purview. He bestows that honor on the 2000 Low Summer Steady Flow experiment (LSSF), which was an example of "opportunity" in adaptive management. In the early days of GCDAMP, some scientists pointed out that stabilizing the river's flow at a low discharge might change the thermal structure of the river, creating warming conditions along the river's edge that could benefit native fish. Managing for a healthier population of native humpback chub in particular was a key element in the environmental impact statement process and continues as a top GCDAMP priority. Humpback chub had evolved in the warmer, sediment-laden waters of the pre-dam river. They were

[81] Jan Balsom, interview by Paul Hirt and Jennifer Sweeney, September 7, 2018, p. 6.
[82] Dongoske, Jackson-Kelly, and Bulletts, "Confluence of Values," 136.

outcompeted and sometimes preyed upon by non-native trout, which thrived in the colder water introduced by typical dam operations. Most other scientists doubted that steadying the river's flow at a low level would lead to appreciable warming at the shoreline, thinking the warmer water would merely mix in with the cold. In the late summer of 2000, Walters found himself standing in the river downstream of the dam, "with one leg in ten-degree [Celsius] water and the other leg in eighteen-degree water, with a thermocline in between." The Low Summer Steady Flow caused dramatic shoreline warming wherever water slowed down along the river, but what surprised scientists most was that the phenomenon did not necessarily benefit warm-water adapted native fish. Rather, Walters, who is a fisheries scientist, remembers that during the Low Summer Steady Flow experiment the edge of the river smelled like a fish hatchery and "looked like a rearing trough for [non-native] trout."[83]

Non-native brown and rainbow trout did not inhabit the warmer, turbid pre-dam Colorado River, although the National Park Service stocked both species in selected Colorado River tributaries soon after the creation of Grand Canyon National Park.[84] Trout stayed in tributary waters until the completion of Glen Canyon Dam, when browns emigrated from creeks to the newly cold waters of the Colorado River and rainbows were stocked in the main stem to facilitate a sport fishery. Scientists initially considered cold water releases from the dam and hydropower-related fluctuations in the river level the most likely causes for humpback chub declines, with predation by non-native species a potential third factor.[85] Scientists and resource managers took predation more seriously by 1990, although a U.S. Fish and Wildlife Service report noted that "interspecific interactions are rarely documented."[86] Having

[83] Carl Walters, interview by Paul Hirt and Jennifer Sweeney, August 8, 2018, p. 15.

[84] The National Park Service stocked brown trout in Shinumo Creek in 1926 and 1930, Garden Creek in 1930, and Bright Angel Creek in 1930 and 1934. It stocked rainbow trout in Bright Angel Creek in 1923, 1924, 1932–1942, 1947, 1950, and 1958, Tapeats Creek in 1923 and 1940, Havasu Creek in 1931, 1944, 1948, and 1954, Clear Creek in 1940, and Phantom Creek in 1942. "Brown Trout below Glen Canyon Dam: A Preliminary Analysis of Risks and Options," September 21, 2017, p. 8, U.S. Bureau of Reclamation website, https://www.usbr.gov/uc/progact/amp/amwg/2017-09-20-amwg-meeting/BT03.pdf (accessed September 18, 2019).

[85] U.S. Fish and Wildlife Service, "Humpback Chub Recovery Plan," August 22, 1979, pp. 8–9, available online at http://www.nativefishlab.net/library/textpdf/13294.pdf (accessed September 18, 2019).

[86] U.S. Fish and Wildlife Service, "Humpback Chub 2nd Revised Recovery Plan," September 19, 1990, p. 12, available online at https://www.fws.gov/southwest/es/arizona/

already implemented habitat-building High Flow Experiments and the water-warming Low Summer Steady Flow, GCDAMP launched an experimental program in 2003 to remove brown and rainbow trout from areas with important chub habitat, such as the mouth of the Little Colorado River where it joins the Colorado River in Marble Canyon.[87]

The initial brown and rainbow trout removal experiment lasted from 2003 to 2006. During the experiment, "23,266 non-native fish were euthanized and 13,268 native fish were released alive back into the river."[88] A 50 percent increase in humpback chub numbers between 2001 and 2008 coincided with the drop in trout population, but other factors, such as the flow experiments and a drought-related temperature increase in the Colorado River due to warmer releases from a lowering Lake Powell, made it impossible to definitively attribute the growing chub population to the trout-culling program.[89] The lack of clarity on humpback chub population fluctuations made the trout-removal program controversial. Although removal of brown trout continued in Bright Angel Creek and at the confluence of that creek with the Colorado River,[90] Grand Canyon Monitoring and Research Center chief John Hamill told Assistant Secretary of the Interior Anne Castle there was no clear link between trout predation and population declines of the humpback chub.[91] Larry Stevens cited similar findings.[92] The extraordinary Grand Canyon environment makes understanding the dynamics of humpback chub populations in the short term nearly impossible, according to scientists Jeff Lovich and Ted Melis. "Temporal issues operate

Documents/RecoveryPlans/Humpback_Chub_1990.pdf (accessed September 18, 2019).

[87] This management action was authorized by the U.S. Fish and Wildlife Service in "Humpback Chub (*Gila cypha*) Recovery Goals: Amendment and Supplement to the Humpback Chub Recovery Plan," August 1, 2002, p. 40, available online at https://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/HumpbackChub/Humpback%20chub-August-02.pdf (accessed September 18, 2019).

[88] U.S. Geological Survey, "An Experiment to Control Nonnative Fish in the Colorado River, Grand Canyon, Arizona," Fact Sheet 2011-3093, August 2011, p. 1, available online at https://pubs.usgs.gov/fs/2011/3093/fs2011-3093.pdf (accessed September 18, 2019).

[89] U.S. Geological Survey, "Status and Trends of the Grand Canyon Population of Humpback Chub," Fact Sheet 2009-3035, April 2009, p. 2, available online at https://www.usbr.gov/uc/progact/amp/amwg/2009-04-29-amwg-meeting/Attach_03b.pdf (accessed September 18, 2019).

[90] Brown trout were still being removed as of 2017. See U.S. Bureau of Reclamation, "Brown Trout below Glen Canyon Dam: A Preliminary Analysis of Risks and Options."

[91] Anne Castle, interview by Paul Hirt, March 26, 2018, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, Part One, 8.

[92] Larry Stevens, interview by Paul Hirt and Jennifer Sweeney, February 6, 2017, p. 15.

on scales of over 10 orders of magnitude, ranging from billions of years to minutes, depending on whether one considers the geomorphic framework of the canyon or the hour-to-hour effects of dam operations on that same framework. This extreme variability happens simultaneously, confounding efforts to determine cause and effect."[93] Thus, the science was uncertain regarding whether mechanical removal of non-native trout would help the humpback chub population recover.

Another source of controversy came from the Pueblo of Zuni and the Hopi Tribe, both of which strongly objected to killing trout in the river. "Mechanical removal" entailed using high-voltage electrical devices in the river to stun fish, which floated to the surface. Researchers would then gather the non-native trout, kill them, and turn their bodies into fish meal. This seemingly heartless killing deeply disturbed Zuni tribal elders in particular.[94] They perceived a causal relationship between trout extermination in the Colorado River, connected to the Zuni community via the now-dry Zuni River, and health issues that manifested in the community at the same time.[95] The Hopi were appalled, too, saying the extermination cast "an aura of death" upon Grand Canyon. Their distress was magnified because the exterminations mainly happened at the confluence of the Colorado and Little Colorado Rivers. This particularly sacred place is where, according to traditional Hopi origin stories, the Hopi emerged into the physical world and where they return when their lives on Earth are finished.[96]

After decades of research, scientists still do not know all of the factors involved in humpback chub population fluctuations. According to Larry Stevens, "There's been about half a billion dollars spent on ten thousand fish. So far. A huge amount of money has been spent trying to keep humpback chub in the picture." In the meantime, imperiled species like the southwestern willow flycatcher are losing their fight, along with "quite a few that aren't

[93] Jeff Lovich and Theodore S. Melis, "The State of the Colorado River Ecosystem in Grand Canyon: Lessons from 10 Years of Adaptive Ecosystems Management," *International Journal of River Basin Management* 5 (2007): 219.

[94] Kurt Dongoske, interview by Paul Hirt and Jennifer Sweeney, August 15, 2018, pp. 8–9.

[95] Val Panteah Sr. to Brent Rhees, February 6, 2017, GCDAMP website, http://gcdamp.com/images_gcdamp_com/3/33/LtrBrentRheesBrownTroutProblemLeesFerry_ZuniGovernorSigned_06February2017.pdf (accessed September 18, 2019).

[96] Leigh Kuwanwisiwma, interview by Paul Hirt and Jennifer Sweeney, September 8, 2018, p. 16.

listed—85 taxa by my count."[97] Stevens believes a good way to tease out the factors that influence the viability of native species in a changed environment is to understand the river's biodiversity as a whole. Information on the ecosystem's estimated ten thousand species promises new forms of knowledge and should be compiled and studied, but that is a huge and, at present, unfunded task.[98]

Conclusion

GCDAMP has been guiding management of the resources affected by Glen Canyon Dam operations for over twenty years. The record of decision for the second environmental impact statement on Glen Canyon Dam operations was signed in 2016. Known as the Long-Term Experimental and Management Plan (LTEMP), this document sets the stage for the next twenty years of GCDAMP resource monitoring and management. Larry Stevens has observed that "fast change is what humans are really good at. Make a policy decision, and we'll take out the dam! Or build a dam!" These quick decisions have an enormous impact on nature and on the lives of people who care about it. People are "not good at stepping back and saying, 'Well, let's study this for a couple decades, actually, to really get at the answers, so we know what the consequences of our decisions are.'"[99]

Getting at the answers could take even longer than Stevens proposes. GCDAMP has amassed a high-quality body of research, especially on applied issues like managing the Colorado River for sediment and monitoring endangered humpback chub, but dealing with uncertainty and regularly changing variables "underscores the importance of long-term studies to describe patterns and processes."[100] In Carl Walters's view, "we need institutional arrangements that will permit and foster experimental studies that span time scales longer than the working lives of the scientists who initiate them."[101] Recently, more non-native species have been found

[97] Larry Stevens, interview by Paul Hirt, February 6, 2017, pp. 23 (first quotation), 24 (second quotation).
[98] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 7.
[99] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 24.
[100] Lovich and Melis, "The State of the Colorado River Ecosystem in Grand Canyon," 219.
[101] Walters and Holling, "Large-Scale Management Experiments and Learning by Doing," 2066.

downstream of Glen Canyon Dam, especially mollusks. Such surprises, Larry Stevens notes, usually mean that "the ecosystem tracks off in some other direction."[102] Surprising findings and uncertain outcomes continually present AMWG members with choices about how to observe, learn, plan, and act. As Bruce Babbitt noted when reflecting on twenty-five years of conducting High Flow Experiments and assessing their effects, "we still haven't learned everything."[103]

There is a conflict inherent in GCDAMP, however, between the fluid, observational, and lengthy nature of the research needed to support adaptive management and the urge to quantify goals and achieve results that Carl Walters acknowledges is an outgrowth of stakeholder collaboration. Former state of Colorado Technical Work Group representative Randy Seaholm acknowledges that the dam has changed Grand Canyon and the Colorado River, but he is frustrated with adaptive management.[104] He would prefer to see a set of resource-management objectives established and met, after which a less-expensive comprehensive monitoring program funded with hydropower revenues would replace the adaptive-management process.[105]

Millions of dollars are spent every year on monitoring and intervention, says former Grand Canyon Monitoring and Research Center chief Jack Schmidt, and the public is still largely unaware that Grand Canyon has been profoundly altered by dam operations. Schmidt maintains that "we have a moral obligation. It's one of the greatest places on planet Earth," although he concedes that "we're also not going to decommission Glen Canyon Dam."[106] Dave Wegner contends that existing and future GCDAMP findings have a potential impact well beyond the canyon's boundaries. The area between Lake Powell and Lake Mead offers "a rich data set" of endangered species and cultural resources and should continue to be carefully observed as a laboratory for assessing the effects of climate change.[107]

[102] Larry Stevens, interview by Paul Hirt, February 6, 2017, p. 10.
[103] Bruce Babbitt, interview by Paul Hirt, September 21, 2018, p. 5.
[104] Randy Seaholm, interview by Paul Hirt and Jennifer Sweeney, April 27, 2019, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, 2–3.
[105] Randy Seaholm, interview by Paul Hirt and Jennifer Sweeney, September 21, 2018, pp. 9–11, 21–23.
[106] Jack Schmidt, interview by Paul Hirt and Jennifer Sweeney, June 11, 2018, p. 22.
[107] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, transcript, Glen Canyon Dam Adaptive Management Program Administrative History, Part Two, p. 15.

Every person interviewed so far for the GCDAMP Administrative History Project believes that the program has value and should continue in some form. "That the public are involved collectively as stakeholders in a program that values good scientifically-generated information to make decisions is a hallmark of a civilized country," Andre Potochnik says. "I think it's a great example of a democracy in action."[108] Dave Wegner's assessment of adaptive management in Grand Canyon is more measured, but no less optimistic. "Is it everything that it could be? No. Is it better than it would have been? Absolutely. Does it have promise for the future? Of course."[109]

[108] Andre Potochnik, interview by Paul Hirt and Jennifer Sweeney, December 4, 2017, p. 55.
[109] Dave Wegner, interview by Paul Hirt and Jennifer Sweeney, August 4, 2017, Part Two, p. 23.