Chapter 15: The Future of Glen Canyon Dam Management and Implications for the Grand Canyon

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INTRODUCTION – *CHALLENGES FOR MANAGEMENT OF THE GRAND CANYON AND GLEN CANYON DAM*

Introduction

The Grand Canyon occurs along a 277 mile stretch of the Colorado River between Glen Canyon Dam and Lake Mead. It is a national treasure, exposing over 2 billion years of geologic history (see Garber, this volume; Kercher, this volume) and several thousand years of human history (see Zagofsky, this volume), providing varied recreational opportunities to millions of visitors annually. It is home to many species of birds, plants and animals. These recreational, historical, and wilderness values were recognized by the federal government in 1919 with the establishment of Grand Canyon National Park, but aquatic and riparian ecosystems in this reach have nonetheless suffered major changes in the past several decades, mostly due to the building of Glen Canyon Dam in 1963 (See Lusardi and Steele, this volume; Kelso, this volume). Glen Canyon Dam impedes transport of sediment and nutrients, and alters the temperature and flow regime of downstream reaches. Recent attempts to mitigate for these impacts have taken the form of an Adaptive Management Program, and High Flow Experiments (see Burley, this volume; Gibson, this volume), but have not yet been successful. The program is currently challenged by a lack of adequate understanding of how (if at all possible) to maintain sandbars post flood, and how and if flood events benefit target species within the canyon. Climate change and changing upstream dam operations will add to these challenges in the future, and may even threaten the existence of the Adaptive Management Program. This paper reviews the challenges facing Grand Canyon and Glen Canyon Dam managers in the coming century, and attempts to identify several of the most likely trajectories for ways in which future management may differ from today's.

Larger Issues of the Colorado River Basin

To understand likely trajectories for management, it is necessary to view the Grand Canyon, and Glen Canyon Dam, in the context of the broader watershed. The Grand Canyon reach of the Colorado river is only a portion of a much larger river system. The Colorado River runs 1,470 miles from its headwaters in Colorado through the Colorado River Delta in Mexico (Grand Canyon Trust, 2006). Current management is challenged by 3 broad issues: 1) Balancing various needs of people and the environment in an over-allocated system; 2) Many interacting (or sometimes not) levels of institutional governance; and 3) Uncertainty in future climate, and in ecosystem responses to management changes. Reaction to these Colorado River issues through time will affect the range of actions available to managers controlling ecosystem and recreation-related flows through the Grand Canyon.

The majority of Glen Canyon Dam management is focused on delivering requisite water supplies to downstream users, driving cumulative annual releases, and on satisfying hydropower demands, which drive daily operations. The Colorado River supplies water to about 30 million people and irrigates 3.5 million acres of farmland, across seven different states and two countries (Nowak, 2011). Complicating these demands is the fact that allocations were decided during a relatively wet period in the river's hydrologic history, which resulted in annual allocations that are larger than the average annual flow (see Vetter, this volume; Parsons, this volume). The total river allocation, set down in the 1922 Colorado River Compact (CRC) and the 1944 Treaty with Mexico, is 16.5 million acre feet per year (Maf/yr), whereas average annual basin yield is about 16.3 Maf/yr (Nowak 2011). For the purposes of Glen Canyon Dam management, the water is divided into three major regions: Upper Basin states, Lower Basin states, and Mexico. The CRC allocates 7.5 maf/yr to each basin, and sets a requirement on the Upper Basin states to deliver no less than 75 maf of water over any 10 year period to the Lower Basin (USBR 2011). The Treaty with Mexico guarantees delivery of 1.5 maf/yr. Glen Canyon Dam is the furthest downstream and largest dam for the Upper Basin states. It was built to provide the Upper Basin with a water supply reservoir with enough storage to ensure that they could also meet their annual and decadal release requirements to the Lower Basin states, even in years of diminished inflows. It provides 73% of storage capacity for the Upper Basin, and approximately 3 years of downstream release requirements when full (Wegner 2008).

Upper Basin states fulfill their repayment obligations for Glen Canyon dam primarily with hydroelectric power revenues (Tarlock 1991). The Western Area Power Administration markets and delivers this power, with a sevice area covering 1.3 million square miles in fifteen states (Wegner 2008). Daily releases from Glen Canyon Dam fluctuate with power demands, with common diel flow differences of several thousand cubic feet per second. These releases that vary seasonally and daily to meet electricity demand are not ideal for the aquatic ecosystem and riparian corridor in two important ways: 1) Temperature – the water released from the hypolimnium portion of the reservoir is significantly colder in summer, and warmer in winter, than with pre-dam conditions, attracting nonnative fish and slowing down productivity for native fish. 2) Aquatic habitat – varied flows are not optimal for retaining sand along the river bed, nor for maintaining sandbars (Wright et al., 2008). Instead, they increase the rate at which the river erodes away potential backwater habitat for endangered species like the humpback chub.

These ecosystem needs are the final competing management objective of Glen Canyon Dam. The Grand Canyon reach is home to five listed species dependent on the river and its riparian corridor: the humpback chub, razorback sucker, southwestern willow flycatcher, Kanab ambersnail, and California Condor. (For more detail, see Lusardi and Steele, this volume; Kelso, this volume; Hartman, this volume.) Further downstream, the Colorado River Delta in Mexico only receives 9% of its historical flow and is currently at only 8% of its historical extent, with a resultant 50 endangered and threatened species in the region (Wegner, 2008). Changes to release timing, magnitude, and structure have all been proposed as ways to assist in protection and re-establishment of some of these endangered species, with more focus typically given to those in the Grand Canyon (and thus protected by the United States' Endangered Species Act).

This large system is governed and managed by an equally large number of institutions: five within the federal government's Department of the Interior, another level of federal involvement in the Department of Energy, seven state governments, and many local and native American institutions. These institutions are often charged with protecting competing demands on the system. The Bureau of Reclamation (Bureau), for instance, is charged with operation of Glen Canyon Dam (and other dams in the system), mainly governed by a host of laws, records of decision, and compacts that are grouped together into the "law of the river." While the law of the river has come to include some environmentally-minded legislation, the Bureau's priority is with the legal water supply requirements of the Upper and Lower basins, and Mexico, and with protecting the reliability of that supply (Tarlock, 1991). The National Park Service (NPS) and U.S. Fish and Wildlife Service (FWS), on the other hand, are tasked with protection of wilderness and environmental assets, but even these two organizations can sometimes clash. The NPS's governing statutes emphasize not only the preservation of species and habitat, but also the preservation of natural processes and dynamics that are necessary for the long-term perpetuation of whole ecosystems. The U.S. FWS is more species-centric, providing consultation and recovery leadership for listed species protected by the Endangered Species Act (USBR 2011). There is also often disagreement at the state level, with Upper Basin states especially sensitive to any change to dam operations and water flows that they think could constitute a "water grab" by the Lower basin (CRGI Interim Report, 2010). These sometimes disjointed levels of governance can make it difficult to create a unified management plan for the system, or for the Grand Canyon as a part of that system (Wegner, 2008).

Management of Glen Canyon Dam and Reconciliation Ecology within the Grand Canyon

Despite these broader issues, there is a certain amount of flexibility available to Glen Canyon Dam managers, mandated by several environmental laws, which allows them to change operations slightly in ways that may help the Grand Canyon ecosystem. This has been manifested in previous High Flow Experiments, and in reductions in summer flows aimed at improving water temperature conditions downstream of the dam for fish (Trammell et al., 2002). However, there is a lack of clear purpose from environmental managers (Suskind et al., 2010). The Grand Canyon is a reconciled ecosystem, much altered from its historic character both physically and biologically. Reconciliation ecology recognizes the permanence of humans as players in most ecosystems, and the need for management to recognize the continuing presence and interaction with human uses of a resource (Rosenzweig, 2003). Instead of aiming to restore a landscape to its original conditions, reconciliation ecologists often aim to promote sustainability of a modified ecosystem, working within human-altered constraints.

While managers of the Colorado River are not attempting to recreate the Grand Canyon of the past and seem guided by the principles of reconciliation ecology, there is not always agreement on what an ideal, sustainable reconciled ecosystem in the canyon should look like. In their comments to the 2011 Draft Environmental Impacts report for High Flow Experiments over the next decade, the Basin States came together with the following statement: "The DEA… does not clearly explain why greater sediment deposition is important… the NEPA analysis would be strengthened by including an explanation of how Reclamation plans to balance the importance of various resources … and how a choice to increase sediment deposition can be reconciled with the costs of doing so." This comment, from all seven states served by the Colorado River system, provides a reminder that as demands on Glen Canyon operators increase, it may be difficult to save flexibility for ecosystem flows without having a clearer definition of their goals.

In addition, the goals that are stated for species protection in the Grand Canyon are sometimes conflicting, as is the case with nonnative rainbow trout, and the endangered humpback chub. A Bureau report in 2011 stated that a healthy trout population in the Lees Ferry reach is a desirable resource, but that conditions that encourage their downstream emigration and thus competition with the humpback chub are not desirable. They then acknowledge that an indirect effect of the high flow experiments seems to be an increase in the rainbow trout population and subsequent movement of trout to humpback chub nursery habitats (USBR 2011). The same report cites creation of habitat for humpback chub and other downstream fishes as a purpose for these high flow experiments. If ecology-driven management of releases is to continue as demands on the river increase, conflicting directives like these will likely have to be better prioritized and clarified.

Managing a System with Uncertainty

Management of these competing interests in the Colorado River basin is further complicated by a host of uncertainties. First, regarding adaptive management of the river for the recovery of physical features and endangered species, there is much uncertainty about the physical and biotic reaction of the system to different management options. Sandbar recruitment is yet to be successful over a long term period (see Burley, this volume, and Gibson, this volume). As another example alluded to in the previous section, Cross and others point out in their 2011 paper on food web responses to a recent High Flow Experiment that even after three of these flood events, "there is a great deal of uncertainty regarding whether controlled flows will positively or negatively influence [humpback chub] ...." These uncertainties make it difficult to identify and ask for ideal operating criteria for the protection of environmental and recreational assets within the Grand Canyon, and make it less likely that management be changed in the interests of species protection.

The second major uncertainty facing system operators is climate change and future system inflows. Even without changes to the climate, paleoclimatic records show that the last 100 years have been unusually wet (Thompson, USGS 2011; CRGI Interim Report, 2010; Vetter, companion volume), indicating that periods of sustained drought might return. And while there is generally good agreement that the region will likely become warmer and more arid over the next century (Barnett and Pierce, 2009; Harding et al., 2012), precipitation and inflow forecasts are much more varied. Predicted changes in precipitation vary from no change, to reductions of about 10% (Barnett and Pierce, 2009), and flow predictions range from modest increases to 30% reductions in the average annual flow (Harding et al., 2012, Christenson and Lettenmaier, 2007). This figure from Harding et al., 2012, shows the range of predictions for changing inflows over the next century, compiled from a variety of different studies:

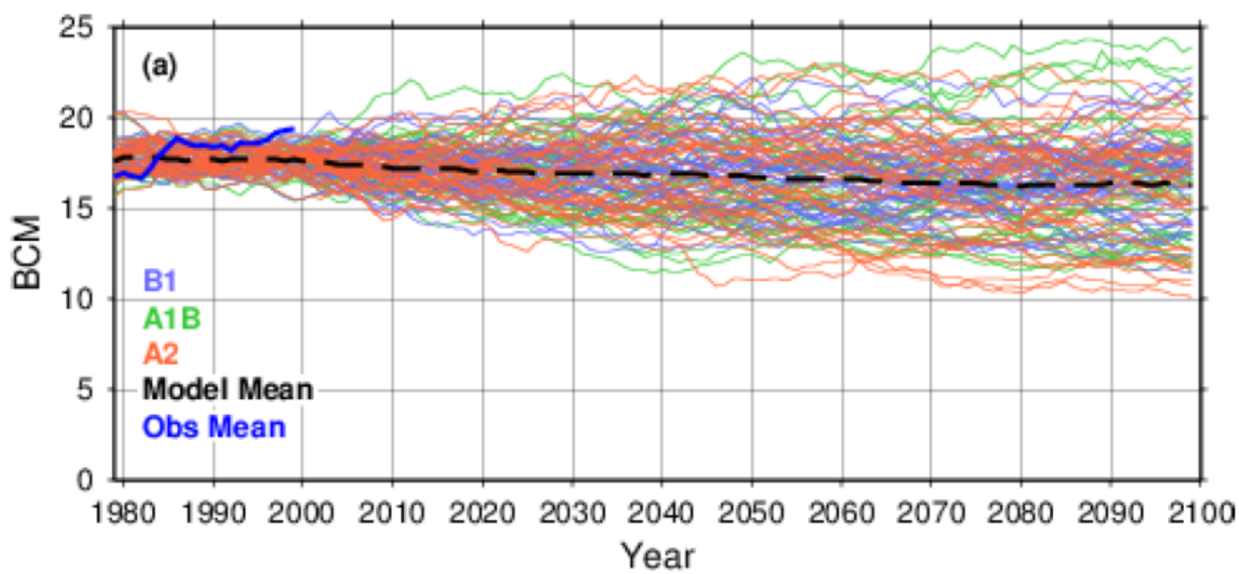

Fig 1 (Fig. 6 in Harding et al., 2012): Simulated 30-yr average streamflows of the Colorado River at Lees Ferry, AZ, 1979 through 2099.

These changes in flow, and responses of the system to management, will both play a role in how the system is managed in the future.

DRIVERS OF CHANGE IN THE COLORADO RIVER SYSTEM

While uncertainty does exist for the system, there are three drivers of change that can be expected to occur with relative certainty: warming climate, increasing population, and increasing energy demands. The uncertainty then shifts to management and governance responses to these drivers.

Climate

Regardless of what happens to inflows over the next century, or to runoff from the headwaters, there is general agreement that the region will warm by 2-4 degrees C by 2050 (Barnett and Pierce, 2009; Harding et al., 2012). In addition, the onset of snowmelt will continue to advance in response to this warming (USGS 2011). Increased temperatures play a major role in surface water flows for the region, because of high rates of evaporation and evapotranspiration. Not only are rates high for the region in general, but the Colorado River system is unique in that it has approximately 4 times the amount of storage as the average annual flow. This means a lot of surface area from which water can evaporate, and also means that the system is more senstive to changes in temperature and inflow than it is to changes in timing of runoff. For example, precipitation during the winter of 2005 was at the 100-year average, but low soil moisture in the basin and higher late-winter temperatures resulted in flows at only 75 percent of average (USGS, 2011). In general, run-off percent efficiency is thought to decrease by 2% in the basin for every 1 degree of warming (Nowak, 2011). This reality impacts flow projections, where even with some models predicting modest increases in flow, evaporative losses can overwhelm those gains. As a result, the most commonly accepted range for predicted available water over the next century is a reduction from current levels of between 5 and 20% (USGS, 2011).

Population and Shifting Demands

Population growth in the Southwest has occurred at a much higher rate than the rest of the nation: 1500% since the early 1990s compared with a national average of about 225% (Nowak, 2011). The number of people dependent on Colorado River water is expected to increase from about 25 million people to 38 million people by 2020 (USGS, 2011). This can have serious implications for shortages in the future, especially if climate change results in decreased inflows. Colorado's Statewide Water Supply Initiative report in 2003 predicted that current and planned water supply projects in the state will only be able to handle 80% of new urban growth by 2030, indicating a 20% shortage (Wegner, 2008). Current Upper Basin depletions are at 5.4 Maf/yr (CRGI, 2010). With just a 10% decrease in flow from climate change, the amount of total water available to the Upper Basin states would fall to 5.3 Maf/yr (CRGI, 2010), meaning that even current demand would not be satisfied. While the law of the river provides some safety to the Lower Basin states with a near-guaranteed decadal delivery of 75 maf, the Upper Basin is much more vulnerable to these combined changes in climate and demand (see Figure 2, from the CRGI Interim Report, 2010).

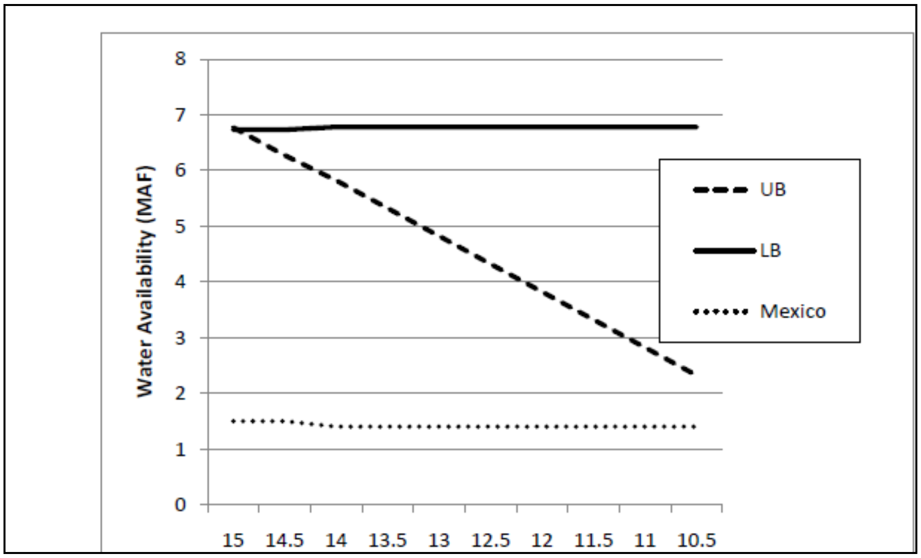

Figure 2. Water Availability (by sub-basin) as a function of long-term average flows. From the Colorado River Governance Initiative, 2010

Some changes in the nature of demand, however, may help to reduce the extra load placed on the water supply system. Spurred by recent drought, the Department of the Interior initiated Interim Surplus Guidelines, to be followed through 2026, which include three main goals: 1) coordinated operations of Lakes Powell and Mead; 2) A mechanism by which states can store excess water in Lake Mead for later use, and 3) Shortage policies for the Lower Basin in times of low reservoir storage, when Lake Powell cannot fulfill its release obligations. As a part of these guidelines, a program called California 4.4 was initiated, which aimed to reduce California's consumption of supplies from 5 maf/yr to 4.4. This was accomplished as of 2003, mostly through on-farm conservation and the subsequent reallocation of saved water to urban areas (Kenney et al., 2010). There may be some savings to be had, then, if some demands transition from agricultural to urban.

Energy

Another growing demand in the basin is for hydropower and other forms of water-dependent energy generation. As the human population increases, so does the demand for energy. Thermoelectric power plants in Arizona, Colorado, New Mexico, Nevada and Utah used approximately 292 million gallons of water per day in 2005 (CRGI, 2010). The Electric Power Research Institute has stated that restraints on thermoelectric power production due to limited water supplies could occur by 2025 in Arizona, Utah, and California (Bull, 2007). Also, if water supply approaches in the future become more energy intensive (like desalination, uphill pumping, etc…) then the stress on water resources becomes even greater. At the same time that these demands for energy increase, decreases in Colorado River flows that are often predicted with climate change studies translate to decreases in the system's ability to generate hydropower. For every 1% reduction in inflows for the system, the resultant loss in head in the reservoirs translates to a 3% decrease in hydropower production (CRGI, 2010).

Acting together, these three drivers are pushing the Colorado River closer and closer to a threshhold at which something will have to change, as all demands on the system will not be met given current management (see Figure 3). Continued development, potential decreases in flow, and increasing energy demands will eventually force managers to either re-think system operations, or re-allocate the water based on a more realistic understanding of actual annual inflows.

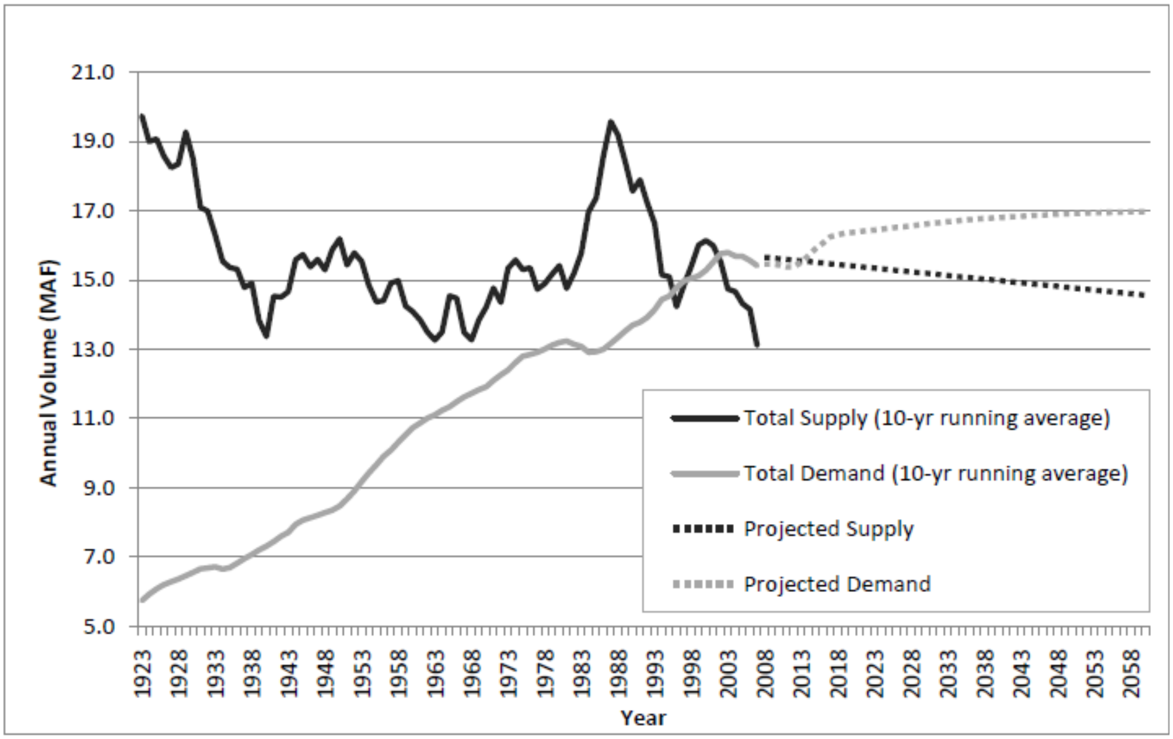

Figure 3. Supplies and Demands on Mainstem Water, from CRGI 2010

FUTURE OF MANAGEMENT AND RECONCILIATION ECOLOGY IN THE GRAND CANYON

Uncertainty exists for the Grand Canyon and Colorado River in two ways: physical realities facing the system, and responses from managers and government. Population and demand increases, coupled with a return to more historically average flows (with or without climate change) are likely to force a change in system management in the near future. While demand-side management of over-allocation is likely to be an important component to any solution, there are also three potential operational changes to the system that are mentioned in reports more often than others: More nuanced coordination between lakes Mead and Powell, restructuring the Law of the River to reflect more realistic understanding of the system, and better use of underground storage. All three of these options will have implications for releases from Glen Canyon Dam, and thus for the ability to manage for a reconciled and sustainable ecosystem in the Grand Canyon.

The first option, more nuanced coordination between Lakes Mead and Powell, is based on two main problems with current management: evaporation and a lack of shortage planning. Because Lake Powell is significantly higher in elevation than Lake Mead, the evaporation rate from Lake Mead is almost double that of Lake Powell (Nowak, 2011). Currently, the Interim guidelines require somewhat equitable storage of water between the two reservoirs, which translates to a higher loss rate than if water was stored preferentially in Lake Powell, thereby decreasing the surface area of Lake Mead (Nowak, 2011). In addition to this change, Rajagopalan et al.,(2009) showed that aggressive shortage management strategies for the reservoirs could significantly reduce the risk of drying in the system. Shortage management in their study took the form of hedging, where deliveries were first curtailed when reservoir levels ranged between 36 and 50% of full reservoir capacity. Under an assumption of 10% flow reduction from climate change, aggressive management reduced drying risk in 2057 from 26% to about 11%. Average annual deficits were lower for the most aggressive management alternative relative to moderate policy changes as well, by about 25%. Both of these operational changes (preferential storage in Lake Powell and aggressive shortage management) would lead to a larger volume of water stored in Lake Powell above the Grand Canyon.

Many reports also advocate the use of groundwater storage as another way to reduce evaporative losses in the system (Nowak, 2011; Living Rivers, 2005). Such storage could also capture and carry over extremely high flows, if and when they do occur. One study asserted that the watershed has enough underground storage capacity to accommodate six years of the Colorado's annual flow (Living Rivers, 2005). Contrary to the more nuanced operations between Lakes Mead and Powell mentioned above, a large switch from reservoir to groundwater storage could actually mean a reduction in the amount of water sitting in Lake Powell above the Grand Canyon.

Further operational changes could come from a more holistic restructuring of the Law of the River itself. A report by the Colorado River Governance Initiative in 2010 made the following observation: "Consider the fact that Compacts are, legally, contracts, and that the Colorado River Compact was a contract based on a factual error (about average flow volumes), an expectation of equal sharing, and an ignorance of climate change. If the agreement can be shown to be severely deficient in those or other areas, then it may be subject to a fundamental reinterpretation or restructuring by the Supreme Court." The report went further to say that exactly this type of contract law was used in 1984 to change the flawed allocation formula in the Pecos River Compact, showing a precedence for the success of that kind of argument. And while it is true that most of the seven states served by the Colorado River are leery of any changes to the compact out of fear that they will lose a portion of their allocation, there is evidence that this viewpoint is changing. In their comments to the 2011 Draft Environmental Impacts report, the Basin states all together (both upper and lower), asserted that amendment to relevant law of the river would be necessary for the continuance of high flow events, to "account for a new purpose for dam operations and to allow for restitution to the Basin Fund and power customers."

All of these scenarios threaten the availability of environmental flows for restoration ecology within the Grand Canyon, but a few also provide some opportunity. Increased retention of water in Lake Powell could, on the one hand, mean more water available for experimentation. On the other hand, if operational rules are re-written without this express environmental allocation in mind, it may be that the water is withheld from downstream releases unless absolutely necessary to fulfill water supply demands. In the case of legal restructuring, there is an opportunity to assert a higher priority for recreational and environmental uses of the water. As it stands, The Bureau of Reclamation must only consult with the Fish and Wildlife Service with respect to activities for which they agency has discretionary involvement, and they have asserted that the Law of the River largely dictates their activities at Glen Canyon Dam, making these activities non-discretionary (Wegner, 2008). However, courts have historically held that water contracts between the Bureau and water users are discretionary actions subject to ESA compliance (Wegner 2008), meaning that a restructuring of this compact would be subject to rules that benefit endangered species, and therefore increase management options throughout the Grand Canyon. However, taking advantage of any of these responses in favor of environmental management will require clear environmental and ecosystem goals. If such clarity is not attained in the near future, it is likely that water supply and energy concerns will take precedence as climate change occurs, and adaptive ecosystem management will become more marginalized than it is today.

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