



March 29, 2024

The Honorable Camille Touton  
Commissioner  
U.S. Bureau of Reclamation  
1849 C Street NW  
Washington, DC 20240

VIA ELECTRONIC MAIL  
mtouton@usbr.gov  
[crbpost2026@usbr.gov](mailto:crbpost2026@usbr.gov)

Dear Commissioner Touton:

Please find attached our proposal for consideration in the development of the U.S. Bureau of Reclamation's Colorado River Reservoir Operations and Post-2026 Operational Guidelines and Strategies for Lake Powell and Lake Mead.

Our proposal suggests an opportunity for flexibility in meeting environmental, cultural, and recreational goals in the management of the Lake Powell/Grand Canyon/Lake Mead ecosystem by decoupling decisions about annual releases through the Grand Canyon from the annual water accounting needs of the Law of the River.

We propose creating an accounting system for Upper Basin and Lower Basin debits and credits in the two reservoirs. This would allow the actual annual wet water releases to be adjusted to meet the suite of environmental, cultural, and recreational needs that now must be subservient to annual water release rules driven by inter-basin accounting.

Our proposal offers a flexible management approach that offers the potential to significantly improve the environmental, cultural, and recreational benefits to the Grand Canyon, without harming the overall basin-scale water management goals you are pursuing. Our plan would work in conjunction with either of the two basin state proposals or a compromise between the two. In the absence of a compromise between the two state proposals, our approach would also be compatible with a solution that Interior chooses, taking elements from each.



We request that you consider our proposal in the preparation of the post-2026 Draft Environmental Impact Statement as way to implement one or more of the alternatives.

We would be happy to discuss our proposal with you and/or your staff in more detail.

A handwritten signature in black ink that reads "Jack Schmidt".

Jack Schmidt, Center for Colorado River Studies

A handwritten signature in black ink that reads "Eric Kuhn".

Eric Kuhn, Glenwood Springs, CO

A handwritten signature in black ink that reads "John Fleck".

John Fleck, Utton Center, University of New Mexico School of Law

CC:

Russ Callejo, Deputy Regional Director, Mid-Pacific Region

Carly Jerla, Senior Water Resources Program Manager

Jim Prairie, Hydrologic Engineer

# Managing the Powell/Grand Canyon/Mead ecosystem after 2026

John C. Schmidt<sup>1</sup>, Eric Kuhn<sup>2</sup>, John Fleck<sup>3</sup>

<sup>1</sup> Center for Colorado River Studies, Utah State University

<sup>2</sup> Glenwood Springs, CO

<sup>3</sup> Utton Center, University of New Mexico School of Law

29 March 2024

## 1.0 Introduction

The most important question that must be addressed by the post-2026 Colorado River Basin Guidelines is how to allocate shortages during a multi-year period of low runoff so that basin-wide reservoir storage does not precariously dwindle. The Upper Basin and the Lower Basin have offered competing proposals of how to share the pain of a declining water supply.

A second-tier question concerning future management of the Colorado River concerns how water storage should be allocated between Lake Mead and Lake Powell and what should be the rules concerning the transfer of water from Lake Powell to Lake Mead. These two reservoirs hold between 60 and 80% of the entire reservoir storage of the watershed. Between Lake Powell and Lake Mead is the Grand Canyon, and the 255-mile Colorado River corridor is primarily managed by the National Park Service and partly by the Hualapai Tribe.

The present policy concerning distribution of reservoir storage is to equally divide the contents between the two reservoirs under a policy that attempts to balance the active storage in each reservoir, and to manage the year-to-year “Law of the River” accounting based on annual releases from Lake Powell. This management strategy can have unintended, but sometimes significant, negative consequences, as in 2011 when large releases caused significant erosion of the Grand Canyon sand resource. In that case, the requirement to meet a Law of the River delivery rule from Powell to Mead required delivery of water, regardless of the environmental consequences and with long-lasting implications.

Because Lake Powell is in the Upper Basin and Lake Mead is in the Lower Basin, releases from Powell represent the delivery of water to the Lower Basin, and the competing proposals of the Upper and Lower Basins are focused on how those deliveries should be defined. The competing proposals differ slightly on how much water should be annually released from Lake Powell and are based on different calculations of the status of basin-wide reservoir storage and whether consideration should also be given to current and past inflows. The competing proposals agree on the need to define the annual release from Lake Powell, and they agree that the basis for defining annual releases should be considerations of water-supply management.

We suggest an alternative: a system that preserves the Upper Basin-Lower Basin accounting that will be required by whatever interpretation of the Law of the River emerges from the on-going negotiation of the post-2026 Guidelines but creates more flexibility in year-to-year decisions about actual Lake Powell releases. We think that increased flexibility in annual releases would allow those releases to be optimized to meet environmental, recreational, and cultural goals while retaining an interstate accounting system that still meets water-supply objectives. Flexibility in establishing the annual releases from Lake Powell would result in more adaptable management of the environmental resources of Lake Powell, the Grand Canyon, and Lake Mead.

This strategy would also allow the distribution of storage between Mead and Powell to be treated in an adaptive framework that is less constrained by the needs of Law of the River accounting. Modeling of future runoff (i.e, water supply) and future consumptive water use indicates that the average volume of stored water in Lake Powell and Lake Mead is unlikely to exceed 50% of the capacity of those two reservoirs (Wheeler et al, 2022), although storage is likely to be larger in rare wet years. If storage will rarely exceed 50% of capacity, then it is logical to ask whether storage in one reservoir ought to be emphasized, potentially reducing evaporation. The competing proposals of the Upper and Lower Basin states assume that the balancing policy remains in place.

Flexibility in annual releases and adaptive allocation of water storage in Powell and Mead allows consideration of environmental, recreational, cultural, and hydropower issues, and can better address tribal concerns and objectives. Consideration of environmental and recreation issues can be accomplished by directing the Glen Canyon Dam (GCD) Adaptive Management Program to make recommendations to the Secretary of the Interior about annual Lake Powell releases. All relevant stakeholders – federal agencies, the seven basin states, five tribes, and NGOs – participate in the GCD Adaptive Management Program, and the program already makes recommendations to the Secretary of the Interior about how Lake Powell releases should be managed on an hourly, daily, weekly, and monthly basis, and we suggest that the charge to the GCD Adaptive Management Program be expanded to also make recommendations concerning annual releases.

## 2.0 Recommendation

We suggest that the post-2026 Guidelines should focus on rules for reducing consumptive use during years when runoff and reservoir storage is unusually low but should not include rules concerning how annual releases from Lake Powell will be determined on a year-to-year basis. Clearly, the post-2026 Guidelines must include guidance concerning the long-term average delivery of water from the Upper Basin to the Lower Basin, but there should not be prescriptive rules that determine the annual Lake Powell release in each year.

Instead, we recommend that reservoir and river operations in the Lake Powell/Grand Canyon/Lake Mead system be adaptively managed. Decisions about each year's annual release from Lake Powell should be made by the Secretary of the Interior, based on environmental and recreational considerations as well as considerations of water supply and hydropower. We

suggest that the decision about annual releases be made by the Secretary after consultation with the states, other interests, and consideration of environmental, recreation, and tribal interests.

Pursuit of this strategy will probably require that the GCD Adaptive Management Program charter be amended. We suggest that this federal advisory committee make formal recommendations to the Secretary regarding the annual release from Lake Powell in addition to recommendations already made concerning shorter duration releases. We also suggest that the geographic scope of the GCD Adaptive Management Program be expanded to include all of Lake Powell and all of Lake Mead, as well as the Grand Canyon ecosystem. The focus of recommendations about annual releases should consider how these releases might best achieve desired future conditions for Lake Powell, the Grand Canyon ecosystem, and Lake Mead.

Contrary to common misunderstanding, the 1922 Colorado River Compact and the 1944 Water Treaty with Mexico do not require a “fixed” annual delivery of water from the Upper Basin to the Lower Basin, as discussed below. The Bureau of Reclamation has the authority to implement a flexible delivery system wherein an accounting system can be established that credits the Lower Basin for water stored in Lake Powell but not delivered in a specific year.

Our suggestion maintains the principle of adaptive management – of learning by doing – that has been pursued in the Grand Canyon since the mid-1990s and is the guiding principle of the Grand Canyon Protection Act. Expansion of the geographic scope of the GCD Adaptive Management Program ensures that the competing issues in the management of recreation and the environment in Lake Powell and Lake Mead are considered along with the competing perspectives on how the Grand Canyon ecosystem is managed.

### 3.0 Background

#### 3.1 Designer flows and annual releases

To date, the strategy for mitigating the adverse effects to the Grand Canyon ecosystem of the existence and operations of Glen Canyon Dam and Lake Powell is to implement short-duration releases, such as controlled floods (administratively known as High Flow Experiments), Macro-invertebrate Enhancement Flows (informally known as bug flows), Low Summer Steady Flows (LSSF), and Trout Management Flows (proposed but not implemented). These types of releases are referred to as Designer Flows, because they do not disrupt long-term water-supply agreements. Designer flows do, however, have the potential to affect hydropower generation.

It has long been hoped that designer flows might offset the adverse effects of large-scale water-supply management, including sediment trapping in Lake Powell, transformations of temperature, and changes in the annual flow regime. Designer flows have been successful in maintaining the size of sand bars and in revitalizing the food base of invertebrates on which fish depend for food. Nevertheless, some underlying attributes of the ecosystem are strongly affected by annual flows.

### 3.2 The role of annual flows in downstream ecological conditions

One of those attributes is the total mass of sand stored on the channel banks and along the channel margin. This is the sand resource that gets mobilized during controlled floods, and progressive depletion of the sand resource ultimately undermines the success of controlled floods. Sand is primarily supplied to the Grand Canyon ecosystem from the Paria River and the Little Colorado River (LCR), the two large tributaries whose delivery of sand is not blocked by Glen Canyon Dam. Sand is primarily delivered during monsoon season floods, and the mass of sand evacuated from Grand Canyon primarily depends on the amount of water released from Lake Powell. Thus, the long-term mass balance of sand that is the supply needed to guarantee the success of controlled floods depends on the number of years when large monsoon-season floods deliver sand to the Colorado River and on the magnitude of releases from Lake Powell.

Topping et al (2021) summarized nearly 20 years of sediment transport data collected in Grand Canyon, and they developed simple relations between the amount of sand accumulated or evacuated by different annual Lake Powell releases when there are large or small inputs from the Paria River and the LCR. Although there is variability in these relations due to other factors that control suspended sediment transport, these relations highlight the dominant role of annual reservoir releases in determining the sand mass balance of Grand Canyon. For example, in years when sand delivery from the Paria River is less than 1.1 million tons, annual releases from Lake Powell must be less than 8.0 million af/yr (acre feet per year) for sand to accumulate in Marble Canyon (Fig. 1). In contrast, in a year when annual delivery of sand exceeds this threshold, reservoir releases can be as large as 9.8 million af/yr without eroding sand from Marble Canyon. Years of small sand supply occur more frequently than do years of large supply, and releases from Lake Powell would have to be less than 8.0 million af/yr to ensure sand accumulation in those years of low supply. Large equalization releases in 2011 that exceeded 11 million af/yr greatly increased sand erosion, and many sand bars never recovered from that wave of erosion. Grams et al (2019) concluded that almost all of the sand erosion between 2009 and 2012 occurred during the 7 months of equalization in 2011. In such years, when releases are made that are greater or less than might be made under accounting rules agreed on among the states or established by the federal government under the Post-2026 guidelines, the accounting system would track the differences to retain Law of the River compliance.

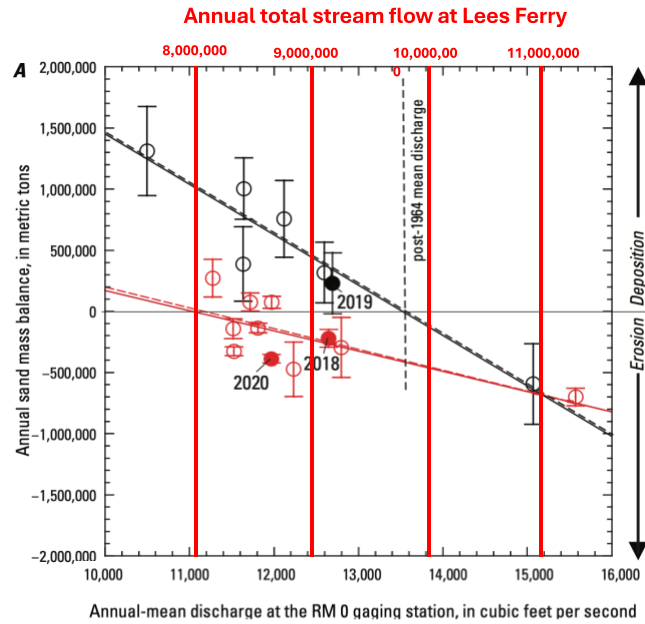


Figure 1. Graph showing annual sand mass balance as a function of annual-mean discharge (in black, bottom X-axis) and annual total stream flow (in red, top X-axis) at Lees Ferry gage for Marble Canyon. Data are separated into relatively large (black) and relatively small annual tributary sand supply delivered from the Paria River. Error bars indicate the magnitude of the uncertainties in annual sand mass balance. The regression line for small sand supply indicates that erosion of sand in Marble Canyon occurs when annual Lake Powell releases exceed approximately 8.0 million af/yr. Note that sand was eroded from Marble Canyon in 2020 when annual releases were 8.71 million af/yr. In this study, year is defined as the period between July 1 and the following June 30, termed a “sediment year.” Adapted from Griffiths et al (2024, fig. 2A).

Annual releases also play important roles in the aquatic ecosystem, because storage in Lake Powell is determined by the difference between the volume of inflows and of outflows. Warmer water is released from Lake Powell when Lake Powell is low (Dibble et al., 2021), and these releases also entrain undesirable non-native species. Today, those species include smallmouth bass that threaten the integrity of the existing fish community in Grand Canyon. Decisions about annual releases that in turn determine the amount of water in Lake Powell will have a strong effect on the aquatic ecosystem when reservoir elevation drops below 3600 ft asl and reservoir contents are less than 50% of capacity. These conditions are highly likely in the future, and decisions will have to be made annually about whether the volume of releases should be adjusted to affect the elevation of Lake Powell and the likelihood of entrainment of non-native fish from Lake Powell into the Grand Canyon.

### 3.3 Uncertainty in scientific predictions and uncertainty in management goals

Another principle that should be considered in managing environmental and recreational resources of the Lake Powell/Grand Canyon/Lake Mead ecosystem is the inherent uncertainty in applying scientific insights to management actions. There are often unforeseen physical or biological processes or unintended consequences of management actions that require

adaptation and revision of management paradigms. In the past, revision of codified rules has been necessary because of new scientific findings, such as numerous revisions of the rules concerning implementation of controlled floods. Those rules were initially addressed in 1996, were significantly changed in the 2012 HFE Protocol because of new scientific insights (Rubin et al., 2002), were revised again in the Record of Decision of the Long-Term Experimental and Management Plan (LTEMP) EIS, and other changes are now proposed in the supplemental EIS that proposes revisions to the LTEMP. Acceptance of the inevitability of scientific uncertainty and the need to revise guiding paradigms in river management suggests that the Lake Powell/Grand Canyon/Lake Mead ecosystem would be better served by providing greater flexibility in the determining annual releases. Flexibility is the basic premise of the GCD Adaptive Management Program that mandates that environmentally-oriented reservoir operations should be pursued in an adaptive framework wherein management actions are treated as experiments and actions can be changed.

Additionally, the values and goals of ecosystem management change over time. Schmidt et al. (1998) argued that the most significant uncertainty in planning environmental river management in Grand Canyon was that the goals of rehabilitation are poorly defined. Conflicting goals will have to be resolved in the future. For example, is the goal of maintaining the existing novel fish community in Grand Canyon that that is dependent on maintaining a higher elevation of Lake Powell a more important management goal than maintaining the emergence of valued cultural landscapes and returning rapids in Glen Canyon that require a lower reservoir elevation? Societal values in 2024 might emphasize one desired future condition over the other, but those values may change in subsequent decades. An adaptive recommendation of annual releases would allow resource management goals expressed by the GCD Adaptive Management Program to change with time without the need to formally amend the post-2026 Guidelines.

Thus, we suggest seeking a strategy that allows adaptive and flexible management of annual releases from Lake Powell. Combining needed certainty in water-supply management with needed flexibility and adaptability in management of the Lake Powell/Grand Canyon/Lake Mead ecosystem will be a significant but necessary challenge. The central question for the future is, “How can the certainty required of water-supply agreements negotiated among the Basin states mesh with the inherent uncertainty of ecosystem management?”

#### 4.0 A proposal – accept uncertainty and adopt adaptive management for the Lake Powell/Grand Canyon/Lake Mead ecosystem

We advocate embracing adaptation and uncertainty in managing the Lake Powell/Grand Canyon/Lake Mead ecosystem. An alternative to embracing flexibility might be to adopt prescriptive rules for target elevations for Lake Powell or desired releases that might focus on a specific environmental management goal: such as fish management or recreational boating. We discourage this approach, because locking in rules based on current scientific understanding runs the risk that rules will need to change as scientific understanding evolves. Additionally, the condition of the Grand Canyon ecosystem may change due to unintended interactions among the native and non-native species, and the values ascribed to the emerging resources of Glen Canyon



may change. Additionally, while the preponderance of the current science points to a drier future, there is considerable uncertainty in how dry that future will be. Thus, we do not know how much managers will struggle to achieve any target elevation for Lake Powell.

Rather than codifying rules based on scientific projections that have unavoidable uncertainty and are based on changing values concerning environmental and recreational resources, we advocate that the post-2026 Guidelines should narrowly focus on balancing water supply and consumptive use. The post-2026 Guidelines should consider the Powell/Grand Canyon/Mead ecosystem as a black box where the management issues associated with passing water through that black box are addressed by yearly decisions by the Secretary of the Interior. The post-2026 Guidelines would establish accounting goals of how much water should be released from Lake Powell based on agreed upon criteria for reductions in consumptive use during dry times, but decisions about the amount of wet water released in any year should be made by the Secretary each year. Additionally, the post-2026 Guidelines need not address the proportion of the water stored in Mead or in Powell. In the next section, we describe an accounting scheme wherein deficits and surpluses in the delivery of wet water from the Upper Basin to the Lower Basin could be tracked.

We suggest the following process by which the Secretary would make decisions about the release of wet water from Lake Powell.

- Annually, the Secretary will decide the annual release from Powell to Mead. That decision will be based on:
  - Recommendations from each of the basin states, assumed to be primarily focused on water supply, reservoir storage, and hydropower production;
  - Recommendations of the relevant federal agencies of the Department of the Interior and the Department of Energy;
  - Recommendations of the GCD Adaptive Management Program stakeholders, presumably based on modeling and monitoring data about sand bar resources, the sand mass balance related to recent inflows of sand, the fish community, and other resources of the Grand Canyon ecosystem, the emerging natural resources of Glen Canyon, and the recreational resources of Lake Powell and Lake Mead; and,
  - Recommendations of the five tribes that participate in the GCD Adaptive Management Program;

The recommendations of the GCD Adaptive Management Program would inevitably result from debate among stakeholders who have different perspectives about the relative value of different pre-dam relict and post-dam artifact resources (*sensu* Schmidt et al., 1998). We acknowledge that expansion of the geographic scope of the GCD Adaptive Management Program may result in changes in the stakeholders who participate in the program. It is recognized that the five tribes providing direct input to the Secretary are members of the GCD Adaptive Management Program, but the Secretary would nevertheless seek direct input from these tribes distinct from the opinions of the GCD Adaptive Management Program.

The buck must stop with the Secretary of the Interior, and the Secretary would make the final decision about annual releases based on consideration of all the input described above. Establishing a flexible approach to defining actual reservoir releases from Lake Powell would ensure that management of environmental resources of Lake Powell, the Grand Canyon, and Lake Mead are considered in a transparent way. This flexible approach preserves the principle of adaptive management and recognizes that annual releases have significant ecosystem effects that cannot be mitigated by designer flow releases. A flexible approach also recognizes the uncertainty in predicting future ecosystem conditions or assigning values to different ecological and recreational values while recognizing that there are likely to be future unintended consequences to some management actions.

The future is deeply uncertain – not merely concerning the amount of future runoff and the ability of water users to limit their consumption of water – but also how the river’s ecosystem will evolve and respond to management actions. Adaptive management of annual reservoir releases will allow ecosystem science and ecosystem management to evolve along with a changing climate and changing water use.

#### 5.0 How might a flexible accounting of Upper Basin deliveries to the Lower Basin work?

The goal of this accounting system would be to set up a transparent accounting system that recognizes a prescribed, but theoretical, annual release from Lake Powell based on water supply considerations as negotiated in the post-2026 Guidelines. We suggest that the new Guidelines allow the Secretary of the Interior to make adjustments to the actual release of wet water from Lake Powell, taking into account other factors such as environmental, recreational, hydropower, and tribal considerations. The difference between the prescribed annual release and the actual release would be credited or debited to the appropriate basin.

#### 5.1 Background to the consideration of a flexible accounting system

For Colorado River Compact purposes, measuring and accounting for flows at Lee Ferry is important. There is no gage at Lee Ferry, and the flow at Lee Ferry is the sum of the flow at the Lees Ferry (USGS gage 90380000) and Paria River (USGS gage 09382000) gages a short distance upstream.

Article III of the Colorado River Compact includes certain disputed flow-related provisions. Article III(d) requires that the four States of the Upper Division not cause the flow at Lee Ferry to be depleted to less than 75 million af every consecutive ten years. Further Article III(c) requires that if there is not sufficient “surplus” water available to meet the annual delivery obligation to Mexico under the 1944 Treaty (normally 1.5 million af/yr), the States of the Upper Division shall deliver at Lee Ferry 50% of the deficiency (the difference between the available surplus and 1.5 million af/yr) in addition to their III(d) obligation. If there is no surplus (and the Upper Division States are not required to cover transit losses), the required delivery is 0.75 million af/yr.

The States of the Upper Division and the States of Lower Division have never agreed on how to interpret and implement Article III(c). In 1970, the Secretary promulgated the Long-Range Coordinated Operating Criteria (LROC) setting a “minimum objective release” from Glen Canyon Dam at 8.23 million af/year. The 8.23 million af/yr happens to be 7.5 million af/yr plus 0.75 million af/yr minus 0.02 million af/yr that is the long-term mean flow of the Paria River. The ~0.15 million af/yr of flow that accrues between the dam and the Lee’s Ferry gage was not considered when setting the minimum objective release or the prescribed annual releases under the 2007 Interim Guidelines. The Upper Division States strongly objected to setting the annual release at 8.23 million af/yr. In response the Secretary made it clear that the release was an objective, not a requirement. and that the Secretary has the legal authority to modify the annual release from the dam. In a 2 June 2005 letter, Secretary Gail Norton reiterated the authority and flexibility provided to the Secretary under the LROC. The 2007 Interim Guidelines do not include a minimum objective release *per se*, but the 8.23 million af/yr release is used as common release amount in the tiering.

## 5.2 A conceptual proposal for flexible accounting

The rules under which annual releases after 2026 will be determined are being negotiated. There are many possible outcomes of these negotiations. One possibility is that agreement between the two basins is not reached, and annual releases in the future are determined under the 1970 LROC as anticipated by the termination provision of the 2007 Interim Guidelines. Another possibility is that the two basins (divisions) reach a compromise on a set of rules that would set an annual release amount under different triggering conditions such as the amount of reservoir storage in the watershed. If agreement is ultimately achieved, it is likely that a “prescribed release” will be defined. If a compromise set of release objectives is adopted, the Secretary would still retain the flexibility to adjust annual releases for purposes other than water supply. In doing so the Secretary could adopt a set of accounting rules that would retain on paper an agreement between the Upper and Lower Basin states, but also retain flexibility to consider environment, recreation, hydropower, and tribal considerations.

If the Secretary determines that the annual release from Glen Canyon Dam should be different than the prescribed release for purposes other than water supply, as described above, then Reclamation would make the adjusted annual release as directed by the Secretary. If the revised annual release is less than the prescribed release, then the difference would be credited to an account referred to as “Lower Basin Water Stored above Lee Ferry” and for Lee Ferry accounting purposes, necessary under the Compact, the water would be considered as having flowed by Lee Ferry in the year the water is credited to the account. If the revised annual release is more than the prescribed release, then the difference would be credited to an account referred to as “Upper Basin Water Stored Below Lee Ferry.” For accounting purposes, the year the water is delivered to the river and credited to the account would not be considered a Lee Ferry (i.e., Compact) delivery. It would be considered a Lee Ferry (Compact) delivery in the year the water is made available for use in the Lower Basin.

Once there is water in the “Lower Basin Water stored above Lee Ferry” account, it would be discharged or credited by either releasing the water from Lake Powell or trading it for a like amount of water in the “Upper Basin Water Stored Below Lee Ferry” account. In the year either option occurs, it would not be considered a Lee Ferry delivery, because, for Compact purposes, it has already been delivered. Water in the “Upper Basin Water Stored Below Lee Ferry” account would be credited as a Lee Ferry delivery when it is made available for use in the Lower Basin. If the water is traded for a like amount of water in the “Lower Basin Water Stored above Lee Ferry” account, it is not considered a Compact delivery the year it is traded. An example of the operation of this accounting scheme is described in Appendix 1.

We note that while this kind of accounting system may be a novel idea for Lake Mead and Lake Powell, similar multi-reservoir accounting systems are used by Reclamation. An example is the accounting system used for the operations of Taylor Park and Blue Mesa Reservoirs under the 1975 Exchange Agreement.

## References

- Dibble, K. L., Yackulic, C. B., Kennedy, T. A., Bestgen, K. R., and Schmidt, J. C. 2021. Water storage decisions will determine the distribution and persistence of imperiled river fishes. *Ecological Applications* 31(2): e02279.
- Grams, P. E., Buscombe, D., Topping, D. J., Kaplinski, M., and Hazel, Jr., J. E. 2019. How many measurements are required to construct an accurate sand budget in a large river? insights from analyses of signal and noise. *Earth Surface Processes and Landforms* 44: 160-178.
- Griffiths, R. E., Topping, D. J., and Unema, J. A. 2024. Changes in sand storage in the Colorado River in Grand Canyon National Park from July 2017 through June 2020: U. S. Geological Survey Open-File Report 2023-1093, 9 p.
- Rubin, D. M., Topping, D. J., Schmidt, J. C., Hazel, J., Kaplinski, M., and Melis, T. S. 2002. Recent sediment studies refute Glen Canyon Dam hypothesis. *Eos* 83(25) 277-278.
- Schmidt, J. C., Webb, R. H., Valdez, R. A., Marzolf, G. R., and Stevens, L. E. 1998. Science and values in river restoration in the Grand Canyon. *Bioscience* 48(9): 735-747.
- Topping, D. J., Grams, P. E., Griffiths, R. E., Dean, D. J., Wright, S. A., and Unema, J. A. 2021. Self-limitation of sand storage in a bedrock-canyon river arising from the interaction of flow and grain size. *Journal of Geophysical Research: Earth Surface* 126: e2020JF005565.
- Wheeler, K. G., Udall, B., Wang, J., Kuhn, E., Salehabadi, H., and Schmidt, J. C. 2022. What will it take to stabilize the Colorado River? *Science* 377(6604): 373-375.
-

Appendix 1: Example Accounting Sequence:

YEAR	Prescribed Release	Actual Release	LBWSALF	UBWSBLF	COMPACT
2030	8.0 maf	7.0 maf	+1.0 maf		8.0 maf

Notes – in this year, the goal was to increase the storage in Powell, so a smaller release 7.0 maf is made. The LBWSALF account was credited with 1.0 maf, but for compact accounting the delivery is considered 8.0 maf.

2031	8.0 maf	8.5 maf		+0.5 maf	8.0 maf
------	---------	---------	--	----------	---------

Notes – in this year the goal is to deliver an additional .5 maf for environmental purposes, so an 8.5 maf is made and the UBWSBLF account is credited with .5 maf and for compact purposes the delivery is 8.0 maf. At this point, since there is water in both accounts, the basins could make a trade. However, let's assume that UD States decide to keep the water in the account.

2032	10.0 maf	9.0 maf	1.0 + 1.0 = 2.0 maf	+0.5 maf	10.0 maf
------	----------	---------	---------------------	----------	----------

Notes - this is a wet year, but goal is to not put 10 maf down the canyon for sediment management, so 9.0 maf is released and an additional 1.0 maf is credited to the UBWSBLF account making its total 2.0 maf. For accounting purposes, the delivery is 10 maf.

2033	8.5 maf	8.5 maf	2.0 maf	+0.5 maf	8.5 maf
------	---------	---------	---------	----------	---------

This is a "no change" year. The prescribed flow and the desired flow are the same and neither basin wants to utilize the water stored in its account,

2034	7.0 maf	8.5 maf	2.0 maf + 1.5 = 3.5 maf		7.0 maf
------	---------	---------	-------------------------	--	---------

In this year the goals are to equalize the power head between Mead and Powell and generate more power at Powell, so the desired release is 8.5 maf. An additional 1.5 maf is credited to the LBWSALF account giving it a total of 3.5 maf. Both accounts have 3.5 so they can cancel each other out. When this happens, both accounts are zero and the UB is not credited with an additional 2.0 maf compact delivery in the year 2034. If the UBWSALF had 1.0 maf and the LBWSBLF had 2.0 maf the 1.0 maf would cancel and the UB could either keep it or make it available to the LB – it then gets credit for a compact delivery)

In this example, the 5-year prescribed total flow is 41.5 maf. The actual flow is 41.5 maf. For Compact purposes, the UB delivery is 41.5 maf.

Several issues arise from this example that would need to be addressed:

- The above example assumes that the two basins and Interior agree on a compromise set of release rules (the "prescribed" delivery). If there is no agreement, the proposed accounting would work for a minimum objective release of 8.23 million af/year (or 8.1 million af/yr if the flows between the dam and gage are considered).
- When the reservoirs are full, the accounts would spill.
- There may need to be limits on how much water can accrue in each account.
- ICS accounts in either reservoir would be on top of the Compact account, (but could be integrated).