Colorado River Insights, 2025

Dancing With Deadpool

Photo Credit: Brad Udall

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A Product of the Colorado River Research Group

Photo Credit: John Fleck

Preface

Welcome to the Colorado River Research Group's (CRRG) inaugural *Colorado River Insights* report. This publication marks a new (and still evolving) direction for the CRRG, transitioning away from the group-authored policy briefs of the past to more personal "Individual Submissions" that allow members to be more focused, direct and sometimes prescriptive than in the past efforts authored jointly and requiring unanimous consent. While each of the Individual Submissions (i.e., Chapters) that follows is unique in structure and tone and detail, each member was given the same charge: to speak directly about issues on the river where they have been directing much of their current focus, and where feasible, to identify a path forward on those issues. Given this approach, each Individual Submission is truly individual—or, in several cases, the product of small groups—and thus should not be attributed to the entire body, although in practice there is usually very little internal conflict on any of the major themes featured throughout these pages. One byproduct of this approach is that it shines a light on some of the CRRG's most glaring holes in terms of disciplines and substantive expertise, helping to steer us to new potential members (and guest contributors) and, perhaps, new approaches. Unless or until that happens, we readily acknowledge that our collective snapshot of current and emerging basin issues is far from comprehensive. But how could it be? That's an impossible standard for a river as vast in size, importance and complexity as the Colorado.

We are hopeful that this new approach can be helpful in better funneling the knowledge emerging from the research community into the hands of decision-makers, journalists, NGOs, water users, and other concerned parties in a more hands-on position to implement the changes needed to restore the economic and environmental sustainability of the River. Clearly, we are in an era screaming for new ideas and new approaches; the *status quo* isn't working.

— Doug Kenney, *CRRG Chair*

The Colorado River Research Group (CRRG) was formed in 2014 to bring scientific insights to Colorado River system management, inspired in part by the salient role played by the Wentworth Group of Concerned Scientists in the Murray-Darling Basin—a similar, drought-stricken region in Australia. It was established as an independent, knowledgeable voice insulated from political constraints, sectoral alliances, and other pressures that might impede the full consideration of relevant ideas and viewpoints. Originally, the CRRG was launched with ten members, all academics with long, well-established involvement in Colorado River scholarship. In 2021 the group was expanded to 14 active members, while four original CRRG members transitioned to emeritus status. CRRG members serve as individuals, rather than as representatives of their universities or other organizations. The administrative home of the CRRG is the Getches-Wilkinson Center at the University of Colorado.

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Photo Credit: John Weisheit

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Executive Summary

Photo Credit: Brad Udall

Conditions on the Colorado River are, to put it bluntly, dire. The reservoirs that, when full, provide Colorado River water users with roughly 4 years of annual flows are now more than two-thirds empty. Additionally, the tradition of collaborative crisis management among the seven basin states may have reached its breaking point, as the ongoing EIS process for developing post-2026 rules has made it increasingly clear that finding truly sustainable solutions is both an exceptionally difficult challenge and is one that can no longer be kicked down the road. Both the water supply and institutional systems are failing; many of the environmental systems failed years ago, with others just hanging on desperately. Another year or two of low inflows and we will completely blow through the cushions provided by reservoir storage and the 20-year truce known as the Interim Guidelines, entering a world where physically moving water downstream becomes limited both by hydrology and engineering, and where the Compact "tripwire" of 10-year annual releases are potentially violated. As our report's sub-title suggests, we have now entered a new era: *Dancing with Deadpool*.

This inaugural *Colorado River Insights* touches on several of these issues in a variety of ways by eleven Colorado River Research Group members joined by eight guest contributors. It's far from a postmortem. The reality is that most of the problems in the basin are, and continue to be, to some degree self-inflicted, and that viable paths forward are available. Unlike many other corners of the world dealing with water stress, the Colorado River basin presumably has the resources and expertise needed to understand and address the multitude of challenges. This has been true for decades, but action has been postponed again and again, largely because the reality of the modern Colorado River does not match the river most States, Tribes, and NGOs felt they were promised. As we've all witnessed in recent years and months, that is a difficult starting point for negotiating solutions.

Given the open-ended nature of the Individual Submissions that comprise this volume, they don't fit together precisely in concept or structure like they would in a more deliberately structured multi-author book. Thus, the organization of the chapters is a "best fit" approach that generally pulls the reader from a discussion of physical conditions to human impacts, and simultaneously, from problem descriptions to more solution-oriented ideas. Again, this is an imperfect typology, as some contributions attempt to do all these things whereas others are much more narrowly focused.

The volume begins in **Chapter 1** with a detailed summary of the reservoir conditions that have inspired the disconcerting sub-title of this report, authored by authored by Jack Schmidt, Anne Castle, John Fleck, Eric Kuhn, Kathryn Sorensen, and Katherine Tara. As they note, the focus on crafting new long-term (post-2026) rules is a needed but dangerous distraction from the short-term crisis and the need to take action

immediately to further reduce consumptive water use across the basin. If winter 2025-2026 continues to be relatively dry and inflow to Lake Powell and other Upper Basin reservoirs is similar to that of 2024-2025, it is likely that less than 4 million acre feet in Lake Powell and Lake Mead would be *realistically available*—given infrastructure and hydropower production constraints limiting consumption of some active storage—for use during the nine months between late summer 2026 and the onset of snowmelt runoff in 2027. If winter 2026-2027 continues to be dry, water supply would be further constrained. The present reservoir operating rules that remain in place through 2026 are insufficient to avert this potential water supply crisis.

The sharp disparity between the river of today versus the river of the past (and the future) is a theme explored further in **Chapter 2** by Jonathan Overpeck and Brad Udall fleshing out the contribution of climate change to the current problem and, more importantly, future conditions. Building on earlier research showing how warming temperatures reduce runoff by affecting local hydrologic processes (such as evapotranspiration), new research further suggests that climate change also negatively influences precipitation patterns—and thus runoff—in the basin by modifying water and air temperatures in the Pacific Ocean. It is a perfect storm of bad news, with the caveat that the underlying cause—greenhouse gas emissions—is a problem that can be managed through human intervention.

In **Chapter 3**, Doug Kenney continues a focus on risk and risk management, noting that the declining reservoirs are not the only "safety nets" that are buckling under the stress of climate change and a broken water budget. The most familiar of those other hydrologic safety nets is groundwater, which according to some of the latest research, is being mined at a pace far exceeding the more visible losses in surface water. Compounding these problems, the federal agencies, programs, and people that exist to understand and address these problems—as well as the underlying problem of climate change—are now being rapidly dismantled. Loss of staffing and financial resources are likely to limit the ability of the "federal partner" to assist the basin states that, increasingly, seem unable to dig out from the policies that threaten regional water supplies. Litigation, once a third rail issue for the states, is now clearly on the table of options, and is increasingly viewed by some as the best (and perhaps only) road forward. Virtually every trend is increasing risks to economic, environmental, and social systems.

The topic of water equity—an issue bubbling just below the surface in virtually all the discussions herein—takes center stage in **Chapter 4**. Bonnie Colby and Zoey Reed-Spitzer's detailed review of all areas receiving Colorado River water illuminates a troubling reality: limited access to clean water (for households and green spaces) and exposure to water pollutants is closely linked to ethnicity, with Hispanic, Black, and Native American populations disproportionately burdened. This topic is largely absent from many of the discussions over the Colorado River's future. Admittedly, this is a difficult problem derivative of policies originating at multiple levels of government and in many substantive areas. Nonetheless, this more nuanced picture of water equity deserves to be part of the policy dialogue on matters of water access, infrastructure spending, and water quality protection.

It's hard to imagine a more flexible and adaptive way to manage risk (and improve equity) on the river at a macro scale than to base allocations on a percentage system, rather than the fixed apportionments that currently characterize the

Law of the River. As reviewed by Eric Kuhn in Chapter 5, that approach has now been seriously considered in 3 instances: first in the 1922 Colorado River Compact negotiations, then revisited for the 1948 Upper Basin Compact, and most recently in post-2026 negotiations occurring over the summer and fall of 2025. In only the 1948 Upper Basin Compact negotiations did this approach prevail. The recent effort in 2025 has been derailed—at least to this point—by two intractable questions: what percentage would each basin receive, and how would this be enforced? Rather than tackle those questions, the sub-basins seem increasingly willing to stick to their own, mutually incompatible, legal interpretations of how shortages should be parsed among sub-basins, even if this inevitably steers the parties to interstate litigation. The only realistic path to a percentage-based apportionment, therefore, may be as a negotiated settlement to litigation, or perhaps the serious threat of litigation.

Chapter 6 offers one potential road forward that looks at the root water management problem: overuse of water. Kathryn Sorensen and Sarah Porter begin by acknowledging the many notable and creative arrangements major water users have crafted in recent years to reduce risks and implement incentivized conservation, but notes that a real solution requires more significant and lasting net reductions in water consumption. Much of the basin's current water use has been promoted and facilitated through federal actions, suggesting an obligation for federal leadership in efforts to permanently reduce use. One approach would be to establish a program of purchase and retirement of some agricultural lands, focused largely on those featuring high water use and low economic productivity. Given the potential socioeconomic impacts of such a program, great care would be needed in the selection of lands and the structure of the program, but it is one of few options available to achieve the scale of water saving needed to balance the regional water budget.

Chapter 7 continues the focus on the agricultural sector, and specifically, the challenge of reducing water use on Upper Basin farms and ranches. Kristiana Hansen, Daniel Mooney, Mahdi Asgari, and Christopher Bastian base their analysis on the notion that water availability for these users will almost certainly decline in the future, regardless of how ongoing interstate negotiations play out. The challenge, thus, is to choose proactive adaptation rather than unmanaged decline in these operations so vital to supporting rural economies. A variety of operational strategies have already been demonstrated—and many others remain to be explored—to achieve the needed reductions in use, pending the development of policy and market mechanisms that make these practices feasible for producers.

The volume concludes in Chapter 8, somewhat ironically, with a discussion of where the laws and policies for the river originate: the governance arrangements. Here, Matthew McKinney, Jason Robison, John Berggren, and Doug Kenney lament the governance deficiencies in the basin in three intertwined areas: inclusivity, transparency, and framing. After doing so, they cast eyes towards a solution: convening a basin-wide conversation about the merits and possible construction of a basinwide entity where current and future issues in the basin can be addressed by sovereigns, technical experts, and concerned citizens and river advocates. This is common practice in much of the world, and is not a new proposal for the Colorado River. Given the disappointing state of river management, both in terms of process and substance, the time has never been better to seriously explore this pathway. •

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Colorado River Reservoir Storage – Where We Stand

Jack Schmidt[1], Anne Castle[2], John Fleck[3], Eric Kuhn[4], Kathryn Sorensen[5], Katherine Tara[6]

Artwork Credit: Patrick Kikuk

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In Brief

The rains of mid-October caused significant flooding in the San Juan River basin and increased reservoir storage throughout that basin and in Lake Powell.[7] However, basinwide reservoir storage remains low, and the October rainfall offerings were insufficient to alleviate the peril of declining overall water supply.

While the attention of the Basin's water management community remains focused on the thus far unsuccessful effort to forge a seven-state agreement on future long-term operating rules, the Basin continues to face the risk of short-term crisis. If winter 2025-2026 is relatively dry and inflow to Lake Powell and other Upper Basin reservoirs is similar to that of 2024-2025, low reservoir levels in summer 2026 will challenge water supply management, hydropower production, and environmental river management. Under such a scenario, it is likely that less than 4 million acre feet in Lake Powell and Lake Mead would be realistically available for use during the nine months between late summer 2026 and the onset of snowmelt runoff in 2027. If winter 2026-2027 is also dry, water supply would be further constrained. The present reservoir operating rules that remain in place through 2026 are insufficient to avert this potential water supply crisis. Action to further reduce consumptive water use across the basin is needed *now*.

How did we get here?

The Basin's reservoirs were nearly full in late summer 1999,[8] acting as a buffer against dry years and serving their fundamental purpose. At that time, the 46 Colorado River Basin reservoirs tracked by the Bureau of Reclamation in its Hydro database held 59.5 million acre feet (maf) in active storage,[9] more than four times the Basin's average consumptive uses and losses in the 1990s (Fig. 1).[10] Beginning in 2000, five years of below average runoff[11] resulted in a 46% reduction in storage in the Basin's reservoirs.[12] During that time, the reduction in storage in Lake Powell and Lake Mead accounted for 90% of the Basin's total loss in storage, because most of the Basin's water was stored in those two reservoirs.

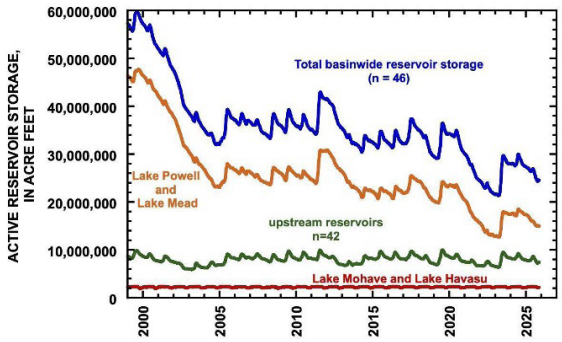

Figure 1. Graph showing active storage in reservoirs of the Colorado River Basin between January 1, 1999, and November 15, 2025. "n" is the number of reservoirs in specific regional groups.

[7] Between 9 October and 8 November, five reservoirs in the San Juan River basin gained 204,000 af in total storage, especially in Navajo and Vallecito Reservoirs. Between 9 October and 20 October, Lake Powell gained 105,000 af in active storage, and the total contents of Lake Powell and Lake Mead increased by 108,000 af between September 25 and October 27.

[8] Schmidt, J.C., Yackulic, C.B., and Kuhn, E. 2023. The Colorado River water crisis: its origin and the future. *WIREs Water* 2023;e1672.

[9] Total active storage in the Basin's 46 reservoirs was at its maximum on 24 August 1999.

[10] Total Basin consumptive uses and losses, including deliveries to Mexico, averaged 14.2 maf/yr between 1990 and 1999.

[11] Average natural flow of the Colorado River at Lees Ferry, estimated by Reclamation, was 9.5 (Water Year, WY) and 9.6 (Calendar Year, CY) maf/yr between 2000 and 2004. Average natural flow for the preceding ten years (1990-1999) was 15.0 maf/yr (WY, CY). Average natural flow for the entire 21st century between 2000 and 2025 was 12.3 maf/yr (WY, CY).

[12] Total active storage of the Basin's reservoirs was 32.0 maf on 19 October 2004.

During the next fourteen and a half years, the amount of storage in the Basin's reservoirs changed little, despite four years of large runoff (2005, 2011, 2017, and 2019). The increase in storage during the few wet years was nearly completely consumed during the more frequent dry years, and active storage in Powell and Mead was only 5% greater in late July 2019 than it had been at the beginning of 2005.[13] When dry years of low runoff returned between 2020 and 2022,[14] the Basin's water users had little of the buffer that they had at the beginning of the 21st century. Combined active storage of Powell and Mead was halved again between mid-July 2019 and mid-March 2023,[15] reducing the combined contents of these two reservoirs to only 27% of what it had been in late summer 1999.[16] If next winter's runoff is as low as it was in 2025 [17] and consumptive use is not significantly reduced, Powell and Mead will drop below the previous unprecedented low stand of mid-March 2023.

How much of active storage is realistically available?

One of the challenges of the current water supply crisis is uncertainty over how much water is actually available in the reservoirs for use. Although Reclamation regularly reports the amount of water in *active storage*, our analysis identifies *realistically accessible storage* as the more appropriate metric of the amount of water that is available for use without challenging the integrity of the dam structures, efficient production of hydroelectricity, or implementation of environmental river management protocols, especially in Grand Canyon.

Reservoir water that can be physically released from a dam is termed *active storage*. In virtually all reservoirs, there is a small amount of water below the elevation of the lowest outlets–the infamously named *dead pool*. Active storage is everything above dead pool–water that can be physically released through the reservoir's lowest outlets.

We know, however, that not all the water above dead pool is readily usable. Engineering assessments have indicated that infrastructure constraints at Hoover and Glen Canyon Dams require that higher reservoir elevations be maintained, thereby constraining utilization of the lowest part of the active storage. We defined *realistically accessible storage* as the volume of water whose release does not impact previously identified engineering or hydropower-production constraints.

At Glen Canyon Dam, for example, the lowest release tubes, called the "river outlets," are at elevation 3370 ft. Reservoir water below that elevation cannot be released and constitutes the dead pool. Above the river outlets, at elevation 3490 ft, are the intakes for the power generating turbines, known as the penstocks. The penstocks are the conduits that withdraw water from the reservoir into the powerplant to generate electricity, and thereafter discharge the water to the Colorado River downstream from the dam. When the reservoir falls below the elevation of the penstocks, the river outlets are the only means of discharging water through the dam (Fig. 2). The river outlets are not routinely used to release water; virtually all normal releases go through the penstocks.

[13] Total active storage in Lake Powell and Lake Mead was 23.0 maf on 1 January 2005 and was 24.2 maf on 28 July 2019, a 5% increase.
[14] Average natural flow at Lees Ferry averaged 9.0 (WY) and 9.2 (CY) maf/yr between 2020 and 2022.
[15] Total active storage in Lake Powell and Lake Mead was 12.7 maf on 14 March 2023, 48% less than it had been on 28 July 2019.
[16] Total active storage in Lake Powell and Lake Mead was 47.7 maf on 19 September 1999.
[17] Reclamation estimates that natural flow at Lees Ferry was 8.5 (WY, CY) maf in 2025.

Experience has shown that the river outlets were not designed for continuous release at the discharge rates required to meet downstream obligations. If the river outlets were to be used continuously, there is significant concern that structural damage to those outlets could occur.[18] Accordingly, Reclamation has determined that it will take steps to avoid Lake Powell elevation declining below 3500 ft, considered a safe elevation for continuous withdrawal of water through the penstocks without risk of harm caused by cavitation to the turbines that produce electricity.[19] Similarly at Lake Mead, Reclamation has indicated its intent to protect the reservoir from going below elevation 1000 ft.[20]

The total volume of active storage in Lake Powell above dead pool but below elevation 3500 ft is 4.2 maf. Release of this stored water is constrained, because it cannot be safely withdrawn through the penstocks, and continuous use of the river outlets is considered unwise. At Hoover Dam, there is 4.5 maf of active storage below elevation 1000 ft, also not realistically accessible. In these two largest reservoirs of the Colorado River Basin, there is a total of 8.7 maf of active storage below the elevations required for safe and efficient operation of the infrastructure (Fig. 3). Thus, of the 14.9 maf of active storage at Lake Powell and Lake Mead on November 15, 2025, only 42% of that active storage, 6.2 maf, was *realistically accessible*.

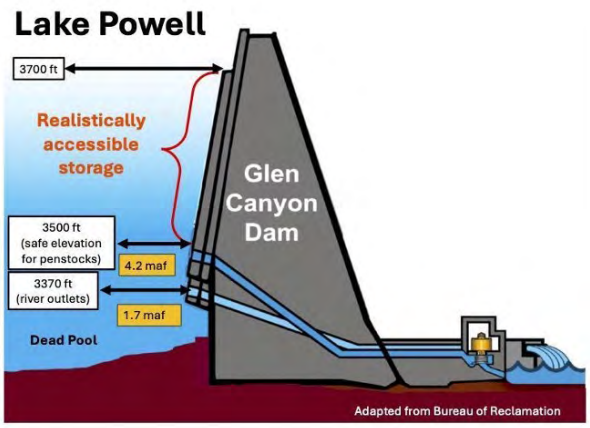

Figure 2. Diagram showing schematic of Glen Canyon Dam elevations at which Lake Powell's waters can be released downstream, and the volumes of water defined by these elevations. Active storage between 3370 and 3500 ft is not realistically accessible for continuous downstream release without risk to engineering infrastructure at the dam and powerplant. Hydroelectricity cannot be produced below 3490 ft, and 3500 ft has been established as a minimum safe level for intake through the penstocks.

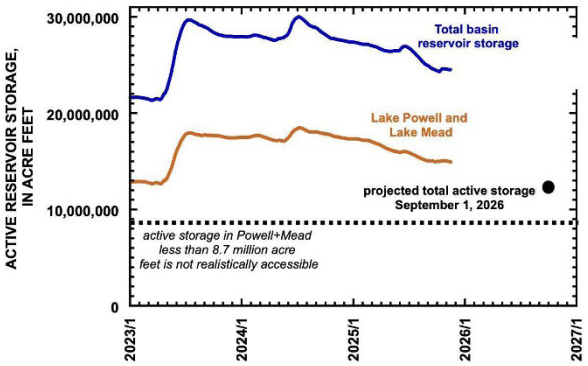

Figure 3. Graph showing active storage of 46 reservoirs in the Colorado River Basin (blue line) and the combined active storage in Lake Powell and Lake Mead (orange line) between January 1, 2023, and November 15, 2025. Realistically accessible storage in Lake Powell and Lake Mead is the quantity of water greater than 8.7 maf (black dashed line). The projected total active storage in Lake Powell and Lake Mead on September 1, 2026, based on the methods described in the text, is shown as a black dot.

[18] Bureau of Reclamation, Establishment of Interim Operating Guidance for Glen Canyon Dam during Low Reservoir Levels at Lake Powell (2024).[18]
[19] Bureau of Reclamation, Supplement to 2007 Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations of Lake Powell and Lake Mead, Record of Decision (2024) (SEIS ROD).
[20] *Id.*

Implementation of environmental river management protocols at Glen Canyon Dam are constrained when the elevation of Lake Powell is low. Since 1996, controlled floods, administratively termed High Flow Experiments (HFEs), have been conducted at Glen Canyon Dam to rebuild eddy sandbars along the river's margin and conserve sediment. HFEs are now an essential component of the Long Term Experimental and Management Plan for Glen Canyon Dam.[21] Reclamation did not, however, release an HFE in 2021 or 2022 when sediment conditions were sufficient to trigger implementation of the HFE Protocol because Lake Powell was low. In early October of those years, when decisions about implementing HFEs were made, active storage in Lake Powell was 7.3 maf (elevation 3545.3 ft) and 5.8 maf (elevation 3529.4) in 2021 and 2022, respectively. Reclamation cited low storage as the reason not to release those controlled floods.[22] Although administrative decisions change with time, it is doubtful that any HFEs would be released if Lake Powell fell below elevation 3500 ft.

Low reservoir levels also impact Reclamation's ability to control the invasion into Grand Canyon of smallmouth bass, and other warm water reservoir fish species, that dominate the recreational fish community of Lake Powell. These nonnatives are significant predators and competitors of endangered or threatened native fish species and live near the surface of Lake Powell. At moderate and low reservoir elevations, water withdrawn through the penstocks (termed *fish entrainment*) includes some fish that survive passage through the powerplant turbines and are delivered into the Colorado River downstream from the dam. These fish have the potential to successfully spawn downstream from the dam if river temperatures are relatively warm, such as occurs when Lake Powell is low and water is only released through the penstocks.

Reclamation has implemented a protocol to eliminate the potential of smallmouth bass population establishment in Grand Canyon by releasing some cooler water through the river outlets when the water released through the penstocks is warm. The objective of these *Cool Mix* releases is to disrupt smallmouth bass spawning downstream from the dam. Water released through the river outlets bypasses the powerplant and does not produce electricity, and Western Area Power Administration (WAPA) must purchase electricity on the open market to replace electricity that the agency contractually committed to provide. WAPA estimated that the cost of replacing contracted electricity was $18.9 million[23] and $6.5 million[24] during the *Cool Mix* releases of 2024 and 2025, respectively. The risk of fish entrainment from Lake Powell increases significantly as Lake Powell's elevation drops, and the need to implement the Cool Mix protocol therefore increases. The risk is minimized if Lake Powell is higher than 3590 ft (10.8 maf active

[21] U.S. Department of the Interior, Record of Decision for the Glen Canyon Dam Long-Term Experimental and Management Plan, Final Environmental Impact Statement, December 2016.

[22] Salter, G. and 7 co-authors, 2025, Reservoir operational strategies for sustainable sand management in the Colorado River. *Water Resources Research* 61, e2024WR038315.

[23] Ploussard, Q., Pavičević, M., and Yu, A. 2025. Financial analysis of the smallmouth bass flows implemented at the Glen Canyon Dam during Water Year 2024. Argonne National Laboratory report ANL 25/44, 17 pp.

[24] C. Ellsworth, Western Area Power Administration, pers. commun.

storage) and significantly increases when Lake Powell is below 3530 ft (5.8 maf active storage).[25] When water is no longer withdrawn through the penstocks, the risk of entrainment decreases, because all water passes through the lower elevation river outlets.

What would happen if the coming winter and spring snowmelt is similar to 2024-2025?

In an analysis released in September 2025, we reviewed what might happen in the coming year if runoff is the same as it was last year and Basin consumptive uses and losses are the average of the past four years. We used a simple mass balance approach and estimated the available water supply and consumptive uses and losses, and calculated the difference between the two. The available water supply is the sum of the natural flow of the Colorado River at Lees Ferry plus inflows that occur in the Lower Basin, primarily in Grand Canyon. Consumptive uses and losses are those associated with diversions that support irrigated agriculture, municipal and industrial use, water exported from the Basin by trans-basin diversions, and reservoir evaporation. The difference between supply and use is the net effect on reservoir storage. We then estimated the effect of the Basinwide imbalance between supply and use on the combined realistically accessible storage in Powell and Mead, i.e., above elevations 3500 and 1000 ft in Lake Powell and Lake Mead, respectively.

In the scenario that we considered, we assumed that natural flow at Lees Ferry in the coming year will be 8.5 maf, the same as in Water Year 2025,[26] and inflow in the Grand Canyon is 0.8 maf. Thus, we assumed a total supply in the coming water year of 9.3 maf. We analyzed a scenario wherein consumptive uses and losses in the United States portion of the Colorado River would be the average of the most recent four years (2021-2024), namely 11.5 maf,[27] and we assumed that 1.4 maf would be delivered to Mexico.

The gap between supply and use under this scenario is 3.6 maf, which would have to be met by additional withdrawals from reservoir storage. Assuming that 75% of this deficit would be withdrawn from Lake Powell and Lake Mead (2.7 maf), then the realistically accessible storage in these two reservoirs would be reduced to 3.5 maf, slightly less than the 21st century low that occurred in mid-March 2023 (Fig. 3).

Our analysis of this one realistically low inflow scenario–the coming year's supply is just like last year's and consumptive uses and losses are the average of the past four years–is consistent with, but less dire than, Reclamation's most recent 24-Month Study minimum probable forecast[28] for the coming year. That study projects that total storage in Lake Powell and Lake Mead will be drawn down by 3.8 maf during the next year, 2.9 maf from Lake Powell alone. Under Reclamation's minimum probable projection, the elevation of

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[25] Eppenhimer, D. E., Yackulic, C. B., Bruckerhoff, L. A., Wang, J., Young, K. L., Bestgen, K. R., Mihalevich, B. A., and Schmidt, J. C. 2025. Declining reservoir elevations following a two-decade drought increase water temperatures and non-native fish passage facilitating a downstream invasion. Canadian Journal of Fisheries and Aquatic Sciences 82:1-19.

[26] During the 21st century, natural flow at Lees Ferry was lower than this amount in 2002, 2012, 2018, and 2021, meaning that this is not a worst case scenario.

[27] In 2024, consumptive uses and losses in the Upper and Lower Basins totaled 11.4 maf.

[28] October 2025 24-Month Study Minimum Probable Forecast. For a discussion of why the Minimum Probable forecast has become a more reliable indicator of the future than the Most Probable 24-Month Study, see Awaiting the Colorado River 24-Month Study, Aug. 14, 2025.

Lake Powell would drop below 3500 ft in August 2026. All of the remaining realistically accessible storage, 2.5 maf in the scenario modeled by Reclamation, would be in Lake Mead. Under the assumption that the current operating rules remain in effect in 2027, Reclamation's projection is that the elevation of Lake Powell would stay below elevation 3500 ft through at least July 2027.

Further complicating the situation is that the status and ownership of water in Lake Mead at very low storage levels is unclear. Lake Mead holds (a) water available for allocation in the Lower Division under the prior appropriation system, (b) at least some amount of the water due to Mexico under treaty obligations, and (c) assigned water. Assigned water, commonly known as Intentionally Created Surplus or ICS, is water that can be delivered independent of the Lower Basin's prior appropriation water allocation system and that is held in Lake Mead by the Secretary of the Interior for the benefit of a specific entity. Assigned water also includes delayed water deliveries held for the benefit of the Republic of Mexico that can be delivered subsequently in amounts in excess of the U.S. treaty obligation to Mexico of 1.5 maf/year. Owners of assigned water have the right to withdraw that water when Lake Mead water levels are above 1025 ft, but entitlement holders in the priority system also have a right to water deliveries, as does Mexico via treaty.

So long as there is water in Lake Mead adequate to fulfill all required and requested deliveries, no conflict arises. However, as the amount of water in Lake Mead decreases, the potential for a clash increases. International treaty obligations take precedence over deliveries pursuant to the priority system within the U.S., but it is unclear how competing priorities and entitlements will be resolved within the U.S. Holders of higher-priority entitlements would likely contest the Secretary's authority to reduce their deliveries while withholding assigned water from the priority system. As of the end of 2024, there was approximately 3.5 maf of assigned water in Lake Mead, almost the same as the amount of realistically accessible water in storage above elevation 1000 ft. If Lake Powell ever became a "run of the river" facility, the potential for conflict over access to water in Lake Mead would also increase.

Implications

We are not weather forecasters and have no crystal ball that reveals the coming winter snowpack. We are not predicting that our assumptions about the gap between supply and use/losses and the resulting drawdown of Lake Powell and Lake Mead will inevitably occur. Our scenario is merely one of many possibilities, but our assumptions are sufficiently realistic to serve as a warning of how close the Basin is to a true water crisis. Our results should serve as a call to action. We need to adopt additional and immediate measures across the Basin to reduce water consumption even further during the next year, well before any new guidelines are in place.

Taking steps now to decrease consumptive uses across the Basin will reduce the need to implement draconian measures next summer or in the following years. Every acre foot saved now is an acre foot available for our future selves, slowing the rate of reservoir decline and creating more room for creative Colorado River management solutions. If, on the other hand, we delay reducing water usage and addressing reservoir drawdown, we may find ourselves in more significant distress at the beginning of the Post-2026 guidelines. As we wrote in October, continued reduction in Lake Powell releases also brings the Basin perilously close to the Colorado River Compact "tripwire," the point at which the ten-year rolling total of water delivered from the

Upper Basin to the Lower Basin might trigger litigation asking the U.S. Supreme Court to interpret long avoided ambiguities in rules written a century ago by the drafters of the Colorado River Compact.

We do not presume to make specific recommendations about the steps that should be taken immediately to reduce consumptive use in the Basin. There are many smart and experienced individuals in the Colorado River community whose sole focus is on the mechanics of operating the Colorado River water system and the impacts of operations on their particular constituencies.

We can, however, highlight the available *mechanisms* for reduction of consumptive use that should be explored for their immediate utility in diminishing the looming jeopardy to the overall system. Such mechanisms include:

- Releases from federal reservoirs upstream of Lake Powell to stabilize storage in Lake Powell.
    - Such releases would be made pursuant to the Drought Response Operations Agreement or similar successor agreement or pursuant to the Secretary of the Interior's inherent authority to operate federal water projects. Obviously, such releases do nothing to solve the imbalance between supply and demand and will create additional depletions in the system when these reservoirs are refilled. Such releases can, however, provide a temporary bulwark against exceptionally low levels in Lake Powell.
- Additional reductions in deliveries from Lake Mead under the Secretary's Section 5 delivery contracts in the Lower Basin, as authorized by Section II.B.3 of the decree in *Arizona v. California*, 376 U.S. 340 (1964).
    - By reducing deliveries from Lake Mead, releases from Lake Powell could also be reduced without the risk of causing exceptionally low storage in Lake Mead.
- Extension of system conservation programs in the Lower Basin, and facilitation of an Upper Basin water conservation program, both funded through compensation from federal or state governments or other water users in the Basin, and requiring specific quantities of saved water.
    - Relying on compensated annual forbearance alone is unsustainable, however, because it is not feasible to pay water users in the long term to forgo the use of water that nature no longer supplies. Permanent reductions in consumptive use are both necessary and also the most productive use of limited funding. In addition, to be effective, changes to state law in some Upper Basin states may be necessary, including recognition of water conservation as a beneficial use for the purpose of avoiding litigation concerning the Colorado River Compact. Finally, authorization for shepherding of saved water to the intended place of storage is essential, including across state borders.
- Reductions in deliveries to Mexico through negotiation of a new minute.
- Reductions in consumptive use by federal water projects in the Upper Basin, if allowable pursuant to the Secretary's authority.
    - It should be noted, however, that in order to benefit the Colorado River system, any such reductions must be recognized at the point of diversion and shepherded to the intended place of storage.

It is obvious that any long-term agreement for future Colorado River operations among the Basin States should be evaluated based on its immediate ability to reverse the storage declines experienced in recent years and anticipated in the future under similar hydrology. An agreement that does not reliably balance supply with uses and losses is not sustainable. Similarly, any operational alternative proffered by the Department of the Interior must achieve the same objectives. When our reservoir storage is as low as it is now, we have very little buffer to rely on–we simply cannot use more water than nature provides.

The focus within the Basin and among its principal water users and state negotiators has been on the formulation of the Post-2026 guidelines for operation of the river. But action is necessary now to avoid creating conditions that will doom the next set of operating principles by initiating their implementation when the Basin is in full crisis mode. No governmental administration, state or federal, wants to see the Colorado River system fail on its watch. Negotiators have worked tirelessly to reach agreement, yet have come up short. The hour is late. The Secretary must take decisive action. ●

Photo Credit: John Weisheit

2

Think Natural Flows Will Rebound in the Colorado River Basin? Think Again.

Jonathan Overpeck[1] and Bradley Udall[2]

Photo Credit: John Weisheit

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Basin status update

Back in 2017, we published a peer-reviewed research paper (Udall and Overpeck, 2017) asserting that climate warming was a principal cause of the then eighteen-year Colorado River drought, a drought that had already seen a 17% reduction in natural flows of the river. We expressed confidence that warming would continue to eat away at these flows until the warming (due to greenhouse gas emissions, high confidence) ceased and suggested that increases in precipitation would likely not be able to compensate for the long-term impact of rising temperatures. We used the term "Hot Drought" to distinguish this period from the "Dry Droughts" in the 20th century. This important concept continues to be researched and confirmed (King et al, 2024, Zhuang et al, 2024). Now, eight years later, as the warming has continued unabated and may be accelerating (Hansen et al, 2025, Ripple et al., 2025), it has become clearer than ever that precipitation declines have also played an important role in causing the worst drought in at least 1200 years (Williams et al., 2022). More troubling, however, is new evidence that human caused climate change is not only driving a steady increase in temperature but is also the main culprit behind the precipitation declines as well.

This is clearly bad news, but there is a silver-lining. But first, let's review where we are with respect to the unprecedented 21st century Colorado River drought, and the new evidence suggesting the situation is worse than we first thought.

Each year one of us updates a figure[3] that was first published in our 2017 paper showing the status of the Colorado River drought and its climate drivers. We've included this figure here, updated through the September 30th end of the 2024-25 water year (Figure 1). The combined volume of water stored in Lakes Mead and Powell has continued its decline to less than 15 maf (million acre-feet), the 26-year average naturalized flow of the Colorado River at Lees Ferry is now 12.2 maf, well below the 16.5 maf mainstem apportionments assigned to the seven Colorado River Basin states and Mexico. Critically, the 6 years since 2020 have averaged 10.8 maf/year, the same as the then-unprecedented low flows during 2000-05 at the start of this record-setting drought.

Matching the long slow decline in naturalized flows over the last century has been a similar long slow decline in precipitation in the Upper Basin of the Colorado (Figure 1, Panel C). Superimposed on this long trend are two notable drought periods with lower-than-average precipitation: one in the 1950's-60's and now the on-going current drought, at 26-years and counting, a multidecadal "megadrought" and the longest drought in the Colorado River Basin instrumental record. Mirroring the century-long declines in precipitation and naturalized flows is a long-term warming trend that started to accelerate in the 1970's and that is clearly linked to on-going global warming (Williams et al., 2020, Masson-Delmotte et al., 2021). Whereas the former drought of record, in the 1950's and 60's, was defined almost entirely by precipitation deficit (Figure 1, left gray shaded area), the current megadrought is being driven by a precipitation deficit compounded by relentless warming (Figure 1, right gray shaded area).

[3] https://coloradoriverscience.org/Current_conditions#The_Colorado_River_.274-panel_plot.27

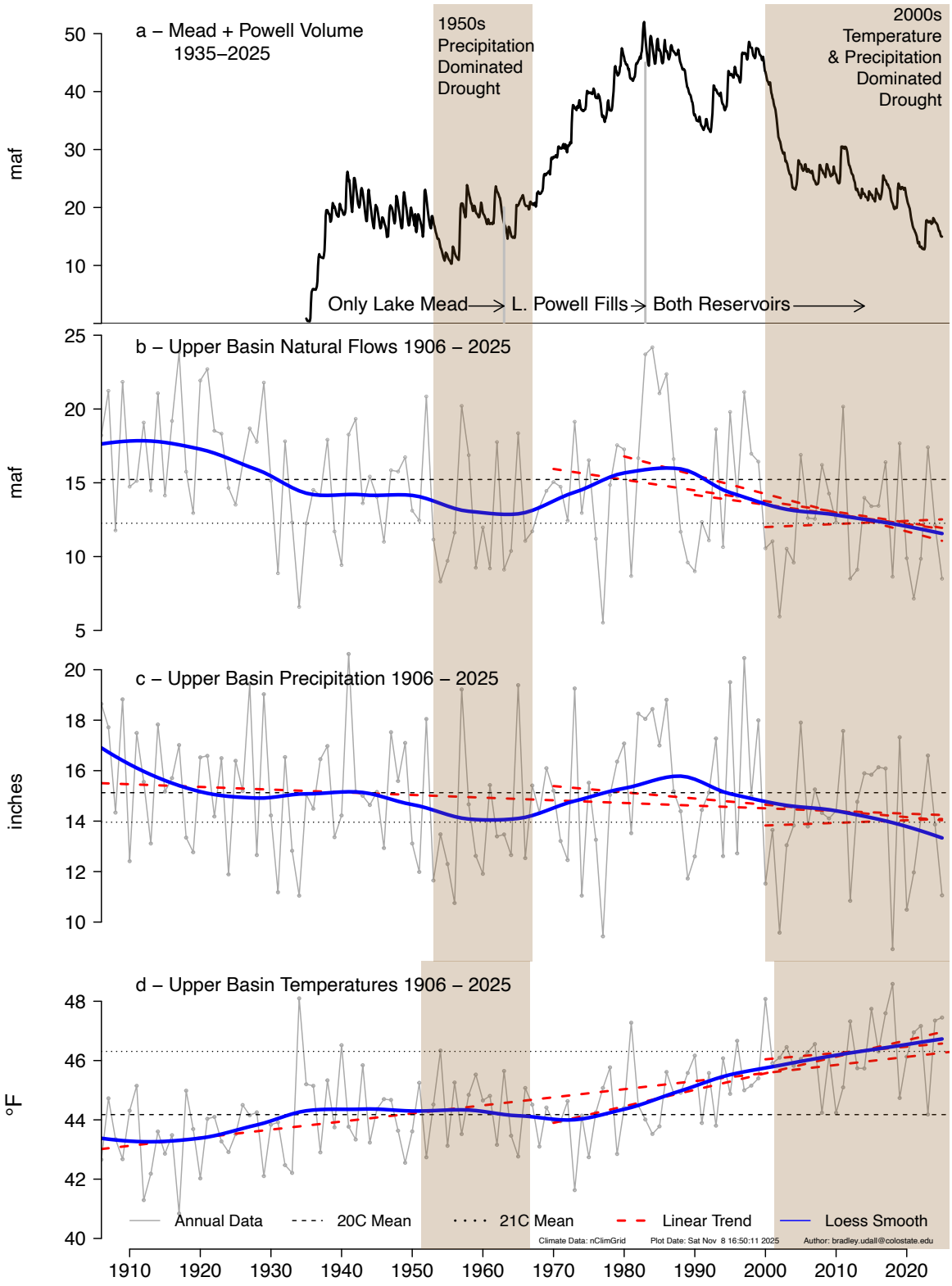
a – Mead + Powell Volume
1935–2025
1950s
Precipitation
Dominated
Drought
2000s
Temperature
& Precipitation
Dominated
Drought
maf
Only Lake Mead
L. Powell Fills
Both Reservoirs
b – Upper Basin Natural Flows 1906 – 2025
maf
c – Upper Basin Precipitation 1906 – 2025
inches
d – Upper Basin Temperatures 1906 – 2025
°F
Annual Data
20C Mean
21C Mean
Linear Trend
Loess Smooth
Climate Data: nClimGrid
Plot Date: Sat Nov 8 16:50:11 2025
Author: bradley.udall@colostate.edu

Figure 1

The impact of a warming climate

As we highlighted in earlier peer-reviewed papers (e.g., Vano et al., 2014, Udall and Overpeck, 2017), warming exacerbates drought in multiple ways. A warming atmosphere can hold progressively more water, and thus as the atmosphere warms it can evaporate more water. At the same time, a warmer atmosphere can cause soils and vegetation to lose more water to the atmosphere via evapotranspiration, especially as the warming atmosphere also causes the growing season in the Upper Basin of the Colorado to become longer (Das et al., 2011; Udall and Overpeck, 2017). Hot, dry springs in the basin bring on early melt and green-up (Hogan and Lundquist, 2024, Lin et al., 2022). Drier soils and vegetation thus mean less water that can eventually end up in the river, and incidentally also explains why the West is experiencing more wildfire (Abatzoglou and Williams, 2016). Atmospheric warming also leads to snow loss, a shorter snow-cover season, and an associated loss of solar radiation reflectivity – this drives further warming and yet more evapotranspiration (Milly and Dunne, 2020; Ban et al., 2023).

Large changes in groundwater supplies in both the Upper and Lower Colorado River Basins have been noted from soil moisture to deeper layers since 2002 (Abdelmohsen et al., 2025, Chandanpurkar et al., 2025). It is becoming increasingly clear that dry summer soils can persist into the fall and winter soaking up snowmelt the following spring thereby reducing runoff (Das et al., 2011, Lapides et al, 2022).

Precipitation declining

Estimates vary, but it appears that up to half of the observed roughly 20% reduction in Colorado flows are likely related to the steadily warming temperatures of the Colorado River headwaters region (Udall and Overpeck, 2017; Xiao et al., 2018; Milly and Dunne, 2020, Bass et al, 2023). Moreover, since 2017 it has become increasingly clear that the other major cause of the flow reductions is a sustained decrease in precipitation (Figure 1, Panel C). Until recently, the big question is whether the observed 7% post-1999 decrease in precipitation relative to the 20th century average was due primarily to natural multidecadal climate variability or human-caused climate change.[4] We now have good reasons to suspect the latter, and this translates to mostly bad news.

Megadrought country

It is now more clear than ever that the southwest United States, including the headwater regions of the Colorado River, is megadrought country. Tree-ring and other paleoclimatic sources reveal that multiple droughts lasting two or more decades took place over the last 2000 years (Meko et al, 2007; Gangopadhyay et al., 2022), and a good case has now been made for the current drought being among the most severe in at least 1200 years in large part because of the unprecedented amplifying effect of warming temperatures during the current sustained period of reduced precipitation (Williams et al., 2020; 2022).

However, there is another important lesson to be gleaned from the rich paleoclimatic record of pre-

[4] NOAA's nClimGrid dataset indicates that over the Upper Colorado River Basin there has been a 7% annual precipitation reduction during 2000-26 compared to 1897-1999. This reduction is not evenly spread over the seasons, however; reductions in the fall (SON), winter (DJF), spring (MAM) and summer (JJA) are 3%, 0%, 11% and 12%, respectively. Fall and winter precipitation for snowpack has thus been close to normal while spring and summer has been much reduced.

20th Century droughts and megadroughts. Given that global temperatures were likely significantly cooler prior to the last 50 years then they are now (PAGES 2k Consortium, 2019), it follows that the many long Upper Colorado Basin droughts that took place over the last 2000 years preceding the current drought were likely due much more to precipitation deficits alone. This means that we have good evidence that precipitation deficits exceeding those of the current on-going drought in both magnitude and duration are not rare, and that the current drought could see not just warmer temperatures in the future (a sure bet), but also even larger and longer precipitation deficits. It is thus critical that we consider what is presently causing the precipitation decline in the headwaters region of the Colorado River, and from that get a better sense of what's most likely ahead. And for motivation, since we wrote our 2017 paper, new evidence has emerged that drought-dominated periods – likely driven mostly by precipitation declines for the reason noted above – as long as 80 years have occurred in the last 2000 years in the Upper Basin of the Colorado River (Gangopadhyay et al., 2022).

The cause of precipitation decline

Could we be in for an even longer period of reduced precipitation than the last quarter century in the years to decades ahead? The answer depends on knowing the cause of the on-going precipitation decline, and there are two primary possibilities. The first is natural climate variability in the climate system, which can cause periods of lower precipitation to oscillate irregularly with periods of higher precipitation. Thus, if the recent period of low precipitation is due to natural climate variability, there could be periods of greater precipitation returning to the Colorado headwaters, although these wet periods would be increasingly unlikely to offset the drying impact of the steadily increasing temperatures. The second potential cause of on-going precipitation deficit is an anthropogenically-forced trend in precipitation decline due to increasing human emissions of greenhouse gases and reductions in Asian, mostly Chinese, aerosols to the atmosphere.[5] Such an anthropogenic trend would likely portend continued low precipitation into the future, in synch with continued warming.

One well-known source of natural variability in precipitation in the Colorado River Basin is decadal and longer variation in the sea-surface temperature patterns of the North and tropical Pacific Ocean, giving rise to what is called the Pacific Decadal Oscillation (PDO). A peer-reviewed research paper just published (Klavans et al., 2025) reviews the scientific literature and notes that decadal and longer variability in the PDO has long been thought to have arisen from atmosphere-ocean interactions internal to the natural climate system and has in turn caused decadal and longer precipitation variability downstream over western North America. The PDO is strongly correlated with La Nina, and both are known to be associated with a dry Southwest US (Seager and Ting, 2017; Lehner et al., 2018; Hoerling et al., 2023, Seager et al., 2023). Klavans et al., 2025 also presents convincing new evidence that anthropogenic forcing in the form of human

[5] Sulfate aerosols are emitted in large quantities when sulfur in fossil fuels is burned. These shiny particles can end up high in the atmosphere where they reduce anthropogenic warming by reflecting sunlight. But near the surface their sulfur-based precursors cause serious human health problems and thus many countries in the last few decades have tried and succeeded in reducing these emissions. China, notably, has made great strides in reducing these emissions but the unfortunate side effect is increased warming, especially in the Pacific Ocean downwind. It is believed that this aerosol cleanup (also underway in ocean shipping) is causing at least some of the accelerated global heating now underway including the additional heating in the northern Pacific contributing to precipitation reductions in the Southwest US.

emissions of greenhouse gases and reductions in atmospheric aerosols is now the primary driver of the same elevated sea-surface temperatures and this forcing is thus the primary cause behind the precipitation decline that has been observed since the start of the on-going Colorado River megadrought. In other words, human-driven climate change has caused the PDO oscillation to lock into its negative dry phase and this situation is likely to persist into the future.

A second new paper (Todd et al., 2025) highlights that higher Northern Hemisphere temperatures from about 11,000 to 6,000 years ago, in this case due to well-understood changes in the Earth's orbit, caused a negative PDO-like Pacific warming that in turn forced western U.S. precipitation to lock into a multi-millennia-long dry phase. This new research thus provides yet more confidence that the odds will favor lowered precipitation in the Colorado River headwaters for as long as human-caused warming persists. Both new research papers (Todd et al., 2025; Klavans et al., 2025) also note that state-of-the-art climate models underestimate the role of human-caused climate change in driving persistent drought in the region containing the headwaters of the Colorado River. Natural decadal and longer climate variability clearly caused the many droughts and megadroughts of the last 2000 years, but looking ahead today, it appears that human-caused climate change

Photo Credit: Kathryn Sorensen

is likely to exert a stronger influence, and this will mean a higher likelihood of continued lower precipitation in the headwaters of the Colorado River into the future.

Conclusion: bad news, good news

To sum it up, since 2017 we now know quite a bit more about how climate change is altering the flows of the Colorado River. Whereas eight years ago we were able to confidently anticipate that human-caused atmospheric warming alone would continue to reduce flows in the river, we now have a better, though still emerging, understanding of how human emissions of greenhouse gases are likely to also cause a continued reduction in precipitation in the headwaters of the Colorado River. Whereas we have known since 2017 that additional future climate warming will cause continued and even larger flow reductions, two new carefully crafted studies strongly suggest we are in for extended dry periods in the Colorado headwaters in the decades ahead.

As we hinted earlier, is important to recognize that the news is not all bad, and there is indeed a silver-lining to our improved understanding of why the natural flows of the Colorado are declining, and what this means for the future. We can say with confidence that human-caused emissions of greenhouse gases are having an increasingly negative impact on the flows of the Colorado River, a river that serves over forty million people and region that has an annual economy in excess of $1.4 trillion (James et al., 2014). This climate change impact will continue to worsen, but because humans cause it, humans can halt it. This is good to know as we work to reduce the greenhouse gas emissions to the atmosphere that are causing the climate change. The Colorado River will benefit. •

Photo Credit: Kathryn Sorensen

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3

The Erosion of the Colorado River "Safety Nets" is Alarming

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Artwork Credit: Patrick Kikuk

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The rapid loss of storage in Lakes Mead and Powell is certainly deserving of the attention and angst it has generated and continues to generate, but it is the tip of larger trends altering the landscape of risk in the basin. The dismantling of many other "safety nets," defined broadly, is happening at a pace far surpassing the already unprecedented declines in reservoir storage. Presumably that's not an immediate problem if new post-2026 rules are able to recover and protect storage in Mead and Powell (and some of the other upstream facilities), but does anyone have that much faith in the power of new reservoir operating rules to combat the forces that have brought us to this point? What about when we have a 10 million acre-feet/year river?

From Groundwater to Governance

Perhaps the most obvious of those other diminishing safety nets is groundwater. Data on groundwater reserves throughout the basin is spotty at best. One approximation of a truly regional assessment comes from a creative use of satellite-based tools—namely NASA's GRACE (Gravity Recovery and Climate Experiment) system that can detect tiny changes in gravitational forces associated with the fluctuating mass of aquifers losing (or gaining) storage. Those findings paint a truly disturbing picture. Despite the familiar (and troubling) images of bathtub rings emerging at Mead and Powell, researchers using GRACE data now estimate that, from 2002 to 2024, nearly two-thirds of storage—both surface and groundwater—lost in the Colorado River Basin actually came from groundwater depletions.[2] Significant groundwater losses have occurred throughout the basin, but the problem is particularly acute in Arizona and is likely to accelerate as shortages in Central Arizona Project (CAP) deliveries are likely offset by groundwater pumping—an ironic outcome given that CAP was originally proposed as the solution to groundwater mining in the region. Simply shifting unsustainable surface water uses to unsustainable groundwater uses does nothing to address the core mismatch of supplies and demands.

A very different and multi-faceted trend undercutting the regional safety nets is happening within the federal government, where federal agencies, programs and science programs are being systematically dismantled under the guise of "efficiency." It's hard to understate the significance of these actions, as it is the federal government that, presumably, has the scope, mandate and resources to oversee the entirety of the River and the full diversity of its roles and values. Interior Department agencies in 2025, like much of the overall federal bureaucracy, have been tasked to achieve significant staffing reductions, and to eliminate (or significantly scale back) spending on key water conservation programs—including programs under the Inflation Reduction Act (IRA) and WaterSMART.[3]

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[2] Abdelmohsen, K., Famiglietti, J. S., Ao, Y. Z., Mohajer, B., & Chandanpurkar, H. A. (2025). Declining freshwater availability in the Colorado River basin threatens sustainability of its critical groundwater supplies. Geophysical Research Letters, 52, e2025GL115593. https://doi.org/10.1029/2025GL115593.

[3] Finding accurate data on federal workforce reductions is challenging; see Competing numbers emerge on federal workforce reductions. Between "incentivized retirements," RIF (reduction in force) layoffs, recently resumed terminations of employees losing court-ordered protections, remaining planned cuts, and the ongoing hiring freeze, the total workforce of the Department of Interior could drop by over a third in 2025. The Interior Department is taking steps to implement layoffs - Government Executive. Similarly, data on efforts to reduce agency budgets is difficult to compile, particularly given the complex back and forth between the administration, Congress, and, increasingly, the courts. The President's 2026 budget request cuts Reclamation's budget approximately by a third (Fiscal-Year-2026-Discretionary-Budget-Request.pdf (see page 28 and Table 2); Briefly: Budget proposal defunds Western water conservation grants - Water Education Colorado). Overall, proposed cuts to the Department of Interior total over $5 billion, or 30.5% of the 2025 enacted budget (Table 2). To this point, that request has not been embraced by Congress.

Additionally, agencies across the federal landscape have mobilized to coerce and shut down climate-related science and scientists, despite the nearly universal acknowledgment among water managers of the central role of climate change in the unfolding crisis.[4] Collectively these efforts constitute a systematic effort to discredit and hide the primary cause of the broken water budget, while sabotaging the most effective coping mechanisms available. As members of the research community, the Colorado River Research Group (CRRG) unfortunately has a front-row seat to this culling of the people and programs essential to long-term data collection and analysis. It defies logic, and is dangerous.

Unfortunately, hostility toward the people and programs essential to responding to the Colorado River crisis is not the full extent of federal obstruction. One largely unappreciated threat to the water budget resulting from federal policy shifts comes from efforts to "re-carbonize" (and accelerate) water-intensive energy generation, in part to meet the demands of AI, a particularly troubling trend given that the previous emphasis on renewable energy generation and enhanced energy conservation was one of the few positive trends working to repair the regional water budget.[5] Attempts to weaken or dismantle bedrock environmental laws, such as NEPA and the Endangered Species Act, are an additional wildcard likely to inflict irreparable harm on already strained species and ecosystems.[6]

Given the turmoil at the federal level, it's tempting to absolve the States for stubbornly clinging to a policy making system reliant on 7-state dealmaking, but that would ignore the reality that the governance of the river has been a problem for decades. A seemingly never-ending series of crisis-inspired negotiations, held in largely secretive forums without direct tribal involvement or tools for meaningful public or scientific engagement, is an uninspired way to manage and protect the economic, cultural and environmental heart of the American Southwest. The river is too big and too important to govern in such an *ad hoc* and primitive manner.

That this approach mostly "worked" to keep deliveries flowing for so long—except, of course, for the tribes and the environment—rested, in part, on the accepted norm that decisions would emerge collaboratively from the States and would not spill over to the federal courts. But even that governance safety net is eroding, as the States seem to be increasingly resigned—and almost "comfortable"—with the notion that the resolution of existing conflicts may not emerge from a negotiated 7-state agreement. For those parties and viewpoints that have historically been left out of the state-dominated processes and the resulting agreements, then maybe this prospect is welcome. But all would concede that would be a stunning outcome with ramifications that are difficult to predict.

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[4] For example, within NOAA, the administration's 2026 budget request "terminates a variety of climate-dominated research, data, and grant programs," and "cancels contracts for instruments designed for unnecessary climate measurements," while also cutting National Science Foundation support of research "with dubious public value, like speculative impacts from extreme climate scenarios" (Fiscal-Year-2026-Discretionary-Budget-Request.pdf; see pages 24-25, and 38).

[5] Data Center Energy and Water Use Trends Explained - Circle of Blue

[6] Regulatory Tracker – Environmental and Energy Law Program

Ever since the *Arizona v. California* experience, the use of litigation to resolve interstate (and/or interbasin) conflicts in the basin has been a third rail issue, and for very good reasons. As shown by the basin's earlier foray into Supreme Court action, the process would undoubtedly be lengthy, expensive, and likely to create as many issues and questions as it resolves. It certainly wouldn't reduce risk, as the states, and the water management community more broadly, would lose control over the process of managing the shared resource. In fact, judicial intervention might be the impetus to trigger yet another traditionally feared decision pathway to be invoked—a Congressional rewrite of river allocation and management—either before or after the litigation concludes. In this setting, the extreme disparity in political influence—as measured by the number of Congressional representatives—between the Upper and Lower Basin is an obvious concern, as is the realization that congressional involvement means the future of the Colorado now becomes a national issue and, potentially, a bargaining chip to be used in the political logrolling necessary to enact legislation in dozens of otherwise unrelated areas.

Rowing in the Wrong Direction

Managing water in the arid and semi-arid West is often more about risk than water. From the seniority concept in prior appropriation to the sizing of infrastructure based on low probability events, the goal of water management is often to clearly define and then minimize the risks of running out. Given that, you'd think that the communities dependent upon Colorado River water would be more committed to protecting (and enhancing) the safety nets that are increasingly critical as storage in Lakes Mead and Powell—the basin's primary risk management tools—increasingly flirt with deadpool. But at the basin scale, that's typically not what I see. Sure, individual water managers serving major cities or districts have their own risk management plans focusing on everything from new infrastructure to market solutions, but that's far from a comprehensive or integrated approach, and safety nets designed by and for the "established players" only deepen the inequities that increasingly divide the Colorado River community.

There's a lot of work left to do in this basin, both prior and after the 2026 deadline. Viewing the problems through the lens of risk management is not a bad place to start. But if doing so, it's also not a bad idea to remember that poor risk management often comes at expense of diminished equity—an indispensable element of an equitable apportionment. Numerous examples around the world remind us that water scarcity can be the impetus for joint problem-solving in a spirit of camaraderie and mutual support, or it can sharpen and refine alliances that further distance the powerful from the weak. In this regard, I'm inclined to think we are rowing in the wrong direction. •

4

Water Equity in the Colorado River Basin

Bonnie Colby[1] and Zoey Reed-Spitzer[2]

Photo Credit: John Weisheit

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Introduction – Water Equity

This article briefly summarizes findings of a recent statistical analysis of demographic patterns, access to water and exposure to pollutants in areas that receive Colorado River water. While studies in many locations have found that minority and low-income populations are disadvantaged, this is the first study to examine patterns using fine-scale spatial data for this large area of the southwestern U.S. Understanding current patterns of disproportionate water access and exposure to pollutants is a first step for including water equity issues into policy dialogue.[3] Identifying which groups are most vulnerable can inform policies on where to target water allocations, water pollution mitigation strategies and infrastructure investments.

Key findings include a distinctly segregated pattern in where people of color live, and highly disproportionate access to household drinking water and exposure to pollutants for the basin's minority populations. There are positive steps that could be adopted to address these water equity issues, and this would require a concerted shift in emphasis. The basin-wide dialogue historically has been, and continues to be, dominated by decisions about allocating water and sharing shortage risk across uses and locations.

Access to water, a concern around the globe, is constrained in many areas of the Colorado River Basin (CRB) by water scarcity, pollution and lack of delivery and treatment infrastructure. These constraints disproportionately affect the basin's Native American,[4] Hispanic and Black populations, groups which often have lower access to resources for mitigation and recovery (Water & Tribes Initiative, 2021; Deria et. al., 2020; Mueller and Gasteyer, 2023; Bandala et. al., 2022; Sanchez et. al., 2023). Moreover, these groups historically have not been represented in policy processes where key decision affecting water access and water quality are made. A number of tribal governments, in recent decades, have been at the negotiation tables due to their status as sovereign governments with significant water rights. However, there is no consistent process for inclusion of low-income communities of color in the basin. The urgent high-level dialogue among tribal governments, federal interests, states, cities and agricultural water users (and, to some extent, environmental NGOs) focuses on allocating the ever-scarer waters of the CRB, with little emphasis on disproportionate access.

Population Distribution in Area Studied

The term *Areas Receiving Colorado River Water* (ARCRW) denotes the geographic CRB plus the areas outside that basin that receive Colorado River water deliveries, shown in Figure 1. The mix of race and ethnicity residing in the ARCRW in 2019, using race and ethnic categories of the U.S. Census, is: 45% White, 36% Hispanic, 12% Other, 5% Black and 2% Native American.[5] [6]

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[3] Disproportionate exposure refers to the distribution of risks across groups of people. Some groups are exposed to hazardous chemicals or conditions at levels above those for the general populations. (Gochfeld and J. Burger, 2011).

[4] There is no official consensus regarding terminology used to refer to indigenous peoples in the United States, and when to capitalize specific words. In this report, Native American and American Indian are used, as well as general capitalization of the terms Tribe and Tribal -- as a sign of respect.

[5] By comparison to the ARCRW, the population of the entire U.S. is 60% White, 19% Hispanic, 12% Black, 8% Other and 0.65% Native American; for the 73,868 census tracts in the U.S.

[6] The U.S. Census designs categories to be mutually exclusive in order to prevent overlap and double-counting in census data. The Hispanic group includes anyone who identifies as Hispanic, and contains people of various races (White, Black, American Indian, etc). "Other" includes people in the ARCRW that identify as non-Hispanic and non-White, as well as Pacific Islander, Asian, some other race, and those identifying as two or more races. People of Color, a term used by the U.S. Census, are composed of these U.S. Census groupings: non-white Hispanic plus Black plus Native American and Alaskan Natives plus Pacific Islander plus Mixed Race).

Before discussing distribution of the population by race and ethnicity, it is worth noting how the census-tract spatial scale data provide a valuable context for considering general population patterns in the ARCRW. Population density varies across tracts, with the lowest density tracts having zero residents (there are eight of these - typically tracts consisting only of an airport or body of water). The highest density tract has 148.09 people per acre and is located in Los Angeles. The mean density is 12 persons per census tract. The average income for all tracts in the ARCRW is $91,406.88.

Figure 1 is shaded to indicate % of People of Color in the 7,764 census tracts of the ARCRW. As Figure 1 demonstrates, many census tracts in rural areas are predominantly populated by People of Color. Many, though not all, of these census tracts are on tribal reservations. Figures 2a and 2b show race and ethnicity in the Phoenix and Denver urban areas. Figure 2 indicates high concentrations of People of Color in specific tracts within urban areas, a pattern also identified in other ARCRW cities such as Los Angeles and Las Vegas. The data displayed in Figures 1 and 2 highlights an uneven distribution by race and ethnicity in both rural and urban census tracts of the ARCRW.

Given the uneven spatial distribution of People of Color, it is natural to examine how access to water-related benefits and exposure to hazards is distributed spatially around the ARCRW and among different populations. Given the ongoing urgent dialogue about managing the waters of the CRB, it also is timely to consider how management of the region's water affects water equity.

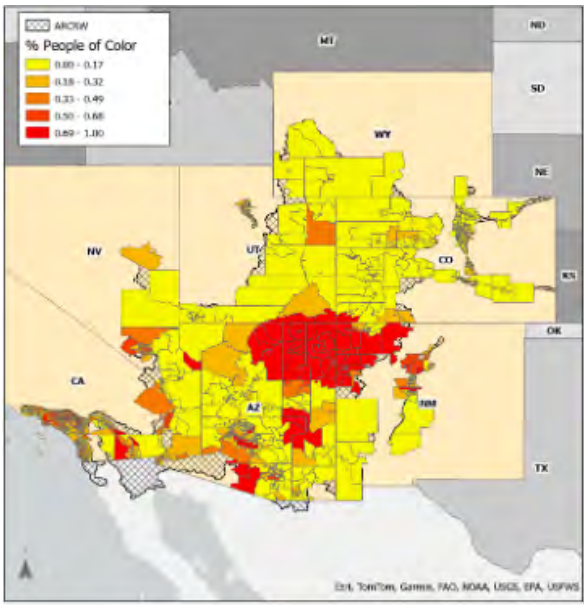

Figure 1. % People of Color in 2019 for U.S. Census Tracts in ARCRW

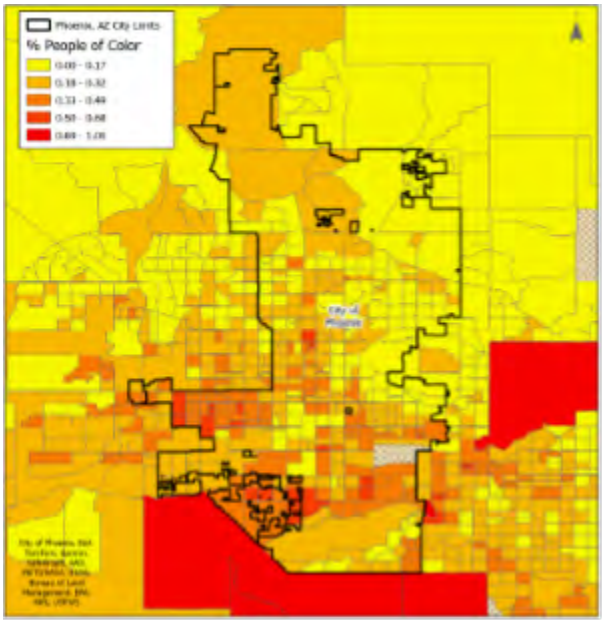

Figure 2a. % People of Color in 2019 for U.S. Census Tracts in Phoenix and Surrounding Areas

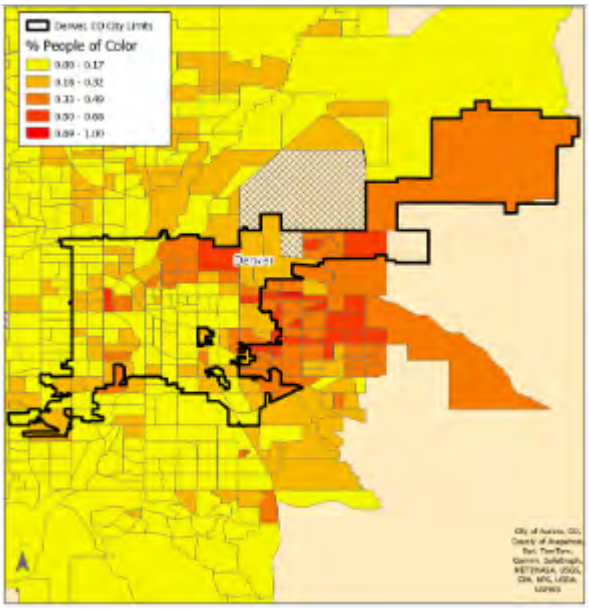

Figure 2b. % People of Color in 2019 for U.S. Census Tracts in Denver, Colorado and Surrounding Areas

Water Equity Analysis and Findings

This research examines differential exposure among racial and ethnic groups to three water-related *burdens*[7]: leaky underground storage tanks, lack of green space, and incomplete household water access.[8] Various aspects of water management affect the three burdens. Leaky underground storage tanks (USTs) release toxic materials that contaminate soil and water. Maintaining and monitoring storage tank infrastructure impacts contaminants released into water sources and populations exposed to those contaminants. Green space requires reliable water allocation to maintain trees, turf, lakes, wetlands and riparian habitat in this arid region. Infrastructure choices that increase impervious surfaces and cropland reduce natural habitat, diminish green space, increase temperature, contribute to air and water pollution and adversely affect mental health (Aram, et al., 2019; Hoge and Wulf, 2023). Incomplete household water access (IHWA) inhibits residents' access to safe drinking water and threaten health. Having to haul water for household use decreases productivity and income. Inadequate household water infrastructure also affects tribal nations' inability to fully benefit from their water entitlements (Sanchez, 2023).

To mitigate water equity impacts of water-related burdens, water management and policymaking must deliberately account for burdens stemming from water contamination, constrained access to water resources and poor infrastructure. The study finding summarized here provide an overview of current patterns of inequity.

Mean income in census tracts with a population that is 90% or more white, is double the mean income of the census tracts that are predominantly people of color. The portion of households with adults having no high school degree is 10 times higher in census tracts that are predominantly people of color.

Statistical models examine the three water equity burdens in detail, with findings summarized here. The statistical models are robust, with independent variables in each model having good explanatory power. The statistical models indicate highly disproportional exposure for people of color. Income, highly correlated to race and ethnicity in the ARCRW, plays a large role.

[7] *Burdens* is a term utilized in research on spatial patterns across population groups. A higher quantity of *burden* measured in a census tract represents a negative effect for those living in that census tract.

[8] These three burdens represent a wider array of pollutant exposure and poor water access, and were selected for this discussion due to their fine-scale data availability for ARCRW. Data from the U.S Council on Environmental Quality is analyzed alongside U.S. Census data.

Those with higher income live in areas with more green space and less leaky USTs. The statistical findings also highlight a strong, positive association between the burdens and population density. Where there are higher density populations, there is also higher incidence of leaky USTs and lack of green space. Those with higher income tend to live in places with more access to green space, nearly zero IHWA and lower percentages of leaky UST. While less than 1 % of ARCRW census tracts have IHWA, this corresponds to about 130,621 households highly concentrated in specific locations on tribal lands (Deitz and Meehan, 2019).

Hispanic, Black and Native American[9] populations are disproportionately exposed to all three water-related burdens examined. White non-Hispanic populations are less exposed to all three. Native Americans (*American Indian* in U.S. Census terminology) are the racial group most strongly exposed to IHWA. Hispanic and Black non-Hispanic populations are disproportionately exposed to Leaky UST.[10] Census tracts with higher percentages of Hispanic and Black populations are also those with higher percentages of lack of green space. Native American populations reside in areas that possess higher percentages of green space, linked to being rural. These findings are consistent with studies from other regions, and provide valuable new levels of spatial specificity that identify important distinctions and nuances regarding population groups and burdens.

Along with the three water-related burdens that are the focus in the report, it is worth noting the disproportionate exposure to a fourth burden, PM2.5. PM2.5 are tiny particulates in the air, readily inhaled and contributing to significant health consequences. In the Southwest, dust is a primary component of PM2.5. This hazard increases in dry periods and as land is cleared of natural vegetation. PM2.5 is related to allocating water to preserve vegetation and vegetated habitat, which reduces dust. At the census tract spatial scale, the mean PM 2.5 level for census tracts that are 90 white is twenty percent lower than the mean level for census tracts that contain 60% or higher people of color. (*U.S. Environmental Protection Agency, 2022*).

The patterns of disproportionate exposure analyzed in this study across the ARCRW are consistent with findings examining smaller spatial areas within the ARCRW. The Covid pandemic's much higher incidence of mortality among Native Americans (compared to the general U.S. population) brought harshly to light longstanding water inequities that face tribal communities (Water & Tribes Initiative, 2021). The pattern of tribal households lacking potable water also is discussed in Tanana et al. 2021a, b; Conroy-Ben and Richard 2018; Teodoro et al. 2018; Indian Health Services 2019. Lack of access to potable water among CRB low-income Hispanic communities was studied by Acquah and Allaire 2023; London et al. 2021; Mueller and Gasteyer 2021; Pannu et al. 2018; Balazs et al. 2012.

Recommendations Based on Water Equity Findings

Study results provide a level of spatial specificity on specific water equity concerns that has

[9] The U.S. Census uses the term *American Indian*. In this piece the term *American Indian* is used interchangeably with *Native American*.

[10] The three water-related burdens are measured as: a) density of leaky USTs within each census tract and within 1500 feet of tract boundaries; b) percentage of census tract land area that is artificial surface such as pavement, buildings and cropland; c) percent of census tract households lacking indoor plumbing

previously been unavailable. The findings identify important distinctions and nuances among minority populations on several fundamental water equity challenges. Clearer understanding of patterns in disproportional exposure to burdens provides a basis for developing a policy framework that can provide more equitable protection while improving the quality and quantity of the Colorado River water supply. Policies governing water access, infrastructure spending and water quality protection are formulated in the ARCRW at multiple levels, by federal, tribal, state and local government agencies and elected officials; so policy responses will need to be multi-pronged and tailored to the governmental powers of these various jurisdictions.

The basin-wide policy dialogue is focused on stretching a scarce water supply. Issues of disproportional exposure to burdens are not regularly featured in these discussions. The results presented here can help in guiding water policy dialogue in the ARCRW to consider water equity concerns. The types of data and analysis presented here help to establish current levels of disproportionate exposure. A proactive policy stance would commit to policies that reduce current disproportionate levels of exposure. The U.S. Infrastructure Bill was intended to provide a proactive approach to addressing water equity.[11]

While current debate over allocating scarce water focuses on allocations and shortage sharing among states and tribes, policy makers also decide how to allocate Colorado River water towards maintaining natural habitat. In this arid region, sufficient stream flows and green landscapes require dedicated water allocations. The spatially specific indicator of green space availability in this study could guide allocation of water and funding to address areas that lack green space. Additionally, households with incomplete access to water exist within the ARCRW boundaries and are concentrated in Native American communities. Aiming federal and state household water infrastructure investments towards tribal communities, based on ongoing government-to-government consultation with tribal nations, could help lessen this burden (Water and Tribes Initiative, 2021).

A "guard rails" policy approach would entail collective agreement to consider water equity and to explicitly avoid exacerbating existing disproportionate exposure. The types of data and analysis presented here are needed to establish the "guard rails" of current disproportionate exposure not to be crossed in making policy decisions. A key accompanying policy stance would commit to proactive approaches that reduce current disproportionate levels of exposure. Implementation of the U.S. Infrastructure Bill, as it determines where and how water infrastructure is funded, could provide opportunity for both the guardrails approach and a proactive approach to addressing water equity. ●

Data Availability

Data are available for download from the U.S. Census Bureau and from the Public Environmental Data Partners, which backed up the CEJST website. All data used in this study are accessible through sources cited throughout the paper.

[11] Efforts have been underway to address disproportionately low historic infrastructure investment and other federal spending for people of color in the CRB. Forty percent of benefits from federal investments are to be directed to marginalized or underserved communities under Justice40 Initiative, which emphasizes water supply, water quality, and wastewater treatment as key components (Executive Order No. 14008, 2021). Implementation has devolved with change in the federal administration the U.S.

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5

The Tale of Three Percentage-Based Apportionment Schemes

Eric Kuhn[1]

Artwork Credit: Patrick Kikuk

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On March 17th, two creative water experts made a proposal to the negotiators representing the seven Colorado River Basin States on how to break the stalled negotiations among the states over how to divide the use of the waters of the Colorado River; given the uncertainties over how much water might be available in the future, the negotiators should consider a percentage-based approach. They even suggested an appropriate split: the upper river states should receive 35% and the lower river states 65%. The negotiators gave serious consideration to the suggestion but ultimately rejected it. Representatives from two of the upper river states insisted on a different approach. They had in mind an apportionment scheme that would make water use on the upper river invisible to the lower river. They wanted an agreement where the lower river could consumptively use however much water was left in the river after the upper river users used whatever they needed without interference from the lower river.

Sound familiar? If yes, you might think I'm describing a recent chapter in the ongoing negotiations saga between the Upper Division States and Lower Division States over the post-2026 operating rules for the Colorado River. The presentation I was referring to, however, occurred on March 17, 1922, at the Phoenix, Arizona field hearings of the Colorado River Compact Commission. The presenters were Nathan Grover, Director of the Hydrologic Branch of the U. S. Geologic Survey (USGS) and his USGS colleague John Hoyt.

Six weeks earlier Grover had attended the Washington D.C. round of the commission's negotiations that had ended in a deadlock. He and his USGS colleagues had two goals in mind: First, he was proposing an approach that might break the stalemate. Second, and perhaps more important from his technical perspective, was that Grover was keenly aware of a hydrologic dispute between E. C. LaRue, his top expert on the Colorado River, and the senior staff of the Reclamation Service. Both its Director, Arthur Powell Davis, and Compact Commission Chair Herbert Hoover had told the other commissioners that with sufficient conservation (in 1922 that meant storage), there was enough water to meet all future needs. Grover knew that LaRue fundamentally disagreed with this conclusion. LaRue believed that the river's water supply was not sufficient to meet the future needs of the basin. A compact based on a percentage apportionment would still be functional even if LaRue was right.

Colorado's Commissioner Delph Carpenter, and his ally, R.E. Caldwell of Utah had a very different approach in mind. They believed that because water users on the lower river needed their support for the Congressional approval for the projects that would become Hoover Dam and the All-American Canal, the upper river states had the better hand. Therefore, they set a high bar. Carpenter proposed a compact that would allow the users on the upper river to consume however much water they needed without any interference from water users on the lower river states. Carpenter argued that because of topography and climate, consumptive uses in the upper river states would never be a threat to uses on the lower river and when pressed, he agreed that his approach would require a fixed limit on exports out of the basin (transmountain diversions).

A few weeks later, at the Denver, Colorado field hearings, Carpenter, Caldwell, and their governors made their case for the Carpenter compact, but the lower river states refused to buy it. Two months later, a U.S. Supreme Court decision forced Carpenter to change his strategy. In *Wyoming v. Colorado*, 259 US 419 (1922), the court ruled that as between or among states

that used the prior appropriation doctrine, prior appropriation could be applied on an interstate basis. The ruling meant that the upper river no longer had the better hand. Carpenter adapted by proposing a 50/50 split between two sub-basins, now referred to as the Upper and Lower Basins, based on the flow of the river at the Yuma gage. The Commission, under the assumption that there was at least 20 million acre-feet per year of water available at international boundary with Mexico (~17.5 million acre-feet per year at Lee Ferry), used Carpenter's proposal as a template. It ultimately decided to split the river three ways; 8.5 million acre-feet per year of beneficial consumptive use for the Lower Basin, 7.5 million acre-feet for the Upper Basin, and a third "surplus" pool that would be used for Mexico and for future apportionments.

The concept of a percentage-based apportionment was not forgotten. In 1948, the five states with lands in the Upper Basin successfully used it to apportion water use in the Upper Colorado River Basin. Under the Upper Colorado River Basin Compact, Arizona, which has a small amount of land in the Upper Basin, but is not a State of the Upper Division, received a fixed apportionment of 50,000 acre-feet per year. After deducting Arizona's share, the four Upper Division States each received a percentage share of the remaining water apportioned to and available for use in the Upper Basin under the 1922 Compact: Colorado 51.75%, Utah 23%, Wyoming 14%, and New Mexico 11.25%.

In his compact report to the Colorado Governor and General Assembly, Colorado's Commissioner Clifford Stone justified the decision to use a percentage-based apportionment approach as follows:

> "While the1922 Compact, by its article III(a), apportions to the Upper Basin the beneficial use of 7,500,000 acre-feet annually, such use is subject to the availability of water. The States of the Upper Division are required by the 1922 Compact to maintain certain flows at Lee Ferry. The water available for use in the Upper Basin is that remaining after the Lee Ferry delivery requirements are satisfied. In view of the uncertainty as to the total amount of water which might be available for Upper Basin the Compact Commission determined that so far as the States of the Upper Division are concerned the apportionments must be in terms of percents of the total amount of water apportioned to and available for use in the Upper Basin."

Utah's Upper Basin Compact Commissioner, Ed Watson, used identical language in his report to the Utah Governor and General Assembly.

Over a century after the 1922 Compact was signed, the Colorado River has changed in profound ways. The river is now fully developed and overused. Climate change has added an additional level of uncertainty as to future flows. The water available for use at the international boundary with Mexico since 2000 may be no more than 13.5 million acre-feet per year, about one-third less than what the commissioners thought available when the compact was signed. Under the umbrella of the post-2026 operating guidelines, the seven Basin States are now negotiating a complex agreement to reduce consumptive uses to a sustainable level. To again break a stalemate, one of the Basin's more creative water experts proposed a percentage-based approach. The concept was that the

amount of water each sub-Basin would get to consumptively use annually would be based on a percentage of estimated average natural flow of the Colorado River at Lees Ferry for the three previous years.

Given that the uncertainties in the future water supply available from the Colorado River, a percentage-based apportionment may seem like common sense, but after considerable optimism that this "supply-based" approach could break the impasse between the Upper and Lower Division States, the Basin States again failed to close a deal. To make a percentage-based approach workable, there are two fundamental questions that need to be negotiated: What percentage will each basin get and what happens if the Upper Division States do not deliver the required percentage to Lee Ferry? Apparently, the two divisions could not reach an agreement on either question. Based on public comments by individual state negotiators, the Bureau of Reclamation was tasked with modeling a range of different percentages with the Upper Division States delivering from 25% to 75% in hopes of finding a "sweet spot" that would work for both divisions.

Photo Credit: John Weisheit

Arizona needed a Lower Basin percentage high enough for the Central Arizona Project (CAP) to supply its critical customers and Colorado (and perhaps the other Upper Division States) needed an Upper Basin percentage high enough to avoid having to impose a non-voluntary curtailment on its users (a "compact call"). The public may never see Reclamation's model results, but clearly whatever the modeling showed, there is not enough water in the river to accomplish what each basin needed to sell the percentage-based approach back home. Since the negotiators could not find a "sweet spot," the states returned their focus to an incremental Band-Aid approach based on the Lower Division States taking the first 1.5 million acre-feet of shortages. In years when more than 1.5 million acre-feet of shortages are necessary, the two divisions would share the shortages in some manner to be negotiated. Whether the seven states can reach an agreement on the details by the (now) February deadline remains to be seen. The question of what happens if the Upper Division States do not reduce their uses by the agreed upon amount is also unanswered.

A fundamental problem with the percentage-based approach and why the states could not find a "sweet spot" may have been that it was just too much of a transformational change for some of the states to accept. As proposed, a percentage approach based on the Upper Division States delivering a percentage of the previous three-

year average natural flow at Lee Ferry would have been easy to monitor and enforce. There would be little reason for arguments. The states within each division would simply have to learn to live with their share of the water that nature provides. To reach an acceptable percentage, however, both divisions and all seven states would almost certainly have to accept some level of deep pain.

At least Arizona and Colorado may have concluded that each would be better off under their interpretations of the current Law of the River. For Colorado, why accept the risk that it would have to curtail existing water uses to meet a fixed percentage when under the current framework, it could argue that under the 1922 Compact the Upper Division States do not have a delivery obligation. Instead, they have a "non-depletion" obligation. This means that if climate change, not depletions by the Upper Division States, is the reason these states cannot meet their flow joint obligations under Article III of the 1922 Compact, then there is no compact violation. As a practical matter, because the Upper Division States are only using about 4.5 million acre-feet per year out of the Upper Basin's 7.5 million acre-feet apportionment, and climate change may have reduced the river's flow by over 2.0 million acre-feet per year, if this argument were to prevail, the risk of future curtailment could be negligible. This result shifts much of the basin-wide risk of climate change to the Lower Division States. This line of reasoning does not acknowledge, however, that every drop of water used in the Upper Division States also depletes the flow of the river at Lee Ferry, regardless of the impact of climate change.

For Arizona, the critical question is the amount of water available to the Central Arizona Project (CAP). If it cannot negotiate a Lower Basin percentage high enough to meet the project's minimum obligations to cities and Indian Tribes in Central Arizona, the CAP would have to turn to buying out agricultural depletions in the Yuma area. Although California's Metropolitan Water District has been using the California version of this strategy for two decades, the dry-up of Yuma agriculture is a very politically charged issue within Arizona. Therefore, it may have concluded that its best-case scenario for both political and water supply reasons is to enforce its view that under the 1922 Compact, the Upper Division States have an obligation to deliver at Lee Ferry 75 million acre-feet every ten years plus one-half of the deliveries to Mexico under the 1944 Treaty, a total of approximately 82.5 million acre-feet every ten years.

If Arizona's argument were to prevail or even partially prevail, it could still provide more water to the CAP than a negotiated percentage. It shifts the burden of climate change to the Upper Division States, until that is, the only rights upstream of Lee Ferry that have legal access to water are pre-compact rights. At this point, the climate risk shifts back to the Lower Division.

Thus, what is the future of a percentage-based apportionment approach in the Colorado River Basin? I can't imagine that either Arizona or Colorado will voluntarily concede to the other a percentage division that doesn't meet its basic interests. Therefore, the only realistic path to a percentage-based apportionment may be as a negotiated settlement to litigation, or perhaps the serious threat of litigation. Because, it is possible, if not probable, that the ten-year flow will drop below ~82.5 million acre-feet (the "trip wire") in the next one to three years, the threat of litigation is both near-term and real. It is also possible that the states will reach a compromise before February 2026 that temporarily reduces the threat of litigation. It's likely that under such agreement no state will permanently give up its right to enforce the 1922 Compact; thus, the

threat of litigation may be delayed but is still real. Future hydrology will control the fate of a negotiated interim solution.

If litigation is initiated, I expect that there will be intense pressure on the states to get back to the negotiating table. The Court or its special master may require a mediated settlement process, perhaps under Article VI of the 1922 Compact, the dispute resolution provision. At that point, I believe that it will be obvious to any mediator or special master that given the uncertainties in hydrology, the most equitable approach will be a negotiated percentage split. The alternative may be a more draconian solution imposed on the basin by the U.S. Supreme Court. ●

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Photo Credit: John Weisheit

6

A Humbly Proffered Proposal to Aid the Colorado River System: Conservation Easements & Land Purchases

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Artwork Credit: Patrick Kikuk

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Introduction

The federal government enabled the development of the large agricultural water uses of the Colorado River basin through construction of Lake Powell, Lake Mead and other reservoirs. Cities, tribes and industries also became the beneficiaries of these projects and the demand for agricultural products here and abroad alongside growing urban centers and industry combined to create enormous pressure on the Colorado River, dubbed "the hardest working river" in the West.[3] It is well documented that water uses from the Colorado River have outstripped water supplies over much of the 21st century. Alarming declines in its reservoirs, particularly in Lake Powell and in Lake Mead, have been the result.[4]

Water managers have diligently deployed many tools to address declining reservoir levels. These tools include quantifying shortages as well as creating assigned water[5] through the 2007 operating guidelines for Lake Powell and Lake Mead, establishing system conservation tools through the 2014 agreement on a pilot program for Colorado River system water and other agreements, establishing Mexican assigned water and system conservation contributions through various treaty minutes, the 2019 Drought Contingency Plan, the 2021 agreement to facilitate near-term actions to maintain water levels in Lake Mead, the 2023 agreement to conserve an additional three million acre-feet in Lake Mead and the Upper Basin System Conservation Pilot Program, among others. Through these efforts millions of acre-feet of water were left in Lake Mead involuntarily as system water and voluntarily as system conservation and assigned water.[6] Water managers are to be lauded for developing these tools and acting diligently to address reservoir declines.

Yet low inflows into the reservoirs have persisted. Scientists tell us that this bad hydrology may be the "new normal."[7] There isn't enough Colorado River water to meet all demands now or, absent extremely high snowpack, in the reasonably foreseeable future and this condition remains constant whether the flows of the river are split between the Upper and Lower Division states volumetrically (as in the Compact) or via percentages of natural flow, as has recently been explored in negotiations between the states over new operating rules for Lake Powell and Lake Mead.[8] Indeed, it is this basic condition that makes agreement between the Divisions regarding

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[3] Colorado River Drought Conditions and Response Measures—Part 1 and 2 Oversight Hearing before the Subcommittee on Water, Oceans, and Wildlife of the Committee on Natural Resources U.S. House of Representatives, 117th Congress First Session, Friday October 15, 2021(Part 1) Wednesday, October 20, 2021 (Part 2) Serial No. 117-10, Statement of Hon. Jared Huffman, a Representative in Congress from the State of California.

[4] Storage in the twelve reservoirs was 56.38 million acre feet on September 6, 1999. Storage of these reservoirs on September 1, 2025, was 22.27 million acre feet. Schmidt et al., The Colorado River water crisis: its origins and the future, 10 WIRES WATER e1672 (2023).

[5] "Assigned water" is a term used to describe water held in Lake Mead pursuant to the Secretary's authority to allocate surplus water articulated in Consolidated Decree, Arizona v. California, 2005, Art. II.B.2; Assigned Water also includes delayed water deliveries held for the benefit of the Republic of Mexico that can be delivered subsequently in amounts in excess of the U.S. treaty obligation to Mexico of 1,500,000 acre-feet of water each year, INTERNATIONAL BOUNDARY AND WATERS COMMISSION, MINUTE 323, EXTENSION OF COOPERATIVE MEASURES AND ADOPTION OF A BINATIONAL WATER SCARCITY CONTINGENCY PLAN IN THE COLORADO RIVER BASIN at V.E.3 (2023). This stored water is assigned to and held by an individual entity independently from the priority system of water allocation to which all other water available for delivery in the Lower Division is subject.

[6] US Bureau of Reclamation, Colorado River Accounting and Water Use Report: Arizona, California and Nevada, calendar years 2007 through 2024.

[7] Wheeler, K. Udall, B., Wang, J, Kuhn, E., Salehabadi, H., Schmidt, J. What will it take to stabilize the Colorado River? *Science* (2022) vol. 377, 373-375.

[8] Sackett, Heather, Colorado River managers present plan to share water based on supply, not demand, Aspen Journalism, (Jun. 26, 2025). https://aspenjournalism.org/colorado-river-managers-present-plan-to-share-water-based-on-supply-not-demand/

the post-2026 operating guidelines for Lake Powell and Lake Mead so difficult to achieve. The large and fundamental imbalance between supply and demand colors the current state of post-2026 negotiations and we seem to be drifting toward an inevitable federal intervention.

It is possible that cuts in water use necessary to stabilize the system (much less actually rebuild storage) surpass the well-known structural deficit of 1,500,000 acre-feet per year and may total as much as 4,000,000 acre-feet per year.[9] For example, basin-wide uses may outstrip natural flows in 2026 by 3,600,000 acre-feet.[10]

Importantly, stabilization of the Colorado River system and re-establishment of storage in Lake Powell and Lake Mead adequate to keep water users from living on the razor's edge year-to-year relies on *system water*—water that is available to entitlement holders in the prior appropriation system of water allocation and that bolsters collective resilience.

The major metropolitan regions of the basin can strengthen individual resilience; they have population funding bases large enough to purchase or enter into long-term leases for farmers' higher priority water-rights. The Metropolitan Water District of Southern California and the San Diego County Water Authority have done just that. Private equity interests have also entered the game. These agricultural-to-urban transactions shift demands between economic sectors but do not reduce overall Colorado River demands. Similarly, efforts to conserve water in one year and store it as assigned water for subsequent delivery outside of the prior appropriation system in a later year create flexibility and protection from shortage for the entity that owns the assigned water—but only move demands in time rather than reducing them altogether. Neither agricultural-to-urban transfers nor assigned water programs significantly reduce overall Colorado River demands and neither significantly bolsters collective resilience or system reliability.[11] Only substantial use reductions and a complete reversal in snowpack do that. We have control over only one of those things.

While environmental non-profit organizations can and have purchased land for the purpose of boosting in-stream flows, which does reduce overall demands and does boost collective system resilience—so long as the water isn't just diverted by another user—such efforts are unlikely to occur in amounts large enough to make a material difference in the major reservoirs. Realistically, only the federal government can create system water in the reservoirs at scale.

There are two main methods available to the federal government to reduce water use to bring the system into a reasonable, long-term balance between demands and supplies. One is to exercise the Secretary's authority to force involuntary reductions in deliveries in strict priority order in the prior appropriation system. The other is to pay contractors to reduce water use each year. The first is politically unpopular and causes harm to the population centers and economic engines of the Colorado River basin—the cities—which mostly have contracts for

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[9] Touton, C. C. (Jun. 14, 2022). Statement of Camille Calimlim Touton, Commissioner, U.S. Bureau of Reclamation, before the Senate Committee on Energy and Natural Resources. https://www.energy.senate.gov/services/files/6CB52BDD-57B8-4358-BF6B-72E40F86F510

[10] Schmidt et al, Analysis of Colorado River Basin Reservoir Storage Suggests Need for Immediate Action, INKSTAIN, (Sept. 11, 2025).

[11] For example, the assessments against assigned water creation, which becomes system water, totaled approximately 320,000 acre-feet over eighteen years. See United States Bureau of Reclamation, Colorado River Accounting and Water Use Report: Arizona, California and Nevada, calendar years 2007 through 2024.

lower priority water. The second is enormously expensive to deploy at a scale necessary to help stabilize the system and relies on inherently uncertain federal appropriations over time.

Our situation in the basin is confounding: there isn't enough water to go around; agricultural interests use the most water and their rights are typically senior,[12] but a strict application of priority harming cities is likely inviable; voluntary conservation tools depend on unreliable federal appropriations; and in the absence of a more strategic approach, the default is to accept that every drop of water in the Colorado River basin has a dollar sign attached.

In a landscape of poor choices, in a flailing river system in which all solutions are deeply unpopular to some or other powerful constituency, potentially harmful to one community or another or inordinately expensive and founded on unreliable funding, it is at least worth considering another option. Times may not be ripe for implementation, but robust debate can pave the way for creative and productive solutions, and as many Colorado River water managers have noted of late, all options should be on the table.

Acknowledgment

This proposal involves the use of water mainly, but not exclusively, on rural and agricultural lands. It is important to acknowledge, up front, the economic, historic and cultural importance of these lands and, more to the point, the manner in which water is used on these lands. This proposal is in no way intended to ignore or even diminish the importance of rural communities, people, their cultures or economies. Rather, it is intended to launch a discussion that might, if conditions ever allow, help stakeholders craft productive solutions that can benefit the entire Colorado River basin.

The Proposal

The federal government can set up a purely voluntary program to retire water intensive land uses by purchasing or exchanging lands or by compensating landowners who agree to permanent restrictions on water use.

To be eligible for federally funded water-use retirement, lands should meet a careful balance of the following characteristics:

- High historic water-use per acre,
- In locations where the economic and other third-party impacts of forgone water use are least painful,
- In locations where the avoided use of water would most benefit critical environmental habitat
- In locations that result in effective and measurable "shepherding" of conserved water into federally managed reservoirs,
- In locations where the land can be used for alternative purposes that support local economies and employment with lower water-use per acre, such as alternative crops, re-creational opportunities or low water-use industry
- On land on which the crops grown could be feasibly grown outside of the Colorado River basin, and
- Contributes to an equitable distribution of conversions from high- to low-water land-uses throughout the Colorado River basin.

Up to now, paying Colorado River basin farmers to use less water has provided significant but only short-term benefits. For the same money, land

[12] Irrigated agriculture accounts for 75% of human consumption of Colorado River water. Richter, B.D., Lamsal, G., Marston, L. et al. New water accounting reveals why the Colorado River no longer reaches the sea. *Commun Earth Environ* 5, 134 (2024).

purchases and exchanges, or compensated water-reduction easements, could provide permanent and enduring benefits in reduced water demand.

"Economic water productivity" (EWP) varies throughout the basin: The same amount of water applied in some areas results in high economic output and in other areas in low economic output.[13] Owners of high water use (HWU), low EWP lands may be interested in the opportunity to sell or exchange their lands or receive compensation for changing their land-use to permanently reduce their water demand.

This proposal is not novel. The United States owns over 45% of the land in eleven western states, administering these lands primarily for conservation, recreation and stewardship of natural resources.[14] Established in 1964 and funded by fees and royalties from offshore drilling, the federal Land and Water Conservation Fund provides funding for the acquisition of land and water and easements on land and water for the benefit of the public. Four federal agencies within the Department of the Interior have statutory authority to acquire and dispose of lands.[15]

The Bankhead-Jones Tenant Farm Act serves as a helpful precedent. Passed in 1937 in the wake of the Dustbowl crisis and Great Depression, the act gave the Secretary of Agriculture the authority and a mandate to acquire "submarginal" lands "to correct maladjustments in land use, and thus assist in controlling soil erosion, reforestation, preserving natural resources, mitigating floods, preventing impairment of dams and reservoirs, conserving subsurface moisture, protecting the watersheds of navigable streams and protecting the public lands, health, safety and welfare."[16] The United States acquired over 11 million acres through the Bankhead-Jones Act.

This is not a proposal for a "buy and dry" program. Rather, it is a proposal to transform HWU, low-EWP land-uses in ways that both benefit the Colorado basin and enable new or more water-efficient local economic activities. Federal policy enabled development of the West's HWU, low-EWP land-uses and it is fair to seek the federal government's help to change them.

Conclusion

Lake Powell and Lake Mead water levels have fallen to near-critical levels. Absent consecutive years of extremely high snowpack, very large water use reductions are necessary to bring the Colorado River system back into a reasonable balance between water supply and demand. While others can create assigned water and develop significant transactions between sectors, realistically, only the U.S. government can create system water at the scale needed to boost collective resilience. A federal, voluntary program to retire water intensive land-uses by purchasing or exchanging lands or by compensating landowners who agree to permanent restrictions on water use deserves consideration. Although this proposal is bound to be controversial, in difficult times on the Colorado River, difficult conversations are worth having. •

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7

Facing the Future: Can Agriculture Thrive in the Upper Basin With Less Water?

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Photo Credit: John Weisheit

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Agriculture forms the backbone of rural economies in the Upper Basin. Irrigated crops and livestock production support farm and ranch livelihoods, as well as regional food value chains. These systems depend heavily on the Colorado River and its tributaries. Today, that dependence is being tested by dwindling flows. How the region responds will shape not just the fate of crops and cattle, but also entire communities that depend on the river to work and live.

Aridification has left the river with less water than when allocations were first made.[5] Major reservoirs are near critical lows and states face pressure to reduce use across all sectors. The future of Upper Basin agriculture will depend in part on how water cuts are negotiated and distributed. However, a major related challenge is not merely how to achieve the required conservation amounts, but to reimagine how farms and ranches can continue operating, or even thrive, under tighter water realities.

The technical playbook for conserving water on farms and ranches is already relatively well established; what's needed now are policy and market mechanisms to make those practices feasible for producers while also sustaining the communities and river ecosystems that underpin them.

Bracing for Less Water

Independent of whether the region starts to experience curtailments and how the current post-2026 negotiations unfold, climate projections indicate the very real probability that water availability for Upper Basin agriculture will be reduced in the future. In a sense, curtailment and the structure of the Compact are a red herring that distract from the real problem, which is the persistent dry hydrology. Regardless of the driver—hydrologic shortage or curtailment—there will be less water in agriculture in the Upper Basin.

There are other water users in the Upper Basin, of course. Large trans-basin diversions transfer water out of the hydrologic footprint of the Colorado River Basin to Albuquerque, New Mexico; Cheyenne, Wyoming; Salt Lake City, Utah; and the Front Range of Colorado. Following the general pattern of development in the U.S. West, these diversions tended to be constructed long after many agriculturalists had begun diverting water. These cities thus tend to have more junior water rights and would be the first to be cut off in the event of a water shortage.

It is undeniable, however, that agriculture with low relative economic value uses the lion's share of water in the Upper Basin (approximately 70% once trans-basin diversions for irrigation are taken into account) and will continue to serve as a source of water transfers to other users to some extent (Asgari and Hansen 2024).

Imagining the Unthinkable

Whether significant water reductions come from a curtailment or from hydrologic shortage, what does a future with significantly reduced water availability look like? Future reductions could unfold under a range of scenarios. To highlight important considerations, we describe three highly stylized scenarios. In an optimistic scenario, water cuts remain modest, and states

[5] Over the past 100 years (1906-2020), the average annual amount of water available for the lower and upper basins and Mexico is 14.7 MAF, but availability has been dropping; just 13.5 MAF was available annually over the past 30 years (1991-2020). These averages are calculated by the U.S. Bureau of Reclamation based on natural flows at Lees Ferry, AZ, the dividing point between the lower and upper basins (Reclamation 2025).

cooperate to align water use more closely with actual river flows. Most agricultural operations remain viable, supported by temporary incentives for voluntary conservation, production innovations, and managed transitions to low-water crops or alternative enterprises.

An intermediate scenario reflects a more fragmented response, characterized by legal disputes, temporary fixes, and uneven reductions. Some farms adapt successfully, but others – perhaps smaller operations, or those with junior rights – face heightened uncertainty. The negative burdens of uncoordinated cutbacks ripple through local economies and food value chains. A pessimistic scenario envisions severe reductions. Widespread curtailments accelerate farm exits, weaken rural economies, and lead to large-scale drying up of irrigated lands, fundamentally reshaping agricultural landscapes and river ecologies across the basin.

A more detailed scenario analysis could consider what a potential curtailment back to 1922 water rights would look like. For example, the Bureau of Reclamation undertakes a related exercise when it imagines many possible futures of water availability, in Decision-Making under Deep Uncertainty (Smith et al. 2022). Upper Basin water users could benefit from the "what if" thinking that Scenario Planning permits. Scenario Planning is often used to imagine low-probability, high-cost futures. Increasingly, observers of Colorado River Basin water management wonder whether what we have here is a high-probability, high-cost future.

Planning for a Drier Future

Given ongoing drought and the additional threat of curtailment restrictions on Upper Basin water use, the agricultural sector must consider strategies for adapting to less water (Mooney and Hansen, 2024). Farmers and ranchers in the Upper Basin are already proving that with creativity and collaboration, it's possible to sustain crop and livestock production even as water becomes scarcer. Although the technical playbook for conserving water on farms is relatively well established, additional research needs do exist. Scientific studies of limited irrigation, crop switching, and other practices have demonstrated real potential for achieving water conservation at the field level.

For example, one potentially less disruptive strategy could be to replace alfalfa and native grass hay forage crops that have traditionally been grown in this region with drought-tolerant alternative forage crops. Although these crops have potential, they are not yet widely adopted in the region, likely due to lack of agronomic information on yields, water use, soil health/water quality benefits, and uncertainty about their effectiveness as a feed crop on cattle performance, among other things.

If producers must reduce hay production in the future due to reduced water availability, they could choose to reduce herd size in response. Or they might decide to maintain present herd size and simply import forage crops from other, non-water-stressed regions (Hansen et al., 2024; BBC Research & Consulting, 2020). They might also consider more significant adjustments to their operation, by transitioning from cow-calf to cow-calf yearling operations. By retaining yearlings and having fewer brood cows, hay requirements could be reduced. Another alternative would be to only graze pasture in the summer and not have a cow-calf operation. While this does not require irrigated hay production, research indicates this is less profitable (Ruff et al. 2017). Each of these adaptation strategies has different economic implications for the total operation under different economic, weather, and policy assumptions.

Determinants of Future Outcomes

Yet, it is not enough to identify effective water conservation practices. Policy and market mechanisms that make those practices feasible for the producers are equally necessary. Examples could include supply chain and market development to encourage crop diversification and value-added enterprises with lower water needs, investing in irrigation efficiency and soil-moisture monitoring to measure and stretch supplies, expanding voluntary and compensated programs that incentivize reductions or water leasing, and supporting regional collaborations like water pools or grass banks to share risks and benefits across operations and communities.

The speed and effectiveness of these policy and support interventions will shape which adaptation pathways remain viable for producers to both remain in operation and contribute to water conservation. At the same time, it must be acknowledged that adaptation alone may not be enough, and major transformations are likely to some extent: less irrigated acreage on the landscape, permanent water transfers to urban and environmental uses, and gradual transitions in rural economies.

What happens next depends on whether the region embraces proactive adaptation or unmanaged decline. Factors that will contribute to the outcome include the level of cooperation and negotiation among states, the design of federal and state mandates, and the inclusion of agricultural stakeholders including agricultural operations, tribes, and local communities in decision-making. Because most water use currently goes to agriculture, the same backbone that has long supported Upper Basin economies – its farmers and ranchers – can now help its reinvention.

Thriving through Change

Reductions to Colorado River allocations appear inevitable, but the future of Upper Basin agriculture is not predetermined. The relevant questions are not whether or when cuts will happen, but how deep will they go, how will they be distributed, and how well can the consequences be mitigated? Keeping agriculture on an optimistic pathway will require cooperation among states and water users, sustained investments in on-farm adaptation, and policy and market developments that reward innovation and flexibility rather than simply compensate losses. Without these actions, the risk of an unmanaged decline increases along with the associated lasting consequences for farms, communities, and river ecosystems. However, with the right combination of support, the way forward for Upper Basin agriculture lies in evolving, not retreating, by finding new ways to operate – and thrive – with less water. ●

For More Information

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Photo Credit: John Weisheit

8

Toward a Basinwide Entity: Moving from Vision to Action

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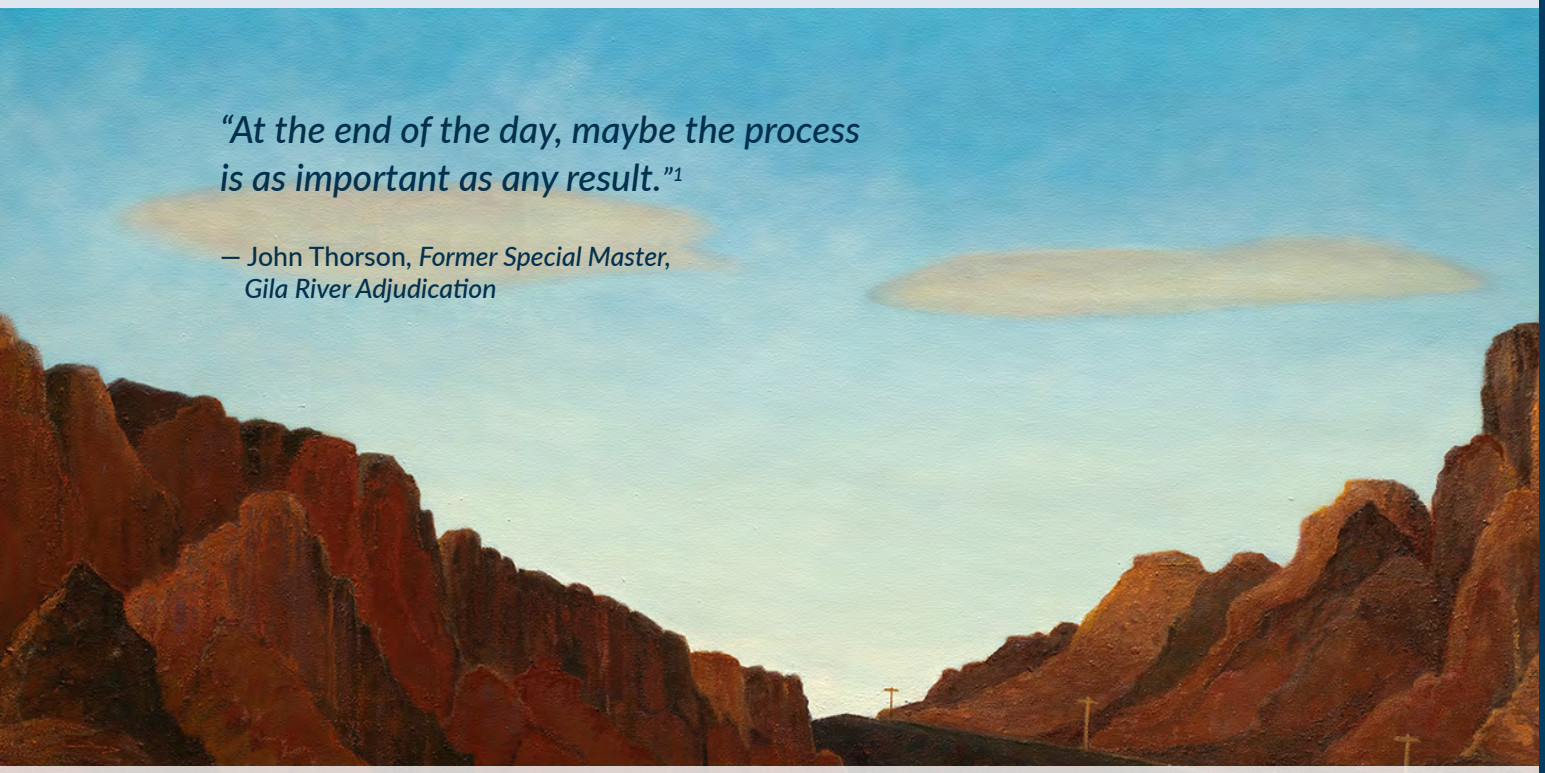

"At the end of the day, maybe the process is as important as any result."[1]

— John Thorson, *Former Special Master, Gila River Adjudication*

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Artwork Credit: Patrick Kikuk

Managing the Colorado River is at an inflection point, substantively and procedurally. The distinction here between substance and process is not trivial. There is a huge difference between what should be done about operating the reservoirs, sharing shortages, and conserving water *and* how people who care about such issues should determine what ought to happen. The first problem is one of substance and the relative effectiveness of alternative policies and plans. The second is one of process—how to bring together the appropriate people with the best available information to address substantive issues in the face of unprecedented drought and climate change.

While state and federal officials have expanded opportunities over the past few years to engage Tribal nations and stakeholders, there is still room to improve the process of collaborative problem-solving and decision-making. This essay examines these procedural concerns from three perspectives: inclusivity, transparency, and framing. Building on a vision that has been around since at least the formation of the 1922 Colorado River Compact, the time has come to establish a basinwide entity to provide more meaningful opportunities for all sovereigns, stakeholders, and the public to be involved in basinwide planning, problem-solving, and decision-making. Most importantly, that the time has come to catalyze a basinwide conversation on this topic. Please accept this essay as an invitation to join us in that conversation.

Some Procedural Concerns

The process of managing the Colorado River involves multiple layers of engagement and decision-making. While progress has been made with this process over the past few years, there is still room for improvement with respect to the issues of inclusivity, transparency, and framing.

Inclusivity

Managing the Colorado River can and should be more inclusive. Many different parties have interests affected by the river system's management, but not all of these parties are meaningfully engaged in problem-solving and planning. Nor are they fairly represented in decision-making bodies and processes. Some parties and values have been dominant, while others have been marginalized. The river's management can and should be improved by providing more opportunities for meaningful engagement and decision-making.

Consider the prevailing basinwide management approach. This process can be traced to the 1922 Colorado River Compact negotiations. Each basin-state governor has appointed a principal negotiator. These "principals" meet behind closed doors—with one another and sometimes with federal officials—and serve as an informal decision-making body. The Secretary of the Interior has numerous responsibilities for operating dams, reservoirs, and other infrastructure across the basin, especially along the Lower Colorado River. In practice, though, the Secretary generally defers to the basin states. If the principals reach agreement on a basinwide management issue, the Secretary commonly goes along with it.

To their credit, federal and state officials have created over the past few years some "first-ever" opportunities to engage Tribal nations, stakeholders, and the public at multiple levels. At the federal level, the Bureau of Reclamation convened up until early 2025 a Federal-Tribes-States group with representatives from all three domestic sovereigns within the basin. The Bureau also has convened a well-attended Tribal Information Exchange and supported use of a publicly available web-based tool for soliciting

input on the post-2026 operating guidelines. Similar developments can be seen in the basin states. The State of Arizona, for example, convenes a broad-based water committee that includes Tribal nations and stakeholders, including representatives from the environmental community. Several basin states—California, Colorado, New Mexico, and Utah—have appointed Tribal leaders to state water boards. In addition, acting through the Upper Colorado River Commission, the four Upper Division states signed a Memorandum of Understanding with the six Upper Basin Tribes to exchange information and collaborate on issues of mutual interest involving the river system.

Nonetheless, while moving toward inclusion and meaningful engagement, these federal and state efforts must be viewed in context. They exist following decades of exclusion. This pattern stretches all the way back to the 1922 Colorado River Compact negotiations—a process from which basin Tribes were fully excluded.[2] Fast forwarding to the present, many Tribes in the basin have called directly for greater inclusion in developing the post-2026 operating guidelines, managing drought, and participating in water conservation programs.[3] Federal and state officials have responded to some of these requests as just noted. But something fundamental is still missing: *structural inclusion*. None of the innovations to engage Tribal nations have been formally integrated into the institutional arrangements for governing the river system. While Tribal sovereigns are arguably more meaningfully engaged now than at any point during the past century, they nonetheless lack a formal role in basinwide federal and state decision-making over managing the river system.

The historical pattern of exclusion also extends to environmental groups and values. In the past, the Law of the River has been viewed by some as consisting solely of the consumptive use-oriented laws and policies on water apportionment and infrastructure. Excluded from this view are the numerous laws and policies addressing biodiversity protection, ecosystem restoration, and water quality, at both the domestic and international levels. The former laws and policies were undoubtedly dominant before the latter ones emerged. But to compartmentalize them is to ignore the reality that *all* these laws and policies—and the values underlying them—shape Colorado River management. Non-consumptive values deserve consideration along the river too, especially given their significance to sizeable segments of the U.S. population and basin-state constituencies, as well as to the increasingly diversified regional economy.

Transparency

Also integral to basinwide decision-making along the Colorado is transparency. Government officials engaged in decision-making derive their authority from the public—they are, indeed, public officials. In line with basic democratic principles, it is critical for members of the public to have visibility into the motivations, positions, and actions of their agents. Yet that is often not the case.[4] Further, although technical data are indispensable for water management, transparency has also been an issue with respect to the generation and availability of data for consumptive uses and losses throughout the river system.

Consider again the prevailing approach to decision-making at the basinwide scale. It generally revolves around an informal body of state principals with primary authority and federal officials who acquiesce to state-consensus positions. These individuals often meet behind closed doors—frequently in smaller groups (*e.g.*, Upper Basin states or Lower Basin states). No public notice of meetings is provided. No meeting

agendas or minutes are publicly circulated. Many members of the public feel left in the dark. Confidentiality is the rationale—the need to maintain it for deliberations—with the public told to trust in the abilities of their agents immersed in the process and later told of its outcomes after the fact. While an appropriate balance needs to be struck in this regard, the status quo is skewed disproportionately towards maintaining confidentiality over honoring the essential principle of democratic transparency.

Another transparency concern involves technical data for the river system—for example, openness in how the data is generated and made accessible to the public. These factors affect perceptions of whether the data is valid and whether it and its provider are trustworthy. The Bureau of Reclamation's annual Lower Colorado River accounting reports, required by the *Arizona v. California* decree, are considered by some a good model in this regard.[5] But there are several other areas where significant data-related issues have been raised. Examples include data for (1) consumptive uses and losses along the Gila River system and other Lower Basin tributaries; (2) evaporation losses along the Lower Colorado River (addressed separately from the accounting reports); and (3) projected consumptive uses in the Upper Basin. The importance of transparency with respect to this data was not as high when basinwide supplies and demands more closely aligned. But that was a quarter century ago.

Photo Credit: John Weisheit

Framing

"Framing," as used here, has to do with how Colorado River management is approached in terms of timelines, spatial scope, and priorities. Overall, we support decision-making that is proactive and aimed at long-term results, emphasizes a whole basin perspective, and integrates management priorities. The status quo generally does not involve such an approach.

On the temporal aspect, consider how basinwide decision-making over operations at Lake Powell and Lake Mead has occurred during the past twenty-five years. It has been crisis-driven and reactionary. Emerging out of highly politicized and often adversarial processes, incremental measures have been adopted in stair-step fashion as each prior piece in the sequence has proven inadequate to stave off massive reservoir drawdown.[6] Illustrative in a similar way are the huge federal investments recently made for water conservation in the basin. These investments have afforded agricultural and municipal water users significant compensation to cut-back on their use. But the arrangements are very limited in duration. The issue, as captured by one basin state principal, is plain: "[R]epeated emergency efforts are not sufficient to address long-term

shrinking flows."[7] Basinwide decision-making has been framed by management strategies focusing on short-term, crisis responses rather than proactive, long-term solutions.

A related aspect of framing has to do with how management is spatially bifurcated and often siloed. The Colorado River Basin is one basin—not two or three—despite how the compact draws an imaginary line at Lee Ferry and the treaty does a similar thing at the international border between the United States and Mexico. This division creates an us/them dynamic between the Lower Division versus Upper Division states, as well as between the United States and Mexico. This dynamic obscures how the basin—and thus the river system's management—is inherently interconnected. Further, as mentioned earlier in relation to inclusivity, modern management is not just about the Law of the River's apportionments and infrastructure operating rules. The Colorado River is, after all, a *river*. In 2025, its management also requires addressing—again, at both the domestic and international levels—the Law of the River's newer pieces on water quality, biodiversity protection, and ecosystem restoration. Yet the programs created for these purposes—rooted in the Clean Water Act, Endangered Species Act, Grand Canyon Protection Act, and U.S.-Mexico Treaty—often involve decision-making that seems separate (or at least considerably distanced) from that associated with the apportionments and infrastructure. Contrasting with the modern paradigm of Integrated Water Resources Management, these intertwined priorities are approached in a siloed way.[8]

A Vision for the Future

So how might the process of managing the Colorado River on a basinwide scale be improved in relation to the issues above? While there are many potential answers to this question, we draw attention to a vision for governing water use in the basin that has been around for more than a century–a "basinwide entity."

Precedents for a Basinwide Entity

Our entry point into the idea of a basinwide entity comes from the late David Getches—former dean and professor at the University of Colorado Law School and arguably the foremost Colorado River legal scholar of his generation. In 1997, three years prior to the onset of the megadrought and aridification in the basin, Getches made a keen observation: "[T]he awkwardness and the intractability of most of the Colorado River's problems reflect the absence of a venue to deal comprehensively with Colorado River basin issues."[9] If only Getches could observe now the gridlock and animosity accompanying negotiation of the post-2026 operating guidelines, including the prospect of U.S. Supreme Court litigation, despite the cautionary tale of *Arizona v. California*. Getches went on to call for "the establishment of a new entity that recognizes and integrates the interests and people who are most affected by the outcome of decisions on major Colorado River issues."[10] In our view, Getches's observation and advocacy have only increased in relevance over the past three decades.

The idea of a permanent Colorado River Commission was introduced and failed during the negotiation of 1922 Colorado River Compact.[11] Since then, the idea of a "basinwide entity" for governing water use in river basins has become common practice in the United States and internationally. A total of twenty-five water apportionment compacts exist in the United States,[12] and more than two-thirds of them—seventeen of the twenty-five—create a formal administrative entity called a "commission" or "administration." The purpose, authority, membership, and activities of these basinwide

entities vary, suggesting that the design of such institutions is adapted to the needs and interests of the particular river basin. The Upper Colorado River Basin Compact—applying solely within the Upper Basin—created the Upper Colorado River Commission.[13] In 2007, responding to concerns expressed by the Committee on Energy and Natural Resources of the U.S. Senate, a Model Interstate Water Compact was prepared by an accomplished, seasoned group of practitioners, policymakers, and scholars.[14]

Between these bookends (1922-2007) and since, the idea of a basinwide entity for the Colorado River system has been explored consistently in scholarship.[15] This trajectory, in practice and scholarship, tracks the evolution of transboundary water law, policy, and practice at the international level, where a duty to cooperate and joint commissions are emphasized.[16] As mentioned above, having some type of basinwide entity to govern water use and management is a common practice among river basins throughout the world.

Moving From Vision to Action

But what exactly should a basinwide entity look like along the Colorado? While there is no single model, one of the primary lessons learned from experience around the world is that the most effective governance arrangements are built from the ground-up, by and for the people with interests in a particular river basin. In other words, sovereigns, stakeholders, and citizens connected to the Colorado River need to come together and seek agreement on the basinwide entity's formation, purpose, composition, scope of authority, funding, and otherwise. We don't provide answers to these questions per se, but we do offer the following thoughts as we move from vision to action.

First and foremost, there should be a basinwide conversation about the creation of a basinwide entity. Keeping in mind the issues or principles of inclusivity, transparency, and framing as discussed above, what is needed as a threshold matter is a critical mass of people willing (1) to acknowledge the absence of an explicit forum for basinwide engagement and decision-making; (2) to consider with an open mind the substantial practical and scholarly work on this subject; and (3) to engage in candid dialogue about the advantages and disadvantages of establishing a basinwide entity, including different options for its design. We hope to facilitate a basinwide conversation of this very sort—and, again, we invite you to join us.

Second, with an eye toward this conversation, one important principle worth considering for the basinwide entity's design is "nesting." The notion of a basinwide entity surely can conjure images of some massive, monolithic edifice that would supplant all existing entities. That is *not* what is envisioned. Rather, what we would suggest for consideration is a structure with multiple parts, each having a dedicated function but connected to the whole. It would be a nested entity that builds on existing institutional arrangements and practices as much as possible. Many reference points appear in existing compacts and the Model Compact.

Third, to drill down a bit more on nesting, the basinwide entity could consist of several bodies whose composition and activities would address inclusivity, transparency, and framing concerns.

- The entity's core could be a formal commission with federal, state, and tribal representatives—including Mexico—ensuring structural inclusion for all the basin's co-sovereigns. Regular meetings would be scheduled and open to the public, and meeting minutes would be provided.

- Built in a similarly inclusive way, a technical panel could be created to (1) inform deliberations of the commission; (2) respond to questions from the commission and the advisory committee (see below); (3) integrate scientific and technical information with Indigenous knowledge; and (4) generate and publicly disseminate technical data for the river system's management, including data on consumptive uses and losses, water quality, and ecological conditions in and along the river system.

- One concentric circle beyond the technical panel could be another essential body: an advisory committee. Its function would be to facilitate public and stakeholder participation. The committee would be composed with this purpose in mind, consisting of members of the public and stakeholders with diverse interests in the river system, and enabling these parties to interact openly and directly with the commission.

While each of the three bodies could be established through formal channels of decision-making, it is also possible to create the technical panel and the advisory committee through more informal mechanisms. This approach might be more efficient and effective, and build some momentum to establish a commission that would most likely need to be created through some formal agreement that would include the United States and Mexico. How the existing system of governance and decision-making would be approached during the process of designing a new entity—including but not limited to the role of the seven basin state principals, Upper Colorado River Commission, and the Bureau of Reclamation and the U.S. Department of the Interior—is an important and open set of questions best addressed through the type of basinwide conversation we envision.

Taken as a whole, the basinwide entity we envision would be inclusive, transparent, integrate multiple objectives, and address the framing issues explained above. The entity would be guided by the best available knowledge, including science and indigenous knowledge, emphasize collaborative learning and adaptive management, and provide explicit mechanisms for consensus building and dispute resolution. In addition to addressing specific tasks and responsibilities, each component of the nested system of governance would also facilitate informal dialogue and deliberation, including opportunities for shared meals, field trips, and catching up during breaks at meetings.

Closing Note

In sum, process matters. Who decides, and how, determines what is decided—in the Colorado River Basin and elsewhere. Basinwide decision-making has been far from easy over the past quarter century given climate change's impacts on the river system. Likewise, the prospect of establishing a basinwide entity admittedly poses many questions of design. But if our collective experience in this space does not yet warrant basinwide dialogue about an idea that can be traced, in one form or another, all the way back to the 1922 Colorado River Compact negotiations, we are hard pressed to come up with the circumstances that might. The status quo can and should be improved. If not now, when? If not us, who?

Please let us know if you are interested in joining a basinwide conversation on the design of a basinwide entity for Colorado River governance. ●

Endnotes

[1] John E. Thorson, *Visions of Sustainable Interstate Water Management Agreements*, 43 NAT. RES. J. 347, 368 (2003), https://digitalrepository.unm.edu/nrj/vol43/iss2/2/.

[2] *Episode Five: First in Time*, KUNC, May 15, 2023, https://www.kunc.org/thirstgap/2023-05-15/first-in-time.

[3] Alex Hager, *"If you are not at the table, you are on the menu:" Tribes submit ideas to manage Colorado River*, KUNC, May 2, 2024, https://www.kunc.org/news/2024-05-02/if-you-are-not-at-the-table-you-are-on-the-menu-tribes-submit-ideas-to-manage-colorado-river. See also the joint letter (May 16, 2024) endorsed by 20 of the 30 Tribes in the Colorado River Basin to the Commissioner of the Bureau of Reclamation. The letter outlines key principles and expectations of the Tribes relative to the post-2026 operating guidelines and Colorado River policy and governance more generally. The letter is available here.

[4] See Elsie Schmelzer, *Amid a Transparency Desert, States Look to Blow Past Colorado River Deadline. What's Next*, Denver Post (November 10, 2025). Available here.

[5] *Lower Colorado River Water Accounting*, BUREAU OF RECLAMATION, https://www.usbr.gov/lc/region/g4000/wtracct.html (last visited Oct. 3, 2025).

[6] Jack Schmidt, et al, *Analysis of Colorado River Basin Storage Suggests Need for Immediate Action* (white paper dated September 11, 2025 and available here).

[7] Jennifer Yachin, *State negotiator: Colorado River plans must dole out less water*, GREENWIRE, July 29, 2025.

[8] See *IWRN Guidelines at River Basin Level: Part 1, Principles* (UNESCO undated), available here.

[9] David H. Getches, *Colorado River Governance: Sharing Federal Authority as an Incentive to Create a New Institution*, 68 COLO. L. REV. 573, 577–78 (1997), available here.

[10] *Id.* at 578.

[11] *See* Getches, *supra* note 6, at 578 n. 16. See also NORRIS HUNDLEY, JR., WATER AND THE WEST: THE COLORADO RIVER COMPACT AND THE POLITICS OF WATER IN THE AMERICAN WEST 181 (1975)

[12] These compacts are surveyed in Douglas L. Grant & Brett C. Birdsong, *Water Apportionment Compacts Between States*, in 3 WATERS & WATER RTS. § 46.05 (2024).

[13] Upper Colorado River Basin Compact, 63 Stat. 31 (1949).

[14] Jerome C. Muys, George William Shirk & Marilyn C. O'Leary, *Utton Transboundary Resources Center Model Interstate Water Compact*, 47 NAT. RES. J. 17 (2007), https://digitalrepository.unm.edu/nrj/vol47/iss1/3/.

[15] The idea of a river basin "entity"—a commission, council, or organization—for the Colorado River has a long history as expounded by several notable scholars and experienced observers. In chronological order, see the following sources: NORRIS HUNDLEY, JR., WATER AND THE WEST: THE COLORADO RIVER COMPACT AND THE POLITICS OF WATER IN THE AMERICAN WEST 181 (1975) (discussing how several negotiators of the Colorado River Compact favored creation of a permanent Colorado River Commission in 1922); Reuel L. Olson, The Colorado River Compact 195–210 (September 1926) (Ph.D. Thesis, Harvard University) (advocating vigorously for the idea of a Colorado River Authority, though it was not included in the compact); Gilbert F. White, A New Confluence in the Life of the River, in NEW COURSES FOR THE COLORADO RIVER: MAJOR ISSUES FOR THE NEXT CENTURY 215, 223 (Gary D. Weatherford & F. L. Brown eds., 1986) (concluding that "[a] means might be found to bring together from inside and outside the basin a group representative of the diverse interests in water and related land resources to assess possible actions beyond those specified in the compact"); Charles W. Howe & W. A. Ahrens, Water Resources of the Upper Colorado River Basin: Problems and Policy Alternatives, in WATER AND ARID LANDS OF THE WESTERN UNITED STATES 169 (Mohamed T. El-Ashry & Diana C. Gibbons eds., 1988) (suggesting an interstate commission to do studies, monitor agreements, and promote dialogue); Douglas Steven Kenney, River Basin Administration and the Colorado: Past Practices and Future Alternatives 439-458, 467–468 (Ph.D. Dissertation, University of Arizona 1993) (proposing a Colorado River Council to be formed by compact, with participation by seven state governors and the Secretary); David H. Getches, Colorado River Governance: Sharing Federal Authority as an Incentive to Create a New Institution, 68 COLO. L. REV. 573, 573–658 (1997) (discussed earlier); John G. Berggren, Transitioning to a New Era in Western United States Water Governance: Examining Sustainable and Equitable Water Policy in the Colorado River Basin (Ph.D. Dissertation, University of Colorado 2018) (examining policies and decision-making processes in the Colorado River Basin); Matthew McKinney, Jay Weiner & Daryl Vigil, *First in Time: The Place of Tribes in Governing the Colorado River System*, 63 NAT. RES. J. 153 (2023); John Berggren, John Fleck, Doug Kenney & Mariana Rivera-Torres, *A Pie No More? Building a More Equitable Colorado River Governance Structure*, in CORNERSTONE AT THE CONFLUENCE: NAVIGATING THE COLORADO RIVER COMPACT'S NEXT CENTURY 207 (Jason Anthony Robison ed., U. Ariz. Press 2022) (arguing for a more intentional governing structure, including a science panel, to enhance participation); Robert W. Adler, *Communitarianism in Western Water Law and Policy: Was Powell's Vision Lost?*, in VISION & PLACE: JOHN WESLEY POWELL & REIMAGINING THE COLORADO RIVER BASIN 28 (Jason Robison, Daniel McCool & Thomas Minckley eds., U.C. Press 2020) (discussing John Wesley Powell's novel proposal for Western watershed commonwealths and calling for revisiting the notion of a comprehensive, basinwide water governance structure for the Colorado River Basin). See also Lorelei Cloud and John Berggren, Opinion: Time is now for a new Colorado River Basin process to bring together and engage sovereigns and stakeholders, COLORADO SUN (August 15, 2024) here.

[16] *See, e.g.*, United Nations Convention on the Non-Navigational Uses of International Watercourses, Art. 8 (1997). International best practices for governing transboundary river basins suggest that an ongoing river basin commission is essential to effective and efficient water management. See generally MATTHEW MCKINNEY, ET AL., A SACRED RESPONSIBILITY: GOVERNING THE USE OF WATER AND RELATED RESOURCES IN THE INTERNATIONAL COLUMBIA BASIN THROUGH THE PRISM OF TRIBES AND FIRST NATIONS (2015) (outlining the historical context, the interests and aspirations of tribes and First Nations, the role of indigenous people in transboundary water management, and lessons for improving governance in the International Columbia Basin); Mariana Rivera-Torres & Andrea Gerlak, Evolving Together: Transboundary Water Governance in the Colorado River Basin, 21 INT'L ENV'T AGREEMENTS: POL., L., & ECON. 553, 553–574 (reviewing literature on transboundary water governance); SUSANNE SCHMEIER, GOVERNING INTERNATIONAL WATERCOURSES: RIVER BASIN ORGANIZATIONS AND THE SUSTAINABLE GOVERNANCE OF INTERNATIONALLY SHARED RIVERS AND LAKES (2012) (arguing that river basin organizations are the key institutions for managing internationally shared water resources); STEPHEN C. MCCAFFREY, THE LAW OF INTERNATIONAL WATERCOURSES (3rd ed. 2019) (examining how to apply the law on international watercourses); UNITED NATIONS ET AL., PROGRESS ON TRANSBOUNDARY WATER COOPERATION: GLOBAL STATUS OF SDG INDICATOR 6.5.2 AND ACCELERATION NEEDS, 2021 (2021) (providing decision-makers with reliable and up-to-date evidence on where acceleration is most needed in the Sustainable Development Goal 6 global acceleration framework implemented to ensure water and sanitation for all by 2030). The Oregon State University Program in Water Conflict Management and Transformation manages an *International River Basin Organization* (RBO) Database. It is a searchable database that provides detailed institutional design data for more than 120 RBOs in more than 110 internationally shared watercourses. The Program also manages a data base on *International Freshwater Treaties* which contains summaries and full texts of over 800 agreements from 1820 to 2021.

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