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Threading the Needle: Upper Colorado River Basin Responses to Reduced Water Supply Availability

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Lakes Mead and Powell, the two largest reservoirs in the Colorado River Basin (CRB) and the entire United States, are at historic low levels due to a 20-year megadrought and steady demand pressures from the Basin's water users. Periodic severe and sustained droughts in the CRB have occurred in the past and will likely continue to occur in the future. Hydrologic models for the basin further project overall decreased annual flows under climate projections of increased temperature and variability in precipitation (Kopytkovskiy, Geza, and McCray, 2015; Salehabadi et al., 2022). Low reservoir levels in Lakes Mead and Powell lead to reduced deliveries to downstream water users and threaten hydropower production.

Low reservoir levels at Lake Powell also have implications for water management in the Upper Colorado River Basin because of how water in the CRB is governed and managed. The interstate compacts, an international treaty with Mexico, and many court rulings, policies, and guidelines governing water allocation in the CRB are collectively called the Law of the River. Two major components of the Law of the River pertain directly to the current water discussions in the Upper Basin.

First is the Colorado River Compact of 1922 (1922 Compact), which apportions 7.5 million acre-feet (MAF) of water to the Lower Division States of Arizona, California, and Nevada and 7.5 MAF of water to the Upper Division States of Colorado, New Mexico, Utah, and Wyoming. The 1922 Compact specifies that the Upper Division States will not cause the flow of the river to be depleted below 7.5 MAF annually, on a 10-year rolling average basis, as measured at Lee Ferry, the dividing line between the Upper and Lower Basins. A portion of Arizona lies within the hydrologic Upper Basin (UB), but Arizona is not an Upper Division State subject to curtailment. For ease of exposition, this article sets aside this technical distinction and refers to just the four states subject to curtailment as the UB states.

The second important element of the Law of the River is the Upper Basin States Compact of 1948, which proportionally allocates water among the UB states. It also establishes that a "curtailment" will occur if flows are depleted below the 7.5 MAF annual rolling average threshold. Under a curtailment, the UB states would be required to turn off their most junior water rights to reduce consumptive water use. In a curtailment, the states would first cut back by the amounts they exceeded their allocation in the previous 10 years. Each state would meet the remainder of the curtailment obligation in proportion to its percentage allocation in the 1948 Compact of post-1922 Compact water rights. Each state would decide how to implement the curtailment within its boundaries (Paige, Hansen, and MacKinnon, 2021). There has not yet been a curtailment, but the current prolonged drought and the resulting drop in elevations at Lakes Powell and Mead have led to concerns that one could occur.

In response, the U.S. Bureau of Reclamation (USBR) and the UB states are exploring the idea of an Upper Basin Demand Management (DM) program. Under a DM program, the UB states would conserve and store water in Lake Powell or one of several other UB reservoirs that have historically been put to beneficial use. This water could be released in future years, as needed, to help the states meet their 1922 Compact obligations, thus reducing—or avoiding altogether—the risk of curtailment. This program is still being studied for technical, policy, and legal feasibility.

Regardless of whether the UB implements a DM program, the threat of curtailment requires that policymakers and water users in the region wrestle with questions about whether and how best to reduce water use. This article identifies some of the challenges and trade-offs that UB states face as they work within the parameters of the 1922 Compact to ensure that they meet their obligations to the Lower Basin (LB). Changes in the amount of water used, and the location of use, are likely to occur under either curtailment or a DM program. The impact of these policy tools on participating and affected communities would differ, depending on the scale and frequency of occurrence. Thus, we also discuss patterns of water transfers and exchanges that are likely to take place as well as their implications for rural agricultural communities and ecosystem service provision. The details of how the UB states meet these challenges—whether through water pricing in urban areas, changes in irrigation technology, or water use efficiency improvements—are beyond the scope of this article.

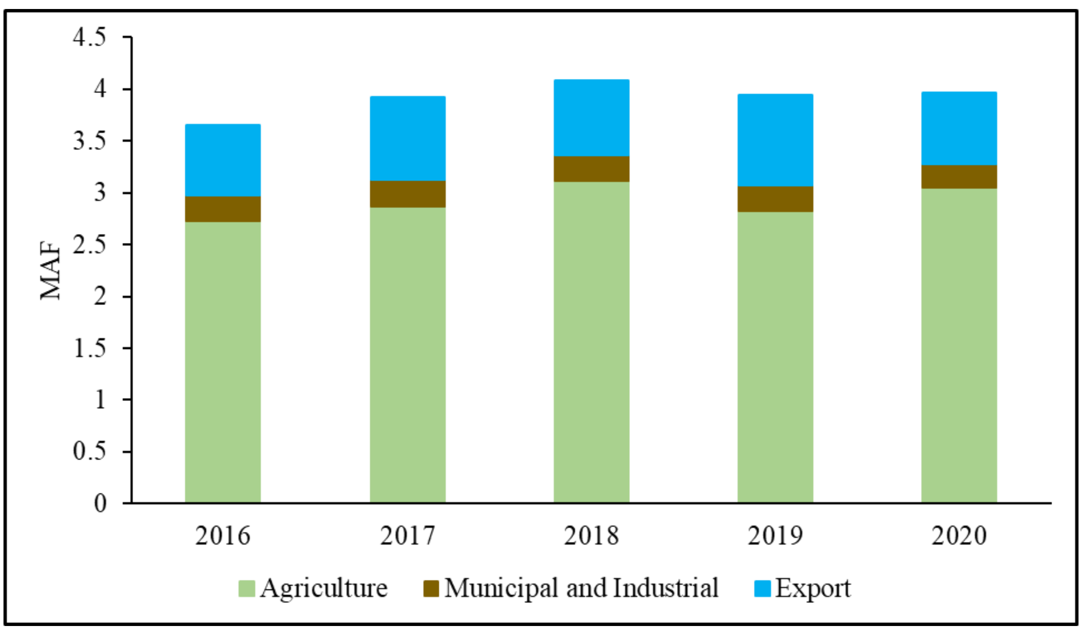
Upper Basin vis-à-vis the Lower Basin

The Colorado River Basin (CRB) has a drainage area of about 242,000 square miles which represents about one-fifteenth of the area of the United States. Less than half of this area, approximately 110,000 square miles, forms the Upper Colorado River Basin (UB) drainage area (USBR, 2022). The UB, with an estimated population of just over 1 million in 2020, is economically different from the Lower Basin (LB), which had an estimated population of more than 8 million that same year (U.S. Census Bureau, 2020).

Both subbasins transfer water to major population centers adjacent to the CRB, though trans-basin diversions in the LB are significantly larger than UB diversions. About 3.6 million people located outside the UB drainage area rely on drinking water from the UB. Most notably, approximately 30% of the water in the UB drainage area is exported to the Front Range of Colorado (which includes Denver) for agricultural and municipal use. By contrast, more than 19 million people located outside the LB drainage area rely on drinking water from the LB. This includes 1.2 MAF exported annually to areas in southern California outside the LB drainage area (MWD, 2024).

Rural economies in the UB rely on agriculture, which has the region’s largest share of water use (see Figure 1). On average, the agricultural land irrigated with water from the Colorado River (including out-of-basin transfers for irrigation) was about 2.16 million acres per year for the 2016–2020 period in the UB (compared to an estimated 3.34 million acres per year in the LB over the same period) (USBR, 2022). The consumptive use of irrigation is more than 62% of the total water used in the UB (USBR, 2022). Agricultural production is less diverse in the UB than in the LB due to its higher elevations and more extreme climate conditions (USDA NASS Reports). Most of the irrigated land is devoted to livestock feed production. Crop sales averaged $131/AF of water consumed in the UB (using 2015 crop revenue data) compared to $814/AF in the LB. Crop sales minus crop-specific input costs averaged $93 in the UB and $485/AF in the LB (Frisvold and Duval, 2024). Agricultural production is thus less profitable in the UB than in the LB.

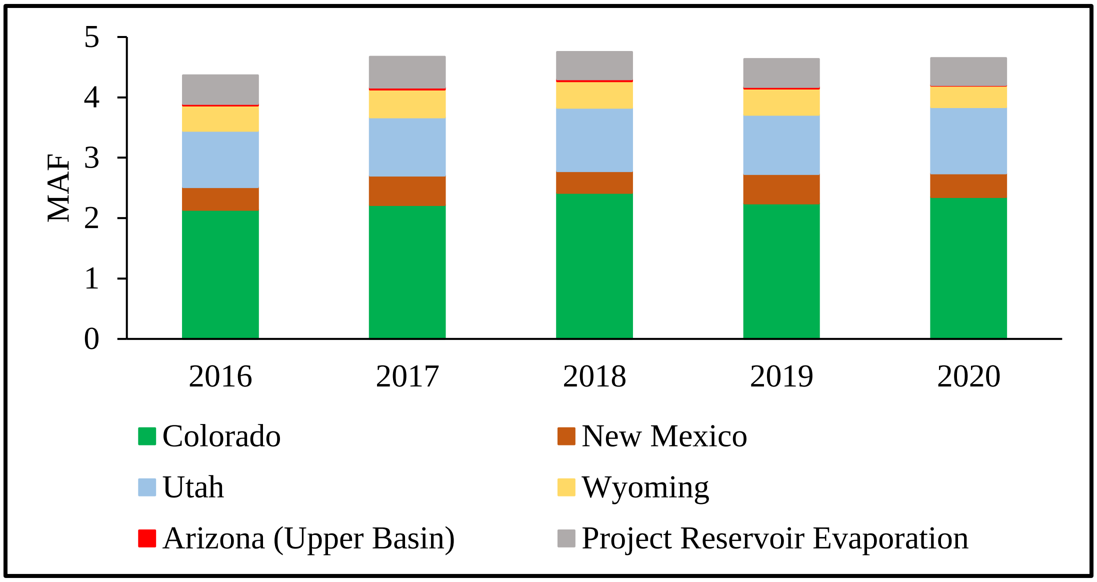
Figure 1. Upper Colorado Basin Estimated Water Use by Type of Use (MAF)



Notes: Agricultural water use includes estimated irrigation consumptive use, stockpond evaporation, and livestock water use. Municipal and industrial water use includes estimated consumptive use of mineral production, thermal electric production, and municipal uses. Exports include transbasin diversions both out of and into the Colorado River System.

Source: Compiled by the authors using U.S. Bureau of Reclamation (2022) report data.

Figure 2. Upper Colorado Basin Estimated Water Use within States (MAF)



Notes: Project reservoir evaporation includes estimated evaporations in reservoirs that participate in the Colorado River Storage Project.

Source: Compiled by the authors using U.S. Bureau of Reclamation (2022) report data.

Another key difference between the UB and the LB is their location relative to water storage. The LB is situated below Lakes Powell and Mead, which gives them access to water stored across years. By contrast, the UB is situated above the major storage reservoirs on the CRB. Although there are a few smaller reservoirs in the upper reaches of the CRB, most UB water users are subject to inter- and intra-annual variability in precipitation. The higher risks associated with water supply at the UB reveal the crucial need to conserve water in the region, even though UB states have developed their water resources at levels considerably lower than the 7.5 MAF apportioned to them in the 1922 Compact. Estimates by the USBR for 1988–2018 show about 4.4 MAF of consumptive use in the Upper Basin. More recent reports show an average of 4.6 MAF of consumptive use in the Upper Basin over 2016–2020 (see Figure 2).

These climatic, economic, and geographical characteristics drive the UB response to reductions in water availability in two important ways. First, UB water use can fluctuate significantly each year in response to annual flow due to the lack of upstream storage. For example, in Wyoming, an increase in the irrigation water supplies (measured in summer precipitation and spring snow water equivalent) positively correlates with irrigated agriculture acres for the year (USDA-NRCS and USDA-NASS Reports). In a curtailment, the UB would respond by reducing consumptive use of water rather than by releasing more water from storage simply because upstream storage is limited. In fact, if more stored water was available, it would have already been released to meet its Compact obligation and avoid curtailment.

Second, the lack of upstream storage, though consistent with the focus of the 1922 Compact on nondepletion of flows at Lee Ferry, results in water shortages yearly in the UB. For example, the USBR estimates that in 2020, the agricultural sector in the UB faced a total of 265 thousand acre-feet (KAF) of water shortage: 8.7% of total water use by the agriculture sector that year (USBR, 2022). The fact that the UB experiences shortages every year due to natural variability in flows is a point often made by the UB representatives at regional meetings.

Water User Responses to Reduced Water Availability

Flow reductions and projections of continued dry hydrology mean that the Compact has become binding on total UB consumptive water use; the risk of curtailment is higher in the UB than in the past. All four UB states follow the prior appropriation doctrine for their surface water rights. Under prior appropriation, those with higher seniority in water rights receive their full share of water before a junior rights holder receives any. Each of the four UB states would likely meet a curtailment obligation by regulating off-water rights in reverse priority (starting with the most junior and working backward in time by priority date) until its obligation was met.

Pre-Compact rights holders tend to be agricultural users, while junior water users tend to be from the municipal and industrial sectors, reflecting the historical pattern of development across the western United States. The municipal and industrial sectors would thus be hit hardest by curtailment.

In a curtailment, junior rights holders could respond by increasing water conservation measures. However, many junior water users may find that they cannot manage water reductions through conservation alone. Alternatively, junior water users may opt to acquire additional water from more senior water rights holders. This replacement water would generally come from the agricultural sector, where the marginal economic value of water tends to be relatively low. A junior user could wait until a curtailment occurred and then contract with senior, pre-Compact water rights holders for short-term leases or exchanges during the curtailment. Alternatively, they could execute an option agreement with senior rights holders before a curtailment to transfer water in the future when a curtailment occurs.

Junior water users could also opt to acquire additional water by purchasing senior water rights. All else being equal, municipal and industrial water users needing replacement water might prefer to purchase rather than lease water rights to ensure a long-term firm and lower-risk water supply (Hansen et al., 2015). Leasebacks, in which municipalities purchase agricultural water rights for future growth but lease the water back to agriculture in the meantime, have been implemented along the Front Range of Colorado. However, permanent water rights transfers out of agriculture to junior water users remain relatively rare in the region. A 2020 focus group of municipal and industrial water users in Wyoming expressed only minimal interest in rights transfers, whether due to the challenge of finding sellers willing to part with rights at acceptable prices or political concerns about long-term regional economic impacts (Paige, Hansen, and MacKinnon, 2021).

Permanent transfers would result in a permanent dry-up of agricultural lands, which can significantly impact exporting communities through losses in income, tax receipts, and employment, particularly in specialized and less diverse agricultural economies (Howe and Goemans, 2003). Specialized, marginal agricultural regions (as in Utah and Wyoming) have been shown to experience more severe economic and social impacts from water rights transfers than regions with higher-value agricultural production, and these impacts are more likely to be long-term (Dozier et al., 2017).

Even short-term transfers have implications for the regional economy. In the absence of processing plants and feedlots, reducing irrigated hay acres would reduce a proportionately large percentage of agricultural activity, especially when that leads to reductions in livestock herd size in the region (Hansen et al., 2021; BBC Research & Consulting, 2020). The magnitude of impacts varies depending on the length of the program, the compensation rate, and assumptions about how much compensation is to be recirculated in the local economy. Transfers—whether permanent or short-term—also have implications for water flows on the landscape. Flood irrigation is the predominant form of irrigation in many high-elevation mountain valleys in the UB. This type of irrigation is less efficient than center pivot or drip irrigation. However, it creates artificial wetlands that provide wildlife habitat for migrating ungulates and bird species. It also generates return flows, which are released in late summer or fall when some creeks might otherwise run dry. This benefits downstream agricultural water users and some fish species. Widespread drying up of irrigated fields could significantly alter return flows and have impacts on ecosystem service provision, groundwater recharge, and downstream water users. However, other fish species and, consequently, recreationists benefit from reductions in consumptive use, through increases in early- and mid-season instream flows. Impacts from change are location-specific and difficult to quantify but significant to water users and recreationists in the region. These impacts on local communities and ecosystems speak to the significant controversy that can result from changes in the timing and location of water use.

Region-Level Responses to Reduced Water Availability

In response to projected shortfalls in water availability and in part to reduce the risk of curtailment, the UB states may implement a Demand Management (DM) program. Under a DM program, water users would be compensated for voluntarily reducing their consumptive water use on a temporary basis. Conceptually, the conserved water would be stored in Lake Powell or other UB reservoirs. The UB could then release water from Lake Powell in dry years when a curtailment would otherwise be announced. This DM program would be a collective response to curtailment risk and allow UB water users to continue historical water use patterns, other than the voluntary and compensated conservation undertaken through the DM program. All four UB states have undergone studies to investigate the feasibility of a DM program (CRCB, 2021; Paige, Hansen, and MacKinnon, 2021).

No UB DM program has been implemented so far. However, the region is undertaking a pilot program, the System Conservation Pilot Program (SCPP), to assess the feasibility of system conservation to increase storage in Lake Powell (UCRC, 2018). During the first four years of the SCPP (2015–2018), 64 projects were supported across the four states. Project types included full- and partial-season fallow, deficit irrigation, alternative cropping in agriculture, and several municipal projects. The cost per acre-foot of water conserved ranged widely from $161 to $670, though by 2018, all projects were compensated at $200/AF. The SCPP resulted in almost 50 KAF in consumptive use reductions during these four years, at a total cost of nearly $8.6 million (UCRC, 2018). The program was revived in 2023 due to concerns during the 2022–2023 winter about low snowpack. In 2023, the SCPP resulted in almost 37.8 KAF in consumptive use reductions, for $15.8 million (UCB System Conservation and Efficiency Program).

One advantage of a DM program over permanent transfers is that its temporary and rotational nature would generate lower regional economic impacts relative to rights transfers. The temporary reductions in water use through a DM program would likely not result in permanent job losses or major shifts in economic activity in the exporting region (Howitt, 1994). Still, concerns about the negative regional economic impacts of a DM program could be addressed prior to its implementation through a mitigation fund.

A DM program also has advantages over curtailment. Curtailment would be mandatory and uncompensated for some less senior water rights holders, whereas water user participation in a DM program would be voluntary and compensated. The compensation received by DM participants would provide an infusion of cash into local communities that would counter some of the negative regional economic impacts associated with reduced water use. Further, a DM program would be proactive, giving water users the opportunity to consider participation on their own timeframe rather than in the rushed moment of a curtailment announcement. However, the concept of a DM program has its own challenges.

The principal among these challenges is funding. The first 4 years of the SCPP (2015–2018) were funded by the USBR and the water utilities serving the cities of Denver, Las Vegas, Los Angeles, and Phoenix. The two most recent SCPP years (2023 and 2024) are funded through the Inflation Reduction Act. However, a long-term source of funds to compensate DM participants has not yet been identified (UCRC, 2018).

Another important challenge for a DM program is the technical details related to implementation. States are working to develop shared metrics and protocols for quantifying and verifying consumptive use reductions. Still of concern is the need to ensure that conserved water is “shepherded” all the way to Lake Powell rather than diverted in transit by other water rights holders. Further, data on how yields and crop consumptive use respond to full and partial reductions of applied water under different soil types and climate conditions is lacking, creating uncertainty for policymakers and water users who want to evaluate the merits of a DM program.

These uncertainties and outstanding questions increase the costs of this proposed new institution. Senior and junior water rights holders have different degrees of exposure to curtailment. Should states invest resources in developing a DM program to protect junior rights holders from curtailment? Whether the benefits of the collective action represented by a DM program outweigh the costs for each state remains to be seen.

In general, whether a DM program (with its compensation provided by an outside funding source and the flexibility provided by banking) is a cost-effective way to shield water users in the region from the disruption of curtailment also depends on the range of curtailment risk that the region faces. If curtailment turns out to be relatively infrequent, the benefit to the region of a DM program would not be worth the expense of establishing one. Alternatively, if curtailment turns out to be more the norm than the exception, a DM program of a size sufficient to substantially reduce curtailment risk would be too expensive. In this latter case, permanent water use reductions would need to be implemented; junior water users affected by curtailment would find themselves needing to either acquire rights or reduce water use to adapt to the new normal.

Though it is possible that some junior rights holders from the municipal and industrial sectors would find ways to reorganize or otherwise adapt to less water available, those who seek to augment supplies would likely lease water from senior agricultural rights holders. So, even in the absence of a DM program, the sector of the economy with reduced water use is likely to be agriculture.

Concluding Remarks

The Colorado River Basin faces many challenges, especially considering projections of climate-induced water supply reductions in the basin. A recent USBR analysis shows that to stabilize elevations at Lakes Powell and Mead over the 2023–2026 period, 0.6 to 4.2 MAF of additional or conserved water is needed annually (Prairie, 2022). Further, the guidelines under which the USBR manages Lakes Powell and Mead will expire in 2026, which, combined with the hydrologic realities of the basin, calls all stakeholders to devise a working plan for the longer term. Continuation of the current management regime is simply not viable. Whether policymakers and stakeholders form a consensus around renegotiating the entire basin management system (unlikely at this point) or modifying effective short-term solutions with bold action plans remains to be seen.

This article has considered just one of these challenges: the UB issue of whether to implement a DM program to reduce curtailment risk. The concept of an Upper Basin Demand Management program has been developed in response to the way that the 1922 Compact distributes water across the Upper and Lower Basins in times of shortage. It is an example of institutional innovation that improves the ability of water managers to address current and projected reductions in water supplies without fundamentally altering the underlying doctrine of prior appropriation. It remains to be seen whether such incremental changes in the tools available to water managers will be sufficient to manage competing demands for water in the basin. Regardless, experience gained by regional water users and policymakers through scoping demand management and implementing a pilot program will help the region understand what flexibilities it has available to address shortfalls in water availability moving forward.

For More Information

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