A Future on Borrowed Time

Colorado River Shortages & the New Normal of Climate Change

An assessment of Upper Colorado River Basin water deficits in a climate change world.

UTAH RIVERS COUNCIL

Public Review DRAFT

The **Utah Rivers Council** is a 501c3 grassroots nonprofit organization dedicated to the conservation and stewardship of Utah's rivers and sustainable clean water sources for Utah's people and wildlife.

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Preface

The Upper Basin is approaching a cliff, a point where climate change will force significant reductions in water use. Yet there is an alarming lack of discussion about this across the Upper Basin.

This report was initiated after hearing claims by some Utah water leaders who have refused to acknowledge that climate change is reducing the flows of the Colorado River alongside claims that new water diversions have no impacts to existing water users. As we show in subsequent pages, this willful ignorance has a real impact on existing water users inside any given Upper Basin state.

The Colorado River is like a household income source and the reservoirs are like a huge savings account. For the last 20 years, the household's income has declined and the residents of the house have been living off their savings. Yet some house residents don't realize they have been slowly draining their savings account.

This report is designed to educate and empower residents in the Upper Basin to do something about this declining income before serious spending cuts have to be made at the last minute. Exorbitant new spending proposals should be curtailed, as anyone who has ever bounced a check knows.

To be clear, new proposed diversions represent irresponsible spending proposals which jeopardize existing water users inside the same state. Proponents of such proposals must be held responsible for their ignorance about the current plight of the Colorado River Basin water supply. Such ignorance effectively results in a failure to protect existing water users inside the same Upper Basin state, as there are real impacts from denying the reality of a shrinking water supply on these users.

Our hope is that this report stimulates greater discussion about the threat posed by climate change and the problems facing existing water users, including cities with junior water rights, farmers and ranchers, Native American Tribes, and conservation-minded audiences who get left out of negotiations about the future of the Colorado River. Good policy is made with public discourse and we see no benefit to backroom decisions which lack transparency, a recipe for discord and costly litigation.

This report is a draft and we welcome any and all comments. Please send comments to info@utahrivers.org.

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Executive Summary

For more than a decade, the Colorado River has been the focus of hundreds of news stories documenting its declining flows, overallocated water rights and competitors jockeying for water in a setting of increasing conflict. Home to America's two largest reservoirs, the deserts of the Colorado River Basin and its water shortages have become almost mythological, attracting reporters from around the globe seeking frontline stories about mankind's collective effort to weather a climate change-afflicted region with a shrinking water supply. There is one question which is commonly asked and seldom answered.

What is the Colorado River Basin's water deficit?

This simple question has a complicated answer because the Basin's hydrology and its century-old water-sharing agreements are difficult to understand quickly. Many leaders and elected officials in the Basin have only discussed the water deficit question in passing, even though it is one of the most important questions facing 40 million people who call the Basin home.

When more in-depth discussions occur – especially in the Upper Colorado Basin – many paint climate change as either a Lower Basin problem or as a temporary anomaly that could be fixed by one wet winter.

If only it were so.

Relying on one big winter to solve our problems is akin to the CFO of a company gambling their last corporate earnings on a roulette wheel in Las Vegas in an attempt to stave off bankruptcy. Such action would result in the termination of such an employee in a properly-run company.

The massive collective reservoir capacity of the Colorado River Basin holds roughly four years of the annual runoff of the Colorado River System. At the time of this writing, these reservoirs are less than half full.[1] This means refilling these reservoirs in one annual spring snowmelt would require a spectacular runoff event, one larger than any that have been observed in the past 115 years.

Yet water leaders in the Upper Colorado River Basin are staking their future—at billions of dollars to the taxpayer – on a series of new water diversion projects. This doesn't just mean that these projects will have no water to put in their pipes, it means that all existing water users, especially those inside their own state, are threatened by these new projects. The most famous example of such a proposal is Utah's proposed Lake Powell Pipeline, the largest new water diversion in the Colorado River Basin.

Water leaders and elected officials who disregard water shortages by denying climate change and advancing new water diversions threaten their own state water users.

Worse yet, instead of focusing on the need for collaboration to represent all water users equally, some water leaders and elected officials have fallen into the pit of tribalism, pitting one state against another and one type of water user against another. Although such optics might ring the political bell, water leaders who overspend their state water allocation by proposing new water diversions amidst a declining water supply threaten their own water users. These leaders should and will suffer serious political fallout from their irresponsible spending spree when the bill comes due.

This report quantifies the water shortages in the Upper Colorado River Basin so the public and its decision makers have some clarity about our shared future. The results are shocking. Before we explore these results, a few words on our methodology alongside a basic understanding of what climate change is doing to the Colorado River System water supply are needed.

In regards to methodology, we have estimated how large the Upper Basin's water shortage would be for different Colorado River flow scenarios but have not predicted the year in which these shortages will occur. Instead, we tie our quantification to reduced flow levels in the Colorado River which are happening as a function of shrinking snowpacks from climate change.

These reduced flow levels are expected to continue as a function of climate change, meaning that any given shortage would occur when the Colorado River reaches a projected level. Through this exercise, we were able to determine how much water each Upper Basin state would be allowed to use if climate change continues to lower the flows of the Colorado River in the future.

To properly understand how the Basin got to this water deficit, it is simply essential that stakeholders understand the impacts of climate change on the Colorado River System.

We recognize the words 'climate change' polarize some decision makers, many of whom govern our water supply and water policies. However, we ask audiences who do not believe in climate change or do not believe mankind has caused climate change to suspend their disbelief long enough to learn about the observed impacts in the Colorado River Basin. Even if one doesn't agree about the cause of the impacts, the impacts themselves are undeniable and must be addressed with intelligence.

The stakes of being wrong about what is happening to our water supply are very high, and having an open mind and hearing diverse viewpoints is not only one of the responsibilities of elected and appointed officials, it's an inspiring exercise in learning how our shared interests unite us more than they divide us.

Water leaders who overspend their state water allocation by proposing new water diversions amidst a declining water supply threaten their own state water users.

Colorado River
Climate Change Observations

Observation #1 Climate change is increasing air temperatures, shrinking snowpacks, and depleting Colorado River flows.

Man-made greenhouse gas emissions are warming the Colorado River Basin at an unnaturally rapid pace, and this is having a number of detrimental effects on the Basin's hydrology.[2] One of the most significant effects is the reduction in the size of snowpacks in the Colorado River's headwater mountain ranges. The mountain ranges of the Colorado River Basin provide the river with about 85 percent of its water in any given year,[3] meaning that smaller snowpacks in these mountains translates into significant decreases in the flow of the Colorado River.

Average flows in the Colorado River have already declined about 19 percent from 2000 to 2018 as a result of climate change,[4] and future projections show these declines could reach as high as 40 percent or more in the future.[5]

Table 1. Projected Declines in Western States' Snowpacks from 1971 – 2000 Baseline

State	Decline in Snow Water Equivalent by 2099
Utah	36%
Colorado	26%
California	57%
Arizona	88%
Nevada	69%
New Mexico	66%

Table 1. Estimated percent decline from 1971 – 2000 baseline period in snow water equivalent by Colorado River Basin state. From the Third National Climate Assessment.

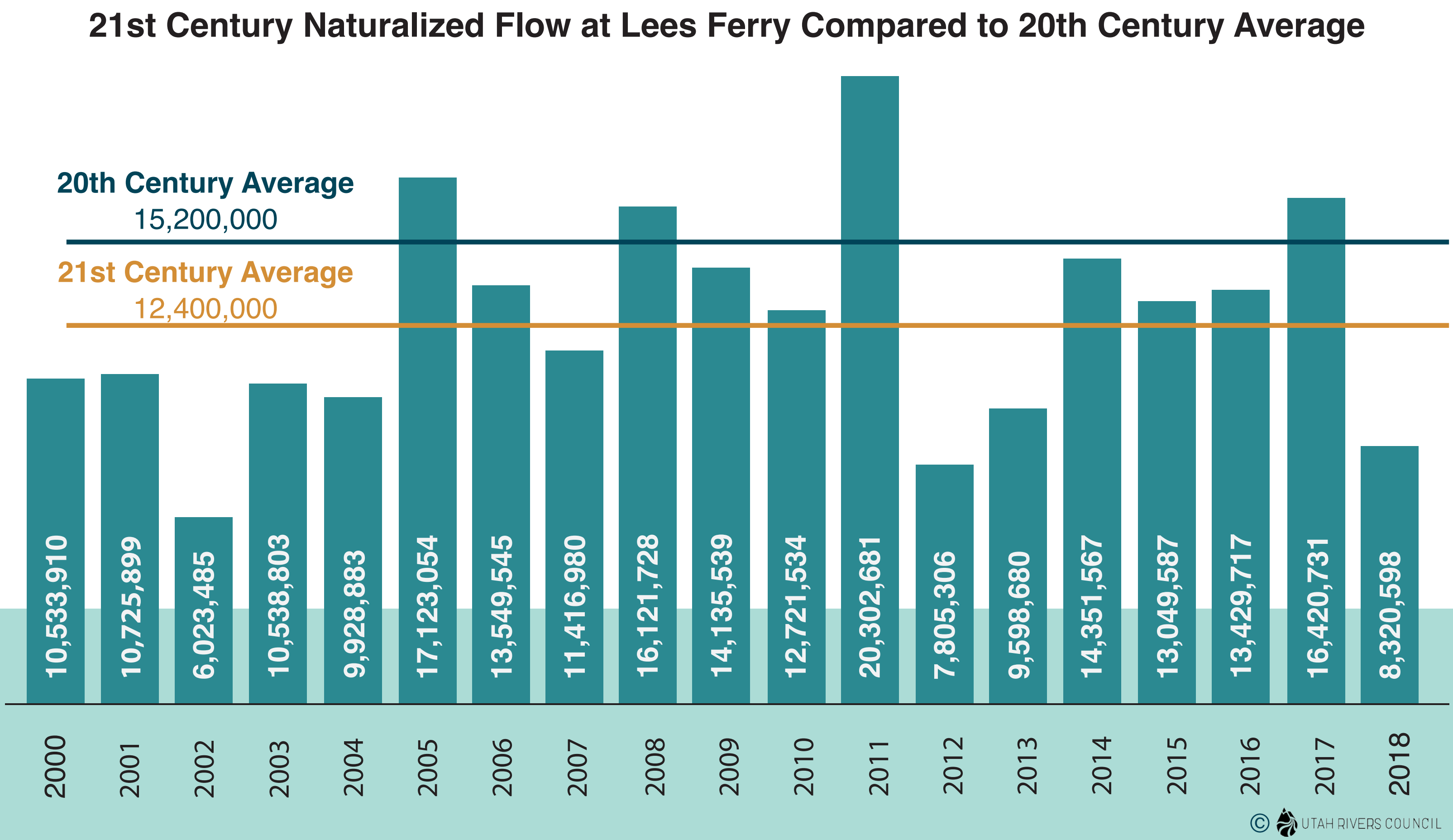


Figure 1. 21st Century Natural Flows of the Colorado River at Lees Ferry. Horizontal lines show 21st and 20th century average Lees Ferry flow levels. Since the year 2000, Colorado River flows have declined substantially. Fifteen of the eighteen years shown had natural flow levels below the 20th century average, resulting in a roughly 19 percent decrease in 21st century average flow levels. Data from Bureau of Reclamation.[6]

Observation #2 Declining Colorado River levels reduce the amount of water each Upper Basin state is allowed to use.

The collection of compacts, treaties, laws, and court decisions that govern the Colorado River System is commonly referred to as the Law of the River. Under the Law of the River, the Upper Colorado River Basin states (Colorado, Utah, Wyoming, and New Mexico) are allowed to use the amount of water remaining after water deliveries to the Lower Basin, Mexico, and other parties are met.[7] Each individual state in the Upper Basin is then allotted their own portion of water according to the percentages established in the 1948 Colorado River Compact. Colorado is entitled to 51.75 percent of the water allotted to the Upper Basin, Utah 23 percent, Wyoming 14 percent, and New Mexico 11.25 percent.[8]

In other words, the Upper Basin states are not guaranteed a fixed amount of water like the Lower Basin states or Mexico are, but rather are guaranteed the "leftovers."[9] This way of dividing up Colorado River water means that as flows decline, so too do the "leftovers," or the amount of water guaranteed to the Upper Basin states.

Table 2. Upper Colorado River Basin Allocations for Various Climate Scenarios

Table 2. Water right allocation for each Upper Colorado River Basin state as per various climate change scenarios. Values in millions of acre-feet, rounded to nearest tenth. Colorado River flows are naturalized flows at Lee Ferry. Numbers don't add to total due to rounding.

Climate Flow Scenario	Colorado River Flow at Lee Ferry	Upper Basin Allocation	Colorado Allocation	Utah Allocation	Wyoming Allocation	New Mexico Allocation
20th Century Average	15.2	6.9	3.6	1.6	1.0	0.8
21st Century Average 19% Decrease	12.4	4.1	2.1	0.9	0.6	0.5
30% Decrease	10.6	2.3	1.2	0.5	0.3	0.3
40% Decrease	9.1	0.8	0.4	0.2	0.1	0.1

Using the framework established by the Law of the River, this report analyzed how much water the Upper Basin as a whole and each individual state in the Upper Basin would be allocated under various historic and potential future flow scenarios. Results for four of these scenarios – one for 20th century average flow, one for current 21st century average flow, one for a 30% decline in flows, and one for a 40% decline in flows – are shown in Table 2.

The Upper Basin states are not guaranteed a fixed amount of water like the Lower Basin states or Mexico, but rather are guaranteed the "leftovers." This way of dividing up Colorado River water means that as flows decline, so too do the "leftovers," or the amount of water guaranteed to Upper Basin states.

It is important to note that there are a number of Native American Tribes in the Upper Colorado Basin who hold federally reserved water rights.[11] Most of these water rights are senior from those water rights held by other Colorado River water users, but are accounted for according to the state in which the Tribe's reservation is located.

For example, the Ute Indian Tribe of the Uintah and Ouray Reservation is located in Utah, so their Colorado River water uses are counted against Utah's allocation, even though Utah does not administer or control the Tribes' water rights. Utah is entitled to 23% of the remaining Colorado River after Lower Basin and Mexico delivery obligations are met, but that does not mean the State of Utah is allowed to use all of that water. A fixed amount of that water is reserved for the Tribes in Utah.

Lake Mead, America's largest reservoir, has witnessed dramatic low water levels triggering historic reductions in water deliveries to Lower Basin states. Upper Basin states have yet to cut their water deliveries and many Upper Basin water leaders are proposing new water diversions. Because Colorado River reservoirs have been slowly drained since the turn of the century, many stakeholders have failed to separate declines in water flows from increased reservoir water deliveries. Luca Temporelli Photo

Observation #3 Three of the four Upper Basin states are likely already using more water than they are allocated.

Once each state's allocation is calculated, it is relatively easy to determine whether a given state is using more or less water than their allocation by comparing their current consumptive Colorado River water use amounts. The Bureau of Reclamation publishes consumptive use estimates for the Upper Basin states in the Consumptive Use and Loss Report.[12] Table 3 shows how much water each Upper Basin Colorado River state has left to develop in their allocation (a surplus) or needs to cut in order to come back into line with their allocation (a deficit). Table 3 assumes the Upper Basin must deliver water to Mexico, but an additional analysis was run that assumes no Upper Basin water delivery to Mexico. The full results of both analyses can be found in the appendices.

Table 3.
Upper Colorado River Basin Surpluses or Deficits for Various Climate Scenarios

Climate Flow Scenario	Colorado River Flow at Lee Ferry	Upper Basin Surplus (Deficit)	Colorado Surplus (Deficit)	Utah Surplus (Deficit)	Wyoming Surplus (Deficit)	New Mexico Surplus (Deficit)
20th Century Average	15.2	2.308	1.078	0.496	0.458	0.275
21st Century Average 19% Decrease	12.4	(0.504)	(0.377)	(0.151)	0.064	(0.041)
30% Decrease	10.6	(2.252)	(1.281)	(0.553)	(0.180)	(0.238)
40% Decrease	9.1	(3.772)	(2.068)	(0.902)	(0.393)	(0.409)

Table 3. Estimated status of each Upper Colorado River Basin state water allocation in terms of a water surplus or water deficit as a function of various climate change scenarios of flow reductions. Includes water delivery obligation to Mexico. Values in millions of acre-feet.

Table 3 shows that Colorado, Utah, and New Mexico are using more water than they are likely allocated given current Colorado River average flow levels of 12.4 million acre-feet per year, which represent a 19 percent decline in water flows from the 20th century average. In other words, if climate change was to stop shrinking snowpacks in the Colorado River Basin and we could somehow lock in these reduced water runoff amounts, the Upper Colorado River Basin would be overusing its right to water by 500,000 acre-feet each year.

If Colorado River flows decline to a total of 30 percent below the 20th century average flow, or to 10.6 million acre-feet per year, and water use does not decrease, all Upper Basin states would overuse their water allocation by more than 2 million acre-feet per year.

This represents a dire warning to Upper Basin states to get ready for future water shortages and to not be fooled by water leaders urging for the construction or approval of new water diversions, particularly those that are not truly necessary for essential needs. Taxpayers should not be fooled into simply trusting the credibility of water authorities proposing new water diversions, particularly those refusing to embrace authentic water efficiency and conservation measures.

Altogether, the Upper Colorado River Basin will have to collectively reduce its water use between 2 - 4 million acre-feet to avoid using more water than it is entitled to. Without such action, serious economic impacts may befall Upper Basin water users including cities, farms and tribes.

The Colorado River near Page, Arizona just a few miles above Lees Ferry. Photo by Adrille.

Figure 2. Declining Upper Basin Water Supply vs. Current Water Use

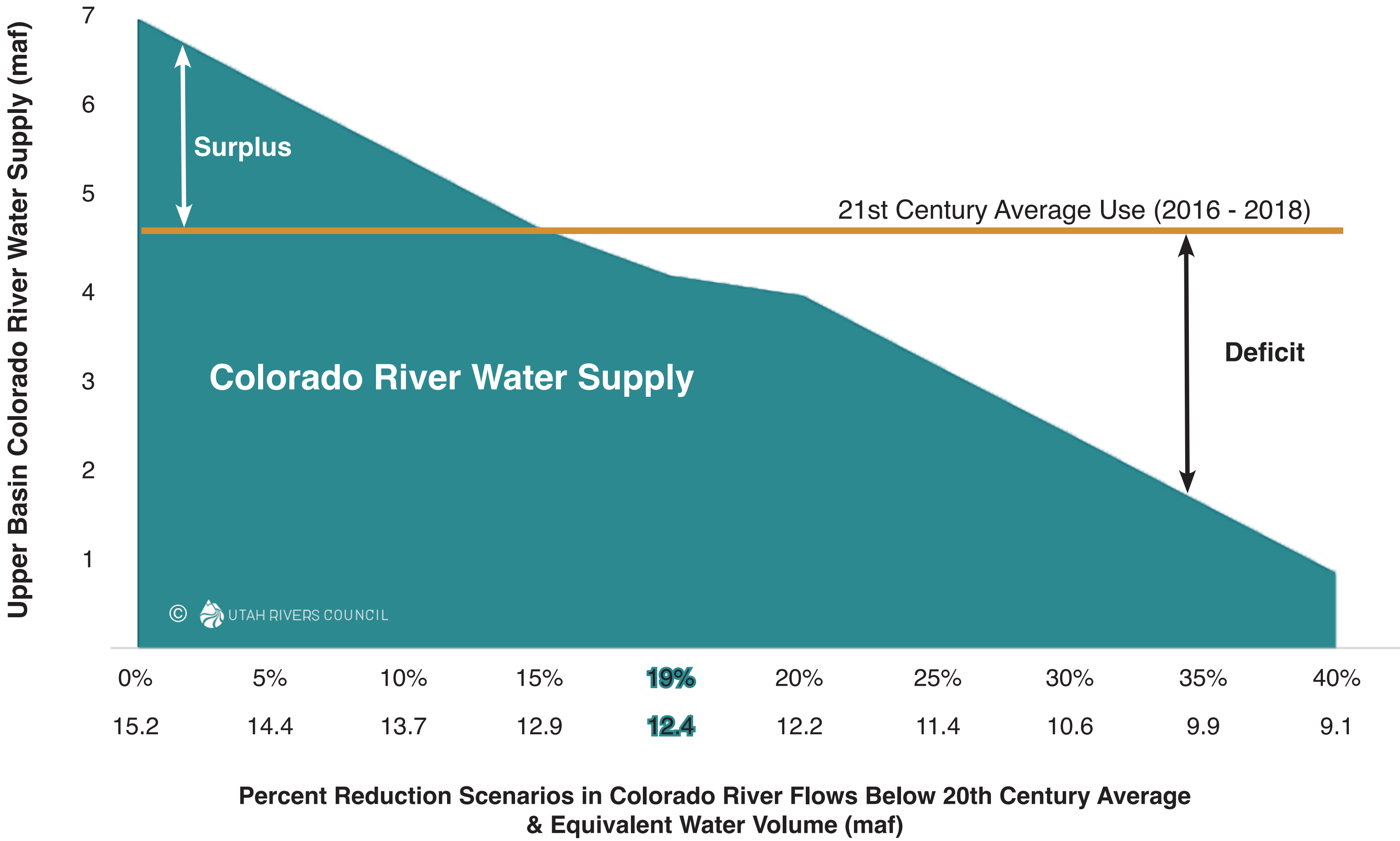


Figure 2. The Upper Basin's Colorado River water supply declines rapidly as climate change depletes the flows of the Colorado River, quickly outpacing the Upper Basin's current Colorado River use, shown as a brown line. Action needs to be taken to decrease the Basin's use to keep the Upper Basin from long term water deficts.

Observation #4. By overusing water, Upper Basin states open themselves up to having their water use reduced, which threatens their own existing water users.

Upper Basin states that use more water than they are allocated from the Colorado River could be forced to reduce their water use via a process laid out in Article IV of the 1948 Upper Colorado River Basin Compact known as curtailment.[13] While the details of curtailment are ill-defined, some aspects are clear. Specifically, the 1948 Compact explicitly states that Upper Basin states who use more water than allotted will have to reduce their water use first, and consequently will have to reduce their water use the most.[14] This would undoubtedly have negative economic and social impacts on the affected state, and threatens to seriously upend many Colorado River dependent communities.

Those who know the Colorado River system well recognize that curtailment may not be far off. The State Engineer of Colorado is reportedly working on plans to deal with curtailment,[15] and the State Engineer of Wyoming has established a program with the goal of creating "a clearly defined and defensible approach to the implementation and administration of an Upper Colorado River Basin Commission initiated curtailment."[16] Similarly, respected Colorado River experts John Fleck and Anne Castle wrote in a recent paper that "declines in the Colorado River's flow could force water curtailments in coming decades, posing a credible risk to Colorado communities…"[17]

If a curtailment scenario occurred, each Upper Basin state would be required to reduce its Colorado River water use by some amount, but the Law of the River does not specify how each state should make those reductions. If curtailment occurs, some water users in the Upper Basin will be forced to forgo their water rights, likely resulting in economic losses and lower social welfare. These water use reductions would happen over a relatively short time span, meaning water users would have little time to adjust. This possibility becomes more and more plausible as climate change worsens and flows in the Colorado River decline.

Upper Basin states and water users should proactively work to reduce their water use and ensure they do not use more than their allocation. By necessity this means that new proposed water diversions should be abandoned, particularly those that are not truly needed, like the proposed Lake Powell Pipeline. The sooner a state gets serious about acknowledging water deficits, the more likely they can protect their water users and implement various water efficiency programs to mitigate shocks to existing users. While water use would still be reduced in this scenario, it could be done in a planned and controlled manner that protects the wellbeing of existing users.

Hydrology of the Colorado River Basin

The Colorado River Basin covers a 240,000 square mile area, stretching north from the Wind River Mountain Range in Wyoming all the way south to the Gulf of California in Mexico.[18] The Basin is commonly divided into the Upper Basin states of Utah, Wyoming, Colorado and New Mexico and the Lower Basin states of California, Arizona, Nevada and Mexico. The dividing point between the basins is called Lee Ferry and is located 17 miles below Glen Canyon Dam on the Colorado River, below the mouth of the Paria River.[19] This is also the location where deliveries of Colorado River water from the Upper Basin to the Lower Basin are officially measured.

Altogether, the Colorado River travels 1,450 miles from its headwaters near Granby, Colorado to its terminus in the Gulf of California. While there are hundreds of smaller streams and rivers that eventually make their way into the Colorado River, a few large tributaries provide a majority of the water.[20]

The Green River is the largest tributary to the Colorado River and starts in the Wind River Range of Wyoming. The Green flows south into Flaming Gorge Reservoir and eventually joins the Colorado River in Canyonlands National Park. Also feeding the Colorado River is the San Juan River, which starts in Colorado's San Juan Range before it flows through New Mexico and joins the Colorado River at Lake Powell. Combined together, these two tributaries provide more water to the Colorado River system than the Colorado River itself.[21]

The majority of the Colorado River Basin is covered in low-elevation, arid lands that produce little to no runoff.[22] Roughly 7/8 of the flows of the Colorado River come from just 1/8 of the land mass, principally in the mountainous regions of Utah, Colorado and Wyoming.[23]

Table 4. Major River Flows of the Colorado River Basin

River	River Gauge Location	1906 -- 2018 Naturalized Flow millions acre-feet / year
Colorado River	Cisco, UT	6.8
Green River	Green River, UT	5.4
San Juan River	Bluff, UT	2.1
Little Colorado River	Cameron, AZ	0.17
Virgin River	Littlefield, AZ	0.17
Gila River	Dome, AZ	1.1

Table 4. 1906-2018 natural flow of the major rivers of the Colorado River Basin. More than half of the water in the Colorado River System comes from tributaries that enter the Colorado River itself.

While these mountains experience many forms of precipitation, recent studies demonstrate that snow is the most important contributor of water as it constitutes roughly 70 – 80 percent of the mountain ranges' total runoff in any given year.[24] This means that the size of winter snowpack in the headwaters determines how much water will flow in the Colorado River for the rest of the year.

A low snow year in any mountain range will dramatically lower River flows, while above average snowpacks could create surplus water. This fact led Jeff Lukas of the University of Colorado Boulder and Ben Harding of Lynker Technologies to describe the snowpacks of the Upper Basin mountain ranges as "an enormous seasonal reservoir that fills and empties every year."[25]

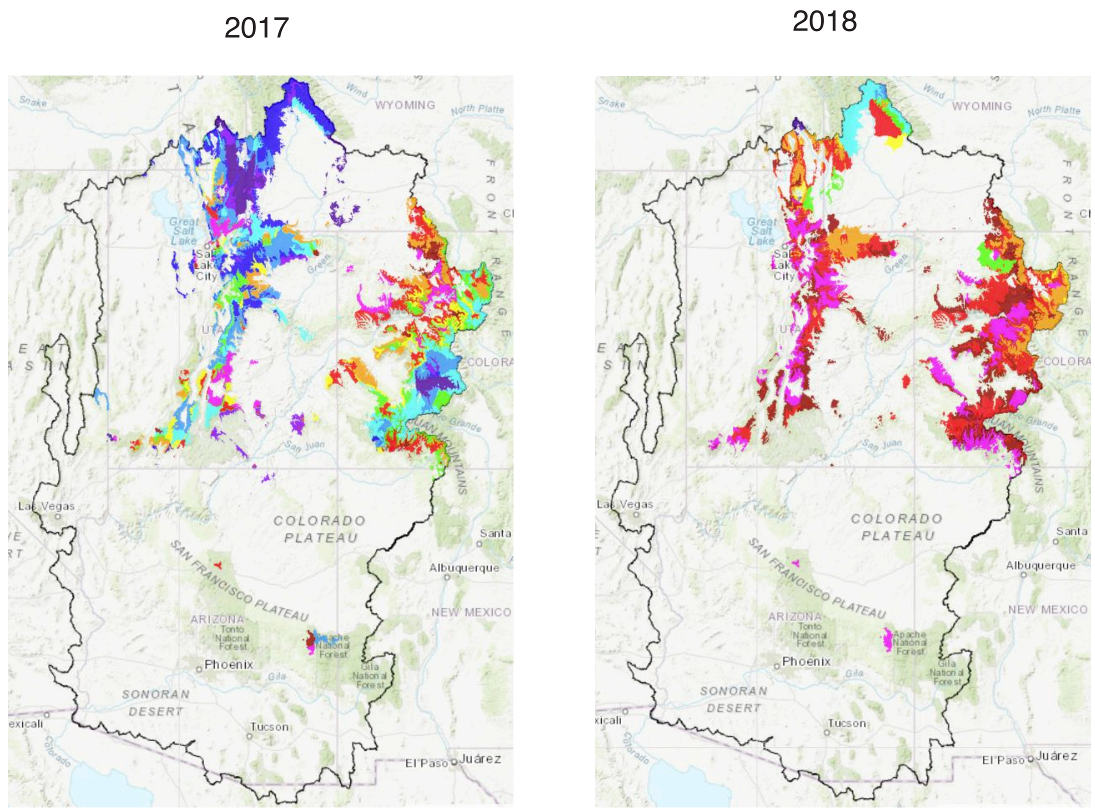
The Colorado River at Dead Horse Point, just a few miles above its confluence with the Green River in the heart of Canyonlands National Park. Photo by Clement Bardot.

The importance of spring snowpack can be seen by comparing two recent water years in the Colorado River Basin. Figure 3 shows two maps of the Basin's April 1st snow water equivalent (SWE) levels in 2017 and 2018.[26] Here, SWE is expressed as a percent of median, with more red/pink colors representing low SWE levels and blue/purple colors representing high SWE levels. the Colorado River at Lees Ferry was just about 8.3 million acre-feet, whereas in 2017 it was over 16 million acre-feet.[28] While there are other factors that could have contributed to the River's total flow during these two years, such as rain in low-elevation areas in the fall,[29] the big differences in April 1st SWE likely was the most significant differentiator.

Figure 3 shows that 2018, which is generally covered in reds and pinks, had much less snow than 2017. This translated into much less water runoff. In 2018, the naturalized flow of

Figure 3. Changes in Water Content of Colorado River Basin Snowpacks for High and Low Water Years

Figure 3. April 1st Snow Water Equivalent for the Colorado River. Low snow water equivalence in 2018 resulted in much smaller Colorado River flows. Natural flow at Lees Ferry was just 8.3 million acre-feet in 2018, whereas in 2017 it was over 16 million acre-feet. Maps from Colorado River Basin Forecast Center.[27]



Colorado River Basin Hydrology Observations

- More than half of the water in the Colorado River comes from the Green and San Juan Rivers, which originate in the mountain ranges of the Upper Basin.
- 85 percent of the water in the Colorado River comes from runoff from a few headwater mountain ranges, which comprise less than 15 percent of the Basin's total land area.
- Snowmelt runoff comprises 70 – 80 percent of the water coming from these headwater areas each year, making snow one of the most important contributors to Colorado River water flows.

The San Juan Mountains in Southern Colorado feed the San Juan River, one of the Colorado River's largest tributaries. Most of the Colorado River's water originates as snow in high-elevation mountains. Photo by David Hilton.

A Cascade of Impacts from Climate Change in the Colorado River Basin

When most people think about climate change and increased air temperatures, they think about warmer summer months. But in the American West, increased winter air temperatures are creating serious problems for our water supply.

In the American Southwest, anthropogenic greenhouse gas emissions have raised average air temperatures significantly. From 1980 to 2019, the Colorado River Basin grew about 2.0°F warmer, an increase of roughly 0.5°F every decade.[30] This made the period from 2000 to present the warmest period in the past two millennia.[31]

Figure 4 from Lukas and Harding (2020) depicts annual temperature variations from the 1970-1999 average in the Colorado River Basin.[32] Air temperatures have increased significantly during the past two decades. Even the coolest temperatures in the post-2000 years (e.g. 2011, 2013, 2019, etc.) have been warmer than the historical average, and some years (e.g. 2017) have been the warmest ever recorded.[33]

Studies have found this warming period was a direct result of human activities (i.e. carbon emissions),[34] and that future carbon emissions will continue to raise air temperatures.[35] Estimates of such scenarios show that the Colorado River Basin could face temperature increases of 4.9°F to 8.7°F by the end of the century, depending on what scenario of human carbon emissions are released.[36] This warming has and will continue to have a number of detrimental effects on the Colorado River Basin's hydrology.

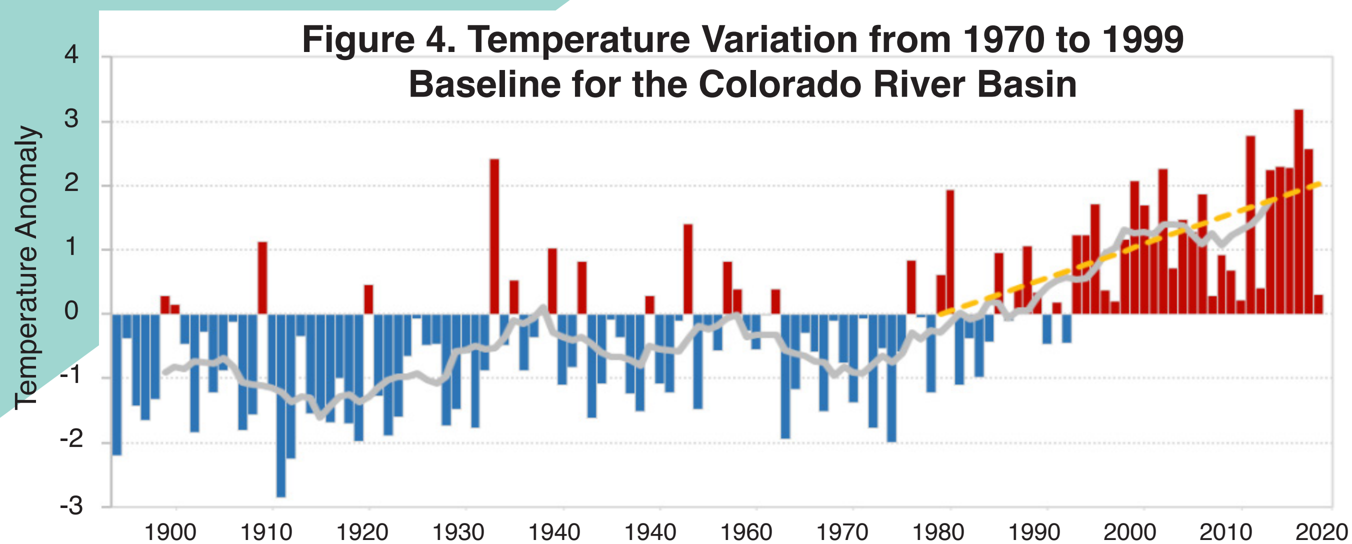


Figure 4. Temperature Variation from 1970 – 1999 Average. After roughly 1990, temperatures in the Colorado River Basin were consistently higher than in the past, an indication of how climate change has affected the Basin. Graphic reproduced with permission from Lukas & Harding (2020).

Increased Likelihood of Megadrought and Aridification

The 21st century has been exceptionally dry, so much so that it has been given a special title, the Millennium Drought.[37] Recent science shows that the period from 2000 to 2018 was the 2nd driest since 800 C.E., exceeded only by a late 1500's megadrought.[38] The same study states that the Millennium Drought became severe because of anthropogenic emissions, which are continuing.

Additional studies have estimated the probability of megadroughts occurring in the future as a function of climate change.[39] The most recent study found there was a 70— 99 percent chance of increased megadroughts, with values near the upper end of the range being the most likely.[40] This shows that prolonged and extreme droughts, like the one affecting the Basin now, are going to become more commonplace in the future.

The likely future persistence of long-term droughts in the Colorado River Basin has led some scientists to argue that the Basin is undergoing aridification, not just mere drought.[41] Aridification describes a "period of transition to an increasingly water scarce environment," whereas drought implies a temporary condition.[42] These scientists argue that climatic shifts in the Colorado River Basin caused by anthropogenic greenhouse gas emissions are creating permanent changes to the Basin, creating a "new normal" of hotter, drier conditions.

While the primary factor in the Colorado River Basin's aridification is temperature increases and river flow declines,[43] other changes include drier soils,[44] significant death of trees,[45] and increased severity of wildfires.[46] All these shifts will create permanent changes to the Colorado River Basin, thereby fundamentally altering its hydrology, ecology, and climate.

Impact 1. More Dust on Snow

Airborne dust particles can travel far distances and settle on snow-covered mountains, creating problems for the snowpack. As more dust settles onto our snowpacks, the snow's ability to reflect sunlight is lowered. This reflection of snowmelt is known as albedo, and numerous studies have found that increased dust decreases the snowpack's albedo and therefore increases radiation absorption from sunlight.[47] Increasing sunlight absorption speeds melting of the snowpack and hence decreases snowpack.[48] It has been found that dust-on-snow events can decrease flows in the Upper Colorado River Basin up to 6 percent.[49] Scientists predict that the long term aridification of the Colorado River Basin will lead to drier lands that produce more dust emissions.[50]

A dust covered snowpack in the Rocky Mountains of Colorado. Drier soils produce more dust, which can travel long distances and settle on mountain snowpacks, darkening the snow. This has the effect of allowing the snowpack to absorb more solar radiation, hastening snowmelt.

Impact 2. A Shorter Winter

Numerous studies have found that the winter season is getting shorter, meaning that the number of months in which snow precipitation occurs in the American West is being reduced from warmer air temperatures.[51] As the duration of winter is reduced, fall and spring are growing longer which further reduces Colorado River Basin snowpacks, a threat to our water supply. One study found that from 2000 to 2010 most measurement sites in the Upper Basin reported runoffs one to three weeks earlier than they did from 1950 to 2000.[52] These shifts are likely caused by declining snowpack sizes, or total snow water equivalence, as a result of increasing air temperatures.

Impact 3. Precipitation Shift from Snow to Rain

Many studies have found that the American West is undergoing a large-scale shift from snow to rain as a result of increasing air temperatures, which in turn leads to smaller snowpacks.[53] Future projections anticipate that this snow-to-rain trend will worsen in the coming decades as air temperatures increase.[54] One study underscores this point well. It analyzes how the percent of the Western U.S. that receive snow precipitation will shrink in the coming decades by comparing a baseline period (1979 to 2012) to a projected future period (2036 to 2065).[55] Over the baseline period (1979 to 2012), roughly 60 percent of the Western US received snow in January. By 2065, it is estimated that less than 30 percent of the Western US will see snow in January.[56] Areas that would have received snow in the past will now receive rain instead.

Rainstorm over Colorado's Rocky Mountains. As the effects of climate change worsen across the Western United States, more mountains will receive rain instead of snow. This shift in precipitation is projected to significantly decrease the amount of snow in mountain ranges across the Western United States and in the Colorado River Basin, thereby leading to less runoff and river flow. Photo by Shadowmeld Photography

Impact 4. Colorado River Snowpack Reductions

Increased air temperatures are reducing the amount of mountain snow in the Colorado River Basin and hence water flows in the Colorado River and its tributaries. Numerous studies have shown that snowpacks in the Western U.S. and Colorado River Basin have declined and will continue shrinking as a result of warmer air temperatures.[57] One study found that Western U.S. April 1st snow water equivalency declined 15 – 30 percent from 1955 to 2014, resulting in a loss of water equivalent in volume to that of Lake Mead.[58] Studies focused on the Colorado River Basin specifically have found that warming air temperatures account for a significant portion of this snowpack decline,[59] and others have noted that decreasing winter-time precipitation has also played a role.[60]

Future projections show that winter-time snowpack levels and water equivalency will continue to decline across the West as temperatures continue to rise.[61] Table 5 was reproduced from the third national climate assessment and shows how much snowpacks are expected to decline in each state under moderate greenhouse gas emission scenarios.[62]

Some of these declines may at first appear modest, like the state of Colorado's 26 percent decline. But it's important to remember that most of the Colorado River's water comes from the snowpacks of just a few select mountain ranges in Utah, Colorado, and Wyoming. In this light, declines of 26 – 36 percent are substantial, and will likely result in significant streamflow reductions in the Colorado River.

Table 5. Projected Declines in Western State Snowpacks from 1971 to 2000

State	Decline in Snow Water Equivalent by 2099
Utah	36%
Colorado	26%
California	57%
Arizona	88%
Nevada	69%
New Mexico	66%

Table 5. Estimated snow water equivalent decline from 1971 – 2000 baseline period in snow water equivalent by state. Data taken from the Third National Climate Assessment.

Impact 5. Decreased River Flows

Declining snowpacks, a shift from snow to rain, shorter winters and increased dust-on-snow events combine to significantly deplete mountain runoffs and river flows. The effects of these reduced flows can be seen in the Colorado River Basin. The period from 2000 to 2018 was one of the driest in Basin history, with only four years of the last 19 years reaching average or above average river flow levels, compared to the 20th century average. Figure 5 on page 20 depicts annual naturalized flow of the Colorado River for the 21st century and compares it to the 20th century historical average, depicted as a horizontal line.

Figure 5 makes evident that most years in the past two decades had flows well below average. In fact, the average River flow from 2000 to 2018 was just 12.4 million acre-feet, roughly 19 percent lower than the 20th century average of 15.2 million acre-feet.

Among scientists there is little debate that the flows of the Colorado River will continue to decline in the coming decades, but there is not yet a consensus on just how large those future declines will be.[64] Lukas and Payton (2020), reviewed 19 papers that estimate what future declines in Colorado River flows will be by mid-century.[65] Their review found a number of papers projecting between a 10 - 20 percent decline in river flows from the 20th century average and another grouping of papers that project larger declines of 30 – 40 percent.

The first subset of papers effectively projects that the Colorado River has already reached the bottom of flow declines – given that flows have already dropped about 19 percent from the 20th century average – while the second subset projects that flows could decrease another 20 percent over the next few decades. This begs the question; which view is correct? Has the Colorado River already dropped to its lowest level, or will flows continue to drop in the coming decades?

Brad Udall and Jonathan Overpeck addressed this question in their 2017 paper entitled *The twenty-first century Colorado River hot drought and implications for the future.* Specifically, they noted:

> ***Fifteen years into the twenty-first century, the emerging reality is that climate change is already depleting Colorado River water supplies at the upper end of the range suggested by previously published projections.***[49]

According to their paper, steadily increasing air temperatures, shrinking snowpacks, and a slew of other climate-change-induced effects will continue to deplete Colorado River flows throughout this century. The implications of this are severe. The Colorado River system has already been greatly strained by the 19 percent decrease in River flows since the start of the century. Additional large declines on top of this could push the system to the breaking point if actions are not taken to prepare for this drier future.

Figure 5. 21st Century Naturalized Flow at Lees Ferry Compared to 20th Century Average

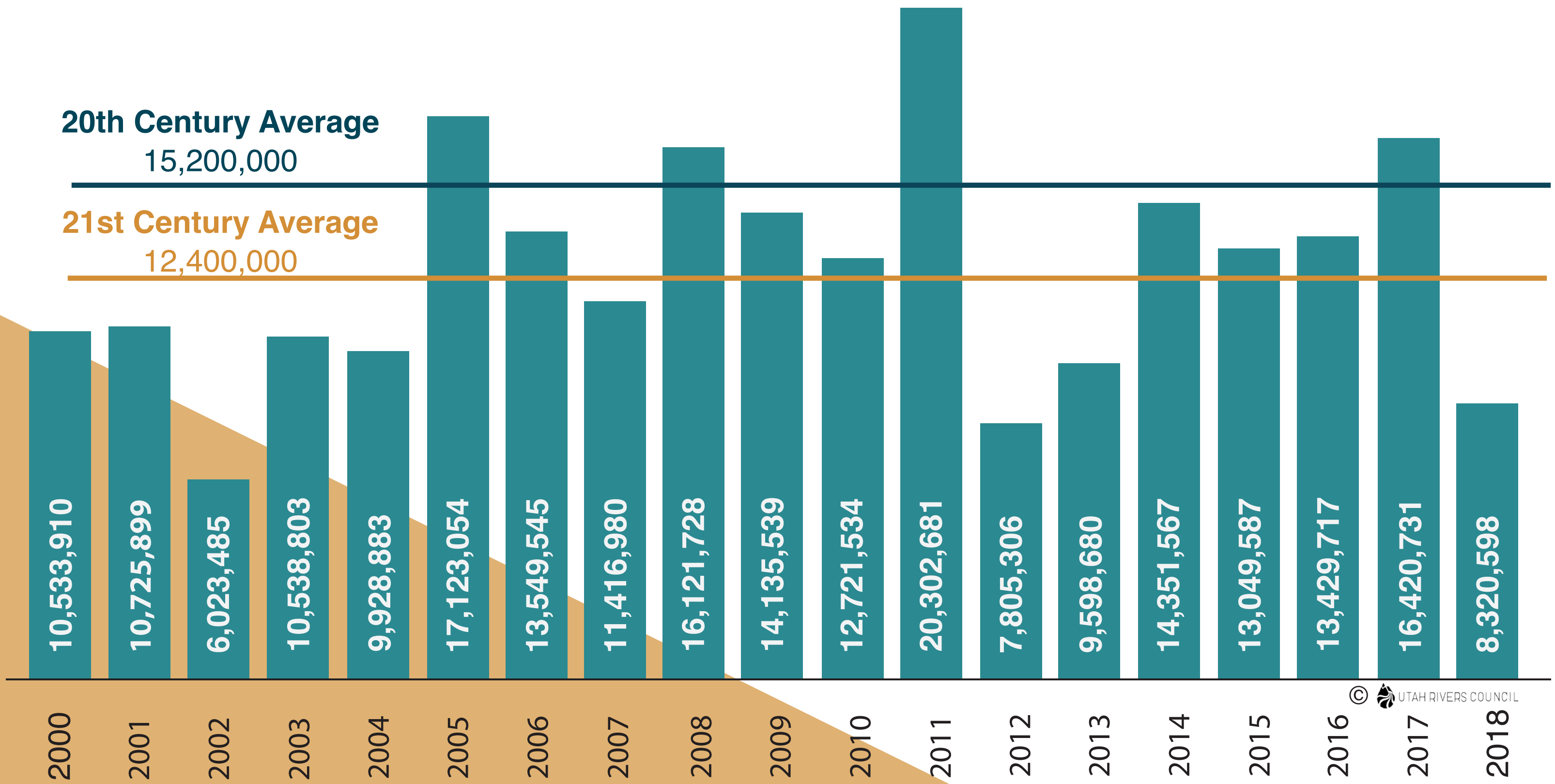


Figure 5. 21st Century Natural Flows of the Colorado River at Lees Ferry. Horizontal lines show 21st and 20th century average Lees Ferry flow levels. Fifteen of the last nineteen years shown had natural flow levels below the 20th century average, resulting in a roughly 19 percent decrease in 21st century average flow levels. Data from Bureau of Reclamation.[63]

Impacts of Climate Change in the Colorado River Basin Observations

- Climate change has increased the temperature of the Colorado River Basin by 2.0°F since 1980 and future temperature increases of 4.9°F to 8.7°F by the end of the century are likely, depending on carbon emission volumes.
- This warming has created a cascade of impacts that have shrunk the snowpacks of the Colorado River, and these impacts are likely to continue into the future.
- Since most of the water in the Colorado River comes from snowmelt, warmer temperatures mean less water in our reservoirs and in the river.
- From 2000 to 2018, the Colorado River had flows 19 percent below the 20th century average. Future water flow declines could be as large as 30 – 40 percent.

A quickly melting spring snowpack in the Rocky Mountains of Colorado. Photo by Sarbjit Bahga.

Lower Colorado River Basin Climate Adaptation

The Lower Basin states and Mexico have begun taking cuts to their Colorado River water supplies in response to reductions in water flows from climate change. A series of agreements have been negotiated requiring Lower Basin users to take water cuts as the level of Lake Mead declines. Table 6 shows how much water the Lower Basin states and Mexico are required to cut under these agreements. At the lowest elevation of Lake Mead, these entities will cut over 1.3 million acre-feet of water.

The Upper Basin currently has no plans to reduce its water use and is in fact proposing new water diversions as if there is no water supply shortage ocurring in the system. The Upper Basin would do well to take a page from its neighbors and start getting serious about climate change by creating a plan to cut water use and stop proposing new water diversions which threaten existing water users in both basins.

Table 6. Water Reductions for Lower Basin States and Mexico Under Existing Agreements

Lake Mead Elevation (ft)	Arizona (ac-ft)	Nevada (ac-ft)	California (ac-ft)	Mexico (ac-ft)	Total (ac-ft)
1,090 - 1,075	192,000	8,000	0	41,000	241,000
1,075 - 1,050	512,000	21,000	0	80,000	613,000
1,050 - 1,045	592,000	25,000	0	104,000	721,000
1,045 - 1,040	640,000	27,000	200,000	146,000	1,013,000
1,040 - 1,035	640,000	27,000	250,000	154,000	1,071,000
1,035 - 1,030	640,000	27,000	300,000	162,000	1,129,000
1,030 - 1,025	640,000	27,000	350,000	171,000	1,188,000
Below 1,025	720,000	30,000	350,000	275,000	1,375,000

Table 6. Total volume of Lower Basin and Mexico water reductions as set out in recent treaties and agreements. The Lower Basin and Mexico are already reducing their water use substantially to adapt to climate change. Data from the Congressional Research Service.

Effects of Climate Change on the Upper Basin's Colorado River Allocation

There is clear scientific consensus demonstrating that the flows of the Colorado River will continue to decline as a result of climate change and its shrinking snowpacks in the Basin's headwaters. Flows of the Colorado River at Lee Ferry have declined 19 percent between 2000 and 2018 from climate change[1] and climatic trends suggest these flow decreases will continue in the future.[68]

Quantifying how much each Upper Basin state is afforded from the Colorado River under a shrinking flow regime is critical to understand if the Upper Basin states are to comply with their obligations under the Law of the River and not use more water than they are allowed. Failure by an Upper Basin state to keep its water use within what is decreed opens that state up to a provision of the Law of the River known as "curtailment" or a "compact call,"[69] where an Upper Basin state would be forced to reduce its water use from the Colorado River.[70] Such a situation would likely cause significant economic harm to residents across that state.

A careful review of each Upper Basin state's water allocations[71] has been made here by calculating a range of climate change flow reduction scenarios and considering Law of the River obligations, including agreements with and obligations to Native American Tribes. Climate change flow scenarios focused only on flow reductions in the Colorado River at Lee Ferry,[72] the official point of measurement for the 1922 Colorado River Compact. Measuring Colorado River flow declines in this way is consistent with previously published studies.[73] This analysis did not include other climate change impacts which could alter water use regimes such as larger water demands from increased temperatures.

Climate change flow reductions were factored in by creating a set of potential future flow scenarios. These scenarios range from a baseline of the 20th century average Lee Ferry flow levels to a 40 percent decrease in Lee Ferry flows, which aligns with the lowest estimates found in current studies.[74] By the end of century, some studies suggest flows could decline as much as 55 percent,[75] meaning that we should not expect a 40 percent decline to be the lowest the Colorado River at Lee Ferry ever gets.

Layered on these projected flow declines is the framework set out in the Law of the River, as it has been articulated by previous studies,[76] which determines how much water each individual state in the Upper Basin is allowed to use. Finally, the Bureau of Reclamation's consumptive water use estimates are applied to determine whether each state would have a surplus or deficit of Colorado River water under a given Lee Ferry flow reduction scenario.[77]

Colorado River Flow Decline Scenarios

The starting point for this analysis is to assess how much water is in the Colorado River at Lee Ferry during different points in history and under a range of climate change scenarios. Table 7 lists various flow scenarios, beginning with the 20th century average (1906 – 1999) of Colorado River water flows at Lee Ferry. This scenario acts as a baseline and is reported by the Bureau of Reclamation, which noted the River had an average naturalized flow of 15.2 million acre-feet at Lee Ferry.[78] The naturalized flow can be thought of as the amount of water that would flow through the Colorado River at Lee Ferry if no human activity affected it.

Each subsequent row represents a different climate change flow reduction scenario, calculated as a percent decrease from the 20th century average baseline. Column A.2 shows what the naturalized flow of the River would be under the scenario as measured at Lee Ferry. The water flow scenarios established in Table 7 are the same throughout the entire report.

The scenario titled "21st Century Average" shows the Bureau of Reclamation estimates of naturalized flows at Lee Ferry for the 2000 to 2018 period. According to the Bureau, the River had a flow of just 12.4 million acre-feet, a roughly 19 percent decrease from the baseline period of the 20th Century Average.[79]

This scenario demonstrates that climate change is already impacting the Colorado River Basin and that previous estimates of less significant flow declines, like the Bureau's 2012 climate modeling estimate of approximately a 9 percent water flow decrease,[80] have already been surpassed. Underestimating the scope of climate change and its impacts on reservoir and flow levels and is fraught with danger.

Table 7 Colorado River water flow reduction scenarios. Each scenario is calculated as a percent decline from the 20th century average (1906 - 1999).

**Table 7.
Colorado River Water Flow Reduction Scenarios**

A. Water Flow Scenario	
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry
20th Century Average (1906-1999)	15.2
5% Decrease	14.4
10% Decrease	13.7
15% Decrease	12.9
21st Century Average 19% Decrease	12.4
20% Decrease	12.2
25% Decrease	11.4
30% Decrease	10.6
35% Decrease	9.9
40% Decrease	9.1

Figure 6 demonstrates this fact by comparing the Bureau's projections of Lake Powell's elevation level – which the Bureau made using their 2012 climate model – to the observed levels of Lake Powell. The Bureau's original projections for Lake Powell comes from Figure G-4 of the 2012 Colorado River Basin Water Supply & Demand Study,[81] while observed Lake Powell levels were collected from the Bureau's online data portal.[82] Figure 6 shows that actual levels in Lake Powell decline much more quickly than the Bureau projected in 2012. This matches up with recent observations of Lee Ferry flows, which have also declined much faster than predicted.

While in theory one could argue that the Colorado River Basin is experiencing an anomalous drought period and flows could increase again in the future, peer-reviewed published science suggests this is unlikely. Numerous studies demonstrate that this century's exceptionally dry period is a result of climate change[83] and that we can expect similar and even drier conditions in the future as air temperatures continue to increase and snowpacks continue to decrease.[84] Therefore, of all the scenarios listed in Table 7, those showing a 19 percent decrease or greater should be considered a likely minimum long term future with less water.

Figure 6. 2012 Bureau of Reclamation Lake Powell Forecast vs. Reality

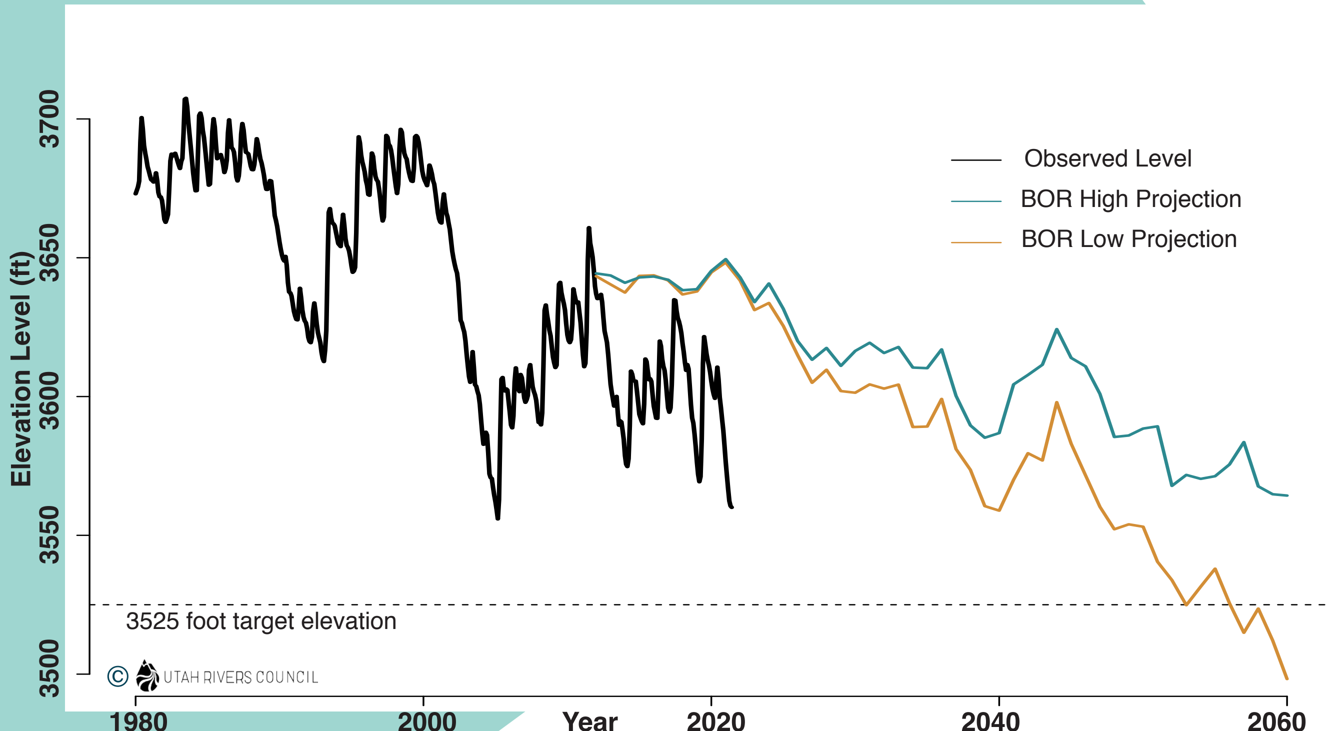


Figure 6. 2012 Bureau of Reclamation projections of Lake Powell levels compared to observed levels. The Bureau's 2012 projections were based on their 2012 climate modelling, which projected long-term Lee Ferry flow reductions of roughly 9 percent. The faster-than-expected decline of Lake Powell demonstrates how quickly flows in the Colorado River System have declined.

Failing to plan for a future with significant flow declines, of up to 40 percent or more, poses substantial risks. If a very-low-flow future materializes, as currently observed trends suggest it may, and little or nothing has been done to prepare for it, water managers and Colorado River water users will be forced to scramble by adopting sub-optimal policies to deal with the crisis. It is much safer and more responsible to consider and prepare for a very-low-flow future now, while we still have time to implement smart and effective adaptation strategies.[85]

Upper Basin Water Allocation Under the Law of the River

Over the last 100 years, the seven states of the Colorado River Basin alongside Mexico and the Native American Tribes of the region have entered into a series of agreements and been party to court decrees that collectively dictate how Colorado River System water is to be shared. This collection of agreements and court rulings is referred to as the Law of the River, and the working understanding of how water and water reductions are shared is an evolving reality as new agreements are made and past litigation is resolved.

There are many aspects of the Law of the River that are either very nuanced or still unsettled, which other scholars have explored in depth.[86] This report's goal is to provide the reader with a working understanding of the provisions that detail how the Upper Basin and the states in the Upper Basin receive their water.

One of the most important provisions in the Law of the River is Article III(d) of the 1922 Colorado River Compact. It mandates that the Upper Basin

> ***"will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years."***

This means that the Upper Basin should deliver on average 7.5 million acre-feet per year to the Lower Basin.[87] There is some debate over the legal specifics of this provision, as the 1922 Compact does not make clear what obligation the phrase "will not cause … to be depleted" actually carries. It is generally accepted that the Upper Basin needs to deliver an average of 7.5 million acre-feet per year to the Lower Basin states to be in compliance with the 1922 Compact.[88] It has been the general practice of the Upper Basin and the Bureau of Reclamation to deliver at least this amount to the Lower Basin.

The 1944 treaty between the United States and Mexico established that Mexico would receive 1.5 million acre-feet of water from the Colorado River.[89] Furthermore, the 1922 Compact established that – should the United States at some point make an agreement with another nation about sharing Colorado River water (like the 1944 treaty with Mexico) – that water would be supplied to that nation first from any "surplus" and then, in the absence of a surplus, equally from the Upper and Lower Basin.[90] Since Mexico's total allotment is 1.5 million acre-feet, in the absence of a surplus, the Upper and Lower Basin would presumably be responsible for delivering 750,000 acre-feet from each Basin.

What counts as "surplus" and what each Basin's obligation to meeting Mexico's right is a source of debate,[91] the specifics of which are complex and outside the scope of this report. However, the upshot is that some institutions in the Upper Basin typically claim that they are not obligated to deliver an annual amount to Mexico, while some institutions in the Lower Basin claim the opposite.[92] This issue has not yet been settled.

To cover all potential interpretations of the Law of the River on this point, we conducted two analyses: one where the Upper Basin is required to deliver 750,000 acre-feet per year to Mexico; and one analysis where the Upper Basin states are not required to deliver any water to Mexico. The results of both analyses can be found in the appendix. Table 8 on page 28 shows the values in Column B2 of the Upper Basin's water delivery obligations to Mexico.

Finally, the 1948 Upper Colorado River Basin Compact established that Arizona, who has a small portion of land in what is classified as the Upper Basin,[93] is entitled to 0.05 million acre-feet (or 50,000 acre-feet), and that Arizona shall receive their 0.05 million acre-feet before the Upper Basin states.[94] Column B3 of Table 8 on page 28 shows this water delivery obligation to Arizona.

After the delivery to the Lower Basin and Mexico have been met, and Arizona has taken their 50,000 acre-feet of water, the Upper Basin states are entitled to use the water remaining in the Colorado River.[95] These provisions can be expressed in terms of an equation, as shown here.

As one can see from the 21st century average of Colorado River flows, the four Upper Basin states and their respective Tribes[96] are currently afforded roughly 4.088 million acre-feet of Colorado River water, as shown in column B4, for the 21st Century Average. Furthermore, under a 40 percent decrease in naturalized flows at Lee Ferry, the Upper Basin water apportionment drops to just 0.82 million acre-feet. This quantification makes obvious that reductions in Colorado River flows significantly deplete the amount of water afforded to the Upper Basin.

$$\text{Upper Basin Apportionment} = \text{Annual Flow of the Colorado River} - \left(\text{Delivery to Lower Basin} + \text{Delivery to Mexico} + \text{Arizona's Upper Basin Right}\right)$$

$$\text{Column B4} = \text{Column A2} - \left(\text{Column B1} + \text{Column B2} + \text{Column B3}\right)$$

It is relatively easy to subtract the Upper Basin's obligations to ascertain the Colorado River water supply remaining to the Upper Basin states as a function of various climate change scenarios. Table 8 on page 28 shows the amounts of Colorado River System water available to the Upper Basin after delivery obligations are met under various climate scenarios.

Table 8.
Upper Basin Delivery Obligations and Leftover Water Amount

A. Water Flow Scenario		B. Colorado River Compact & Treaty Obligations			
1. Flow Reduction of the Colorado River at Lee Ferry	**2. Naturalized Flow at Lee Ferry**	**1. Lower Basin Delivery per 1922 Compact**	**2. Mexico Delivery per 1944 Treaty**	**3. Arizona Upper Basin Right per 1948 Compact**	**4. Upper Basin Apportionment**
20th Century Average (1906-1999)	15.2	7.5	0.75	0.05	6.900
5% Decrease	14.4				6.140
10% Decrease	13.7				5.380
15% Decrease	12.9				4.620
21st Century Average 19% Decrease	12.4				4.088
20% Decrease	12.2				3.860
25% Decrease	11.4				3.100
30% Decrease	10.6				2.340
35% Decrease	9.9				1.580
40% Decrease	9.1				0.820

Table 8 shows the water delivery obligations in columns B.1, B.2, and B.3. Column B.4 shows the quantity of water available to the Upper Basin after all water deliveries are satisfied under a range of climate change scenarios. This latter water volume is also called the Upper Basin Apportionment.

Comparing Current and Future Upper Basin Water Use to Projected Allocations

The final step in the analysis is to compare the Upper Basin's current and projected consumptive water use amount to their projected apportionment under various climate change scenarios. In other words, now that we know the amount of water available to the Upper Basin as per the Law of the River, the next step is to ascertain how much water the Upper Basin states are using. These calculations are shown on Table 9 on page 30. In terms of an equation, this looks like the following:

Upper Basin Surplus or Deficit = Upper Basin Apportionment - Upper Basin Use

Estimates used to determine current Upper Basin use come from data assembled by the Bureau of Reclamation. The Bureau reports Upper Basin consumptive uses, including evaporative losses from large, shared reservoirs (Lake Powell, Flaming Gorge, Morrow Point, and Blue Mesa). From 2016 to 2018, consumptive use and evaporative losses in the Upper Basin averaged about 4.59 million acre-feet.[97] This amount is listed in column C1.

As we observe from Table 9, under the 21st century Average Flow level of 12.4 million acre-feet, the Upper Basin is entitled to roughly 4.088 million acre-feet of water per year. After subtracting 4.59 million acre-feet of current Upper Basin water use, the Upper Basin has a deficit of about 0.50 million acre-feet (500,000 acre-feet), as shown in C2. In other words, the four Upper Basin States of this region are collectively using more Colorado River than they are afforded by the Law of the River.

Additionally, numerous Tribes in the Upper Basin hold substantial rights to deplete Colorado River water, some of which have yet to be put to use.[98] Other Tribes in Upper Basin have water rights that have yet to receive legal recognition.[99] If these Tribes start using their full Colorado River rights, consumptive water use in the Upper Basin could increase by roughly 0.44 million acre-feet (440,000 acre-feet) to a future total use of 5.04 million acre-feet for the entire Upper Basin.[100] This amount is shown in column C3. Factoring Tribal water use into current use increases the Upper Basin's current deficit to 0.947 million acre-feet (947,000 acre-feet), as shown in C4.

This analysis makes clear that declining Lee Ferry flows threaten the security of the Upper Basin's water supply. If flows continue to decrease, the Upper Basin could be forced to curtail their use of Colorado River water to avoid taking more water than they are entitled to. This is especially true if Tribes in the Upper Basin fully develop their water rights, as they intend to do.

Table 9. Upper Basin Use for Various River Flow and Consumptive Use Scenarios

A. Water Flow Scenario		B. Colorado River Compact & Treaty Obligations	C. Upper Basin Use			
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	4. Upper Basin Apportionment	1. Total Upper Basin Use	2. Surplus (Deficit)	3. Total Upper Basin Use w/ Full Tribal Rights	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	6.900	4.592	2.308	5.035	1.865
5% Decrease	14.4	6.140		1.548		1.105
10% Decrease	13.7	5.380		0.788		0.345
15% Decrease	12.9	4.620		0.028		(0.415)
21st Century Average 19% Decrease	12.4	4.088		(0.504)		(0.947)
20% Decrease	12.2	3.860		(0.732)		(1.175)
25% Decrease	11.4	3.100		(1.492)		(1.935)
30% Decrease	10.6	2.340		(2.252)		(2.695)
35% Decrease	9.9	1.580		(3.012)		(3.455)
40% Decrease	9.1	0.820		(3.772)		(4.215)

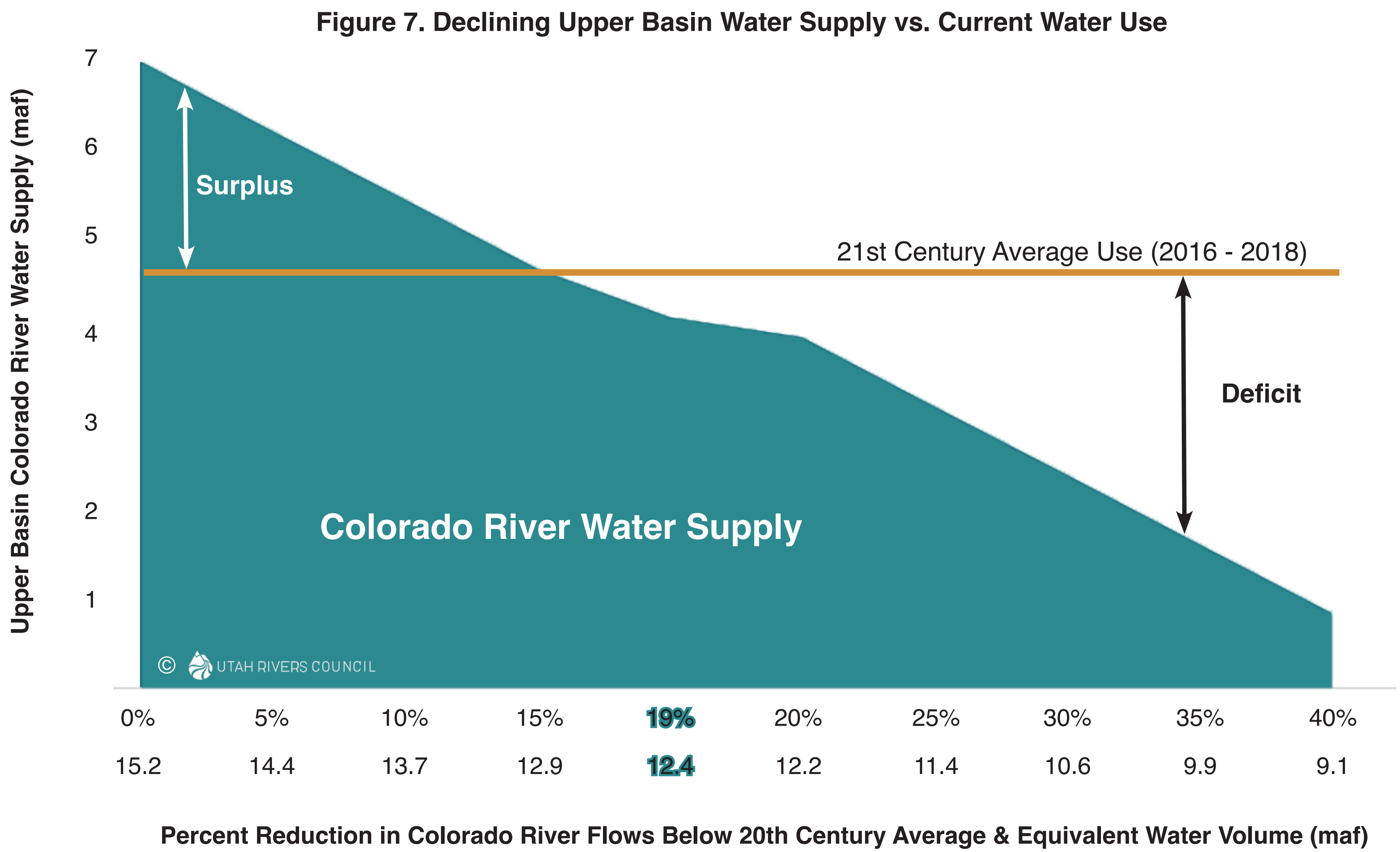


Figure 7. The Upper Basin's Colorado River water supply is projected to decline rapidly as climate change further depletes the flows of the Colorado River, quickly outpacing the Upper Basin's current Colorado River use. Action needs to be taken soon to decrease the Basin's use to keep the Basin from using more water than allowed.

Effects of Climate Change on the Upper Basin's Colorado River Allocation Observations

- The Upper Colorado River Basin is entitled to the amount of water leftover after deliveries to the Lower Basin, Mexico and other parties have been met, although there is some dispute over whether the Upper Basin is required to deliver water to Mexico or not.

- Declining flows of the Colorado River at Lee Ferry shrink the amount of water the Upper Basin is entitled to. This analysis shows that under 21st century average conditions, the Upper Basin is entitled to 4.1 million acre-feet. That could shrink to 0.8 million acre-feet if Colorado River flows decline 40 percent, a shocking prospect.

- If water use levels stay the same, the Upper Basin could face a deficit of 500,000 acre-feet under current 21st century average water flow levels. This deficit could grow to 950,000 acre-feet if Tribes in the Upper Basin fully develop their water rights and assuming that climate change does not further reduce the Colorado River water supply.

- If one assumes that climate change will continue shrinking the Colorado River this century, the Upper Basin water supply will shrink to dangerously low water levels, especially after a 30 percent reduction in river flows.

Effects of Climate Change on State Allocations in the Upper Colorado River Basin

The analysis of water availability described in the previous sections makes clear that the Upper Basin as a whole will have its water apportionment squeezed as Colorado River flows decline. This is because decreasing the flows of the Colorado River reduces the water afforded to each Upper Basin state, as the states are guaranteed only a percentage of the River's "leftover" water – after deliveries to the Lower Basin, Mexico, and other parties have been made.

In this section we take this analysis a step further by considering each individual state in the Upper Basin (Colorado, Utah, Wyoming, and New Mexico) to determine how their individual Colorado River allocations could be affected by projected decreases in Lee Ferry flows.

Since the methodology applied to each state in this section is identical, we chose to use Utah and its rights to Colorado River System water in the face of declining water flows to explain our analysis. However, each Upper Basin state has a similiar methodology, albeit a different percentage allocation to Colorado River System water. Results for each Upper Basin state can be found in the appendix.

How Upper Basin States Divide the Upper Basin Apportionment

Narrowing the Upper Basin's water apportionment to each Upper Basin state is straightforward since the 1948 Upper Basin Colorado River Compact established how water would be shared among the four states. Each Upper Basin state receives a percentage of the "leftover" water after all Lower Basin, Mexico, and other party delivery requirements are satisfied. Colorado is entitled to 51.75 percent, Utah to 23 percent, Wyoming to 14 percent, and New Mexico to 11.25 percent.[101] Finding any Upper Basin state's water allocation is simply a matter of multiplying the percentage for that state's share times the Upper Basin's apportionment under each Lee Ferry flow scenario:

Utah's Allocation = 23% X Upper Basin Apportionment

Table 10 shows Utah's allocation for the various climate change flow reduction scenarios. It is worth noting that Table 10 assumes that the Upper Basin is required to deliver 0.75 million acre-feet of water to Mexico each year, which is in dispute. One analysis was modeled assuming that the Upper Basin needs to deliver water to Mexico, and a second analysis was modeled assuming that no such delivery is required. The results of these analyses are presented individually in the appendix.

Table 10. Utah Allocation of Colorado River Water

A. Water Flow Scenario		B. Colorado River Compact & Treaty Obligations	D. Allocation
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	4. Upper Basin Apportionment	1. Ute, Navajo & Utah Allocation (23%)
20th Century Average (1906-1999)	15.2	6.900	1.59
5% Decrease	14.4	6.140	1.41
10% Decrease	13.7	5.380	1.24
15% Decrease	12.9	4.620	1.06
21st Century Average 19% Decrease	12.4	4.088	0.94
20% Decrease	12.2	3.860	0.89
25% Decrease	11.4	3.100	0.71
30% Decrease	10.6	2.340	0.54
35% Decrease	9.9	1.580	0.36
40% Decrease	9.1	0.820	0.19

Table 10 shows that if Colorado River flows at Lee Ferry remain at the 21st Century Average level of 12.4 million acre-feet, then Utah's allocation would be 0.94 million acre-feet (940,000 acre-feet). In other words, if climate change's impacts in reducing the snowpacks of the Colorado River Basin do not worsen more than has been observed over the last 20 years, Utah and the sovereign Tribes living within its borders may use 940,000 acre-feet of water each year. This calculation is based on the agreements that Utah and all other Colorado River Basin states have entered into as described above, which are part of the Law of the River.

One important aspect of this table that merits a special note is that each state in the allocation portion of the table is named by all water users in that geographic area. This is done in an effort to draw attention to Native American Tribes, who generally hold the most senior rights to water in any Upper Basin state and are as (or more) entitled to the water apportioned to any particular state as the government of the state itself.[102] Therefore, the names are listed by including both the Tribes of that state and the state itself. For example, Utah's allocation is not listed simply as "Utah" but as "Ute, Navajo & Utah Allocation."

Table 10. Utah's share of Colorado River water for various climate change scenarios.

Comparing Current and Future Upper Basin State Water Use to Projected Allocations

The final step in the state-level analysis is to compare each Upper Basin state's current and future expected Colorado River consumptive use to their projected allocation. This will determine whether the state has a surplus or deficit of Colorado River water. Table 11 demonstrates this analysis for Utah.

The portion of Table 11 entitled, E. Current Use, shows how Utah currently uses its Colorado River water. The Bureau of Reclamation tracks each Upper Basin state's consumptive use figures and reports it in the *Provisional Upper Colorado River Basin Consumptive Uses and Losses Report*.[103] The current use amount is taken directly from that report.

The Bureau of Reclamation also estimates the total amount of water lost to evaporation from the four large, shared Colorado River reservoirs in the Upper Basin (Lake Powell, Flaming Gorge, Morrow Point, and Blue Mesa). This amounted to about 0.478 million acre-feet each year on average from 2016 to 2018.[104] Article V of the 1948 Upper Basin Colorado River Compact establishes that these losses should be split among the Upper Basin states and counted as part of that state's total consumptive use.[105] The State of Wyoming demonstrated how to do this in their State Water Plan for the Green River Basin.[106]

Our analysis follows the methodology established by the State of Wyoming and attributes each state a share of the 0.478 million acre-feet of evaporative losses by the percent of water that state is entitled to under the 1948 Compact. For Utah, this is 23 percent and is shown in column E2. Adding together the state's current consumptive use and their share of evaporative losses gets each state's total current consumptive use, shown in column E.3. The next portion of Table 11 entitled, F. Remaining Allocation w/ Current Use, shows whether the state has a surplus or deficit of Colorado River water. Values in black represent a surplus and values in red represent a deficit. This is calculated by subtracting the state's current total consumptive use from its allocation given a certain climate change scenario.

The portion of Table 11 labelled, G. Future Additional Use, shows what extra consumptive uses the state could develop in the future. The first category is column G.1, labelled "Unused Tribal Depletion Rights," which represents the amount of water Tribes in that state are allowed to deplete (or claim they are allowed to deplete if they have not yet settled their water rights) but are not yet using. This figure comes from the *Tribal Water Study Report*.[107] This additional use is added to the total current uses from column E.3 to create a projection of the state's future total consumptive use and is shown in column G2.

Column H. Remaining Allocation w/ Future Use, shows whether the state has a surplus or deficit of Colorado River water given their expected future consumptive use total.

Table 11 shows that Utah currently uses 1.09 million acre-feet (column E3) of Colorado River water (including the state's share of evaporative losses), a deficit of roughly 150,000 acre-feet over the 21st century average allocation as shown in column F4. The Navajo Nation and Ute Indian Tribe have rights and claims to an additional 188,000 acre-feet that they have yet to develop (column G1), which would bring Utah's total consumptive use to roughly 1.2 million acre-feet (column G2) and increase Utah's deficit to 340,000 acre-feet (column H4) if these Tribes fully develop their water rights and Utah does not reduce its use.

Table 11. Utah's Current and Future Colorado River Use

A. Water Flow Scenario		E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Natural-ized Flow at Lee Ferry	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	0.981	0.110	1.091	0.496	0.188	1.279	0.308
5% Decrease	14.4				0.321			0.133
10% Decrease	13.7				0.147			(0.041)
15% Decrease	12.9				(0.028)			(0.216)
21st Century Average 19% Decrease	12.4				(0.151)			(0.339)
20% Decrease	12.2				(0.203)			(0.391)
25% Decrease	11.4				(0.378)			(0.566)
30% Decrease	10.6				(0.553)			(0.741)
35% Decrease	9.9				(0.727)			(0.915)
40% Decrease	9.1				(0.902)			(1.090)

The Importance of Recognizing Tribal Water Rights in Utah

There are two main Native American Tribes in Utah with rights to the Colorado River: the Navajo Nation and the Ute Indian Tribe of the Uintah and Ouray Reservation. They are each some of the state's largest water rights holders, and because of a landmark Supreme Court decision referred to as the *Winters* doctrine, these Tribes are also some of the most senior water rights holders.[108]

Some communities have historically prevented Tribes from fully developing their water rights, either by withholding funding for water infrastructure, by failing to formalize tribal water rights, by revoking agreements made with Tribes, or by using their political power to pressure the tribes into inequitable deals.[109] In practice, this tactic has allowed states to coopt unused Tribal water and put it into development elsewhere. An attorney for the Quechan Indian Tribe, a Tribe in the Lower Basin, summarized this in a recent article by saying, "the basin is free-riding off of undeveloped tribal water rights."[110] This has created a number of issues for Tribes, including a decreased ability to build and sustain their own economies and in some cases, provide running water to tribe members. For example, over 40 percent of the households in the Utah portion of the Navajo Nation lack access to running water or adequate sanitation.[111]

The Navajo Nation recently finalized a water rights agreement with the State of Utah, guaranteeing the Tribe the ability to deplete 81,500 acre-feet of water per year.[112] Currently, the Navajo Nation depletes about 14,000 acre-feet, meaning they can and will increase their Colorado River depletions by 68,000 acre-feet in the future.[113]

Similarly, the Ute Indian Tribe of the Uintah and Ouray Reservation has a large amount of Colorado River depletion rights. The Ute Tribe is currently using roughly 130,000 acre-feet of water, and has a claim to use an additional 120,000 acre-feet, although Utah has thus far failed to fully recognize the Tribe's claim, forcing the Tribe to litigate the issue.[114] Certain aspects of the Tribe's case are still being heard in court.

Altogether, this means that the Tribes plan to develop an additional 188,000 acre-feet of Colorado River water. However, as shown Table 10, Utah is already using its full Colorado River allocation, meaning that there is not an excess 188,000 acre-feet of wet water to fulfill the Tribes' water rights. This means that as the Tribes develop their water rights, Utah water users will have to "make way" and reduce their water use to free up enough wet water to fulfill the Tribes' water rights.

Any efforts by Utah to impede or prevent the Tribes from developing their rights could constitute a violation of the state's own agreements, of the Tribes' sovereignty, and in some instances of peoples' fundamental human right to clean water and adequate sanitation.

Effects of Climate Change on Individual Upper Basin States' Allocations of the Colorado River Observations

- Declining Colorado River flows are shrinking the size of individual Upper Basin states' water allocations.
- Utah's current estimated allocation given 21st century average flows is 940,000 acre-feet but could drop to as little as 190,000 acre-feet if flows decline 40 percent.
- Under current river flow and use levels, Utah uses 150,000 acre-feet more water from the Colorado River than they are allocated. This could grow to a deficit as large as 340,000 acre-feet if the Tribes inside Utah fully develop their water rights.

The Danger to the Upper Basin of Exceeding its Colorado River Allocation

Declining Colorado River flows could push states in the Upper Basin to use more water than they are allowed under the Law of the River unless they decrease their use of water to compensate for reduced water supplies. If an Upper Basin state uses more Colorado River water than allowed, that state could have its water use forcibly reduced via the curtailment provision of the 1948 Upper Colorado River Basin Compact.

Article III(d) of the 1922 Colorado River Compact established that the Upper Division states "will not cause the flow of the river at Lee Ferry to be depleted below an aggregate of 75,000,000 acre-feet for any period of ten consecutive years…"[115] In other words, the 1922 Compact mandates that the Upper Basin states deliver at least 75 million acre-feet of water every ten years to the Lower Basin.[116] In the event that this does not occur, the Lower Basin states can issue a compact call, in which they mandate that the Upper Basin deliver their agreed upon water allotment at Lee Ferry.[117]

The Upper Basin states all agreed on a method for dealing with a potential compact call in Article IV of the 1948 Upper Colorado River Basin Compact when they set out the terms of "curtailment."[118] Curtailment is the name given to the process of determining how much each Upper Basin state needs to reduce its use to satisfy the Lower Basin's compact call.

There are two tiers to the curtailment system established by the 1948 Compact. Under the first tier, states who have used more Colorado River water than they were legally allocated will be required to reduce their water use.[119] By overusing its legal Colorado River allocation, a state opens itself up to a first tier reduction.

If the first tier does not produce enough water to meet the Lower Basin's compact call (i.e. if Upper Basin states' water reductions are not sufficient to get the Upper Basin to their required 75 million-acre-foot delivery amount), then a second tier of curtailment is initiated. The second tier reduces water from all Upper Basin states in a manner proportional to their use of water, although the legal specifics of how the second tier would be implemented remain unclear.[120] The upshot is that under this scenario, a state could have to reduce its Colorado River water use even further.

Stated more simply, the 1948 Compact makes clear that states who overuse their water allocation will face water reductions first and will likely also take the largest water reductions. There is one important exception to this rule. The 1948 Compact states that any water right with a priority date of November 24th, 1922 or older cannot be reduced via curtailment.[121] These pre-compact rights are protected, making them particularly valuable.

Therefore, by using more water than allowed from the Colorado River, a state places itself in a risky position. If a curtailment is initiated, that state will be one of the first states to take water reductions. It may also take some of the largest water reductions.

There are two potential ways that water reductions could be administered in any given state under a curtailment scenario. The first method is to reduce water use based on the seniority of a state's water right priority system. Western water rights are administered on a first-in-time, first-in-right priority basis with the senior water rights holders having the most secure water rights. Under this system, water would be removed from junior rights holders first, and senior rights holders last.

However, the Law of the River does not require that water reductions in any given state occur via the priority system. The way in which a state reduces its water use is left up to that individual state, so long as it does not affect pre-1922, protected rights. In theory, states could simply compel Colorado River water users to reduce their water withdrawals from the Colorado River, regardless of the seniority of their water rights. Under this method, water reductions would become political decisions, likely targeting those water users with the least amount of political sway.

Under either scenario, agriculture would likely face pressure to reduce its water use. This is because agriculture is by far the largest user of Colorado River water in the Upper Basin, using about 65 percent of all of the Upper Basin's Colorado River water.[122] Most agricultural water users have senior water rights compared to young suburbs, as agriculture was among the first major industries to intensively develop and use water in the Colorado River Basin, making their rights particularly valuable, especially if they were established before 1922.

Generally, municipal and industrial water users have more junior water rights than agricultural users as many cities were built after agricultural operations were established. This means that municipal water users, particularly in relatively new suburbs, are more vulnerable during a curtailment scenario based on water rights seniority. Given this setup, and given how quickly flows in the Colorado River at Lee Ferry are declining, cities are becoming more concerned about the security of their own water. Although still somewhat taboo, tentative first steps have started to develop "buy and dry" programs, where cities pay farmers to not plant crops and instead allow their water to flow downstream to municipal users.

Wall Street and private investors have also started to pick up on the trend, and are quickly recognizing the increasing value water possesses in the climate change stricken West. In Arizona, GSC Farm LLC bought the rights to a little over 2,000 acre-feet of agricultural water near the rural community of Cibola, then sold half of it to a fast-growing Phoenix suburb for several million dollars.[123] The sale was permitted by the state and bemoaned by residents of Cibola, who felt like the state had given away their livelihood.[124]

As climate change continues to deplete flows and as the possibility of curtailment becomes more threatening, pressure will mount on the Upper Basin's largest water users (farmers) to sell their valuable water rights. This could lead to significant loss of farmland, which would have negative economic and cultural impacts to the Basin, especially on rural communities.

In 2020, the American Farmland Trust examined and scored each state's policy response to farmland conversion pressures. None of the Upper Basin states received a higher score than 32 out of 100, indicating that there are major opportunities to update existing poor policies to protect farms.[125] Unless action is taken to protect farms, mounting pressure from water overuse and declining flows could lead to a significant loss of farmland.

The Danger to the Upper Basin of Exceeding the Colorado River Allocation Observations

- Overusing a state's Colorado River allocation opens that state up to curtailment, where its water allocation would be forcibly reduced.
- If curtailment occurs, states could either reduce water use according to their pre-established water right priority system or through a political decision-making process.
- If water use is reduced based on water right seniority, junior users – typically suburban municipal users – would be most at risk. If water use is reduced via political decisions, water users with the largest shares of water and least amount of political power, like farmers and tribes, may be at most risk.

Curtailment Survival Guide

The Upper Basin Can Lessen Curtailment Impacts by Getting Smart

Here are five lessons that Upper Basin water leaders and elected officials can implement from successful water programs in other parts of the country and from across the globe. The sooner this work begins, the less impacting it will be on the communities relying upon Colorado River water to adapt to water cuts in the future.

Lesson 1. Get serious about flow declines.

Water leaders in the Upper Colorado River Basin need to develop river and water management plans to deal with our low-flow future. These states must recognize that climate change is having real impacts on the Colorado River right now and flows may not return to 20th century levels for many decades or more. The time of crossing one's fingers and hoping for a big winter to solve our problems is over.

Proposals and policies that fail to recognize this new reality jeopardize all water users, particularly inside any state that lags behind in accepting reality. Much of the Colorado River Basin has failed to plan for this low-flow future. Over the past 21 years, Colorado River reservoirs have dropped from being 94% full in the year 2000 to being 48% full today.[126] Yet many water leaders and elected officials fail to "believe" that climate change is real and/or see little need to ask themselves how future water supply declines will impact their constituents.

Climate change is creating a new normal of low-flows, and states need to develop plans to address this future. The Basin's reservoirs are simply a savings account and water users and their state leaders need to recognize that our income, or water flows, are in long-term decline.

Lower Basin water suppliers have been producing climate studies evaluating future declines to the Colorado River water supplies for the last two decades. Yet in the Upper Colorado River Basin, relatively few water suppliers have produced their own climate studies which quantify future reductions to their water supplies from shrinking snowpacks. This demonstrates some of the negligence in protecting water users through simple bias against climate science. Water leaders who fail to embrace basic science around water supply declines should be replaced with leaders willing to work with open minds to listen to the public and protect their own water users.

The Colorado River at Lake Powell from Hite Bridge, showing the dropping reservoir water levels from the turn of the century to today. The decline in Lake Powell over the last 20 years is as a function of shrinking snowpacks in the headwaters of the Colorado River Basin from climate change. Some Upper Basin stakeholders blame reservoir declines on Lower Basin users while others simply refuse to acknowledge the role of shrinking snowpacks from increased winter air temperatures.

Lesson 2. New Water Uses Threaten Existing Water Users.

Since the Colorado River water supply is declining and most Upper Basin states are using more than their share of Colorado River water, each new diversion pushes the Upper Basin closer to the curtailment cliff, requiring its people to reduce their water use. New water uses in a declining water system also create major equity issues, as curtailment affects many water users. Existing water users may end up having to reduce their water use even though they did not trigger curtailment. Stated simply, new water diversions threaten to sink the entire ship, bringing down everybody else onboard.

Water reductions under a curtailment scenario could either be doled out according to the state's water rights priority system[127] – where junior water rights holders have to reduce their use before senior rights holders do – or by some other process where a state decides who has to reduce use. In this latter scenario, water cuts become decisions subject to the same political pressures as any other state policy matter.

If water cuts are decided by a political decision-making process, it's possible that a state decides that a new water diversion is more important than a venerable use of water for a city or farm. This would be especially true for projects where the state is financially incentivized to keep water flowing to repay taxpayers who pay for these bad ideas.

Utah's proposed Lake Powell Pipeline provides a good example of a bad idea threatening other water users. The project is slated to cost $2 – 3+ billion, and Utah taxpayers will carry the project debt for many decades.[128] The plan is to raise funds for the project with 500% increases in water rates, alongside major impact fee and property tax increases among the water users of the Washington County Water District (WCWD).[129]

Utah taxpayers will be on the hook for billions of dollars of debt and dependent on Lake Powell Pipeline water sales to be repaid for this debt. When curtailment occurs, the State of Utah could be incentivized to not reduce Lake Powell Pipeline water deliveries, as that would reduce water sales revenue and leave taxpayers holding more debt.

New diverters of water may seek to insulate themselves from curtailment impacts through traditional lobbying efforts. The WCWD has spent over $1.7 million on lobbyists[130] and has secured a number of legislative victories for itself, including a seat on the five-member Colorado River Authority of Utah even though this water district isn't using any of Utah's share of Colorado River water today.[131] In a curtailment scenario, the WCWD may be better poised to protect its new water uses from the Lake Powell Pipeline, over other senior water rights holders inside Utah because of the WCWD's lobbying influence.

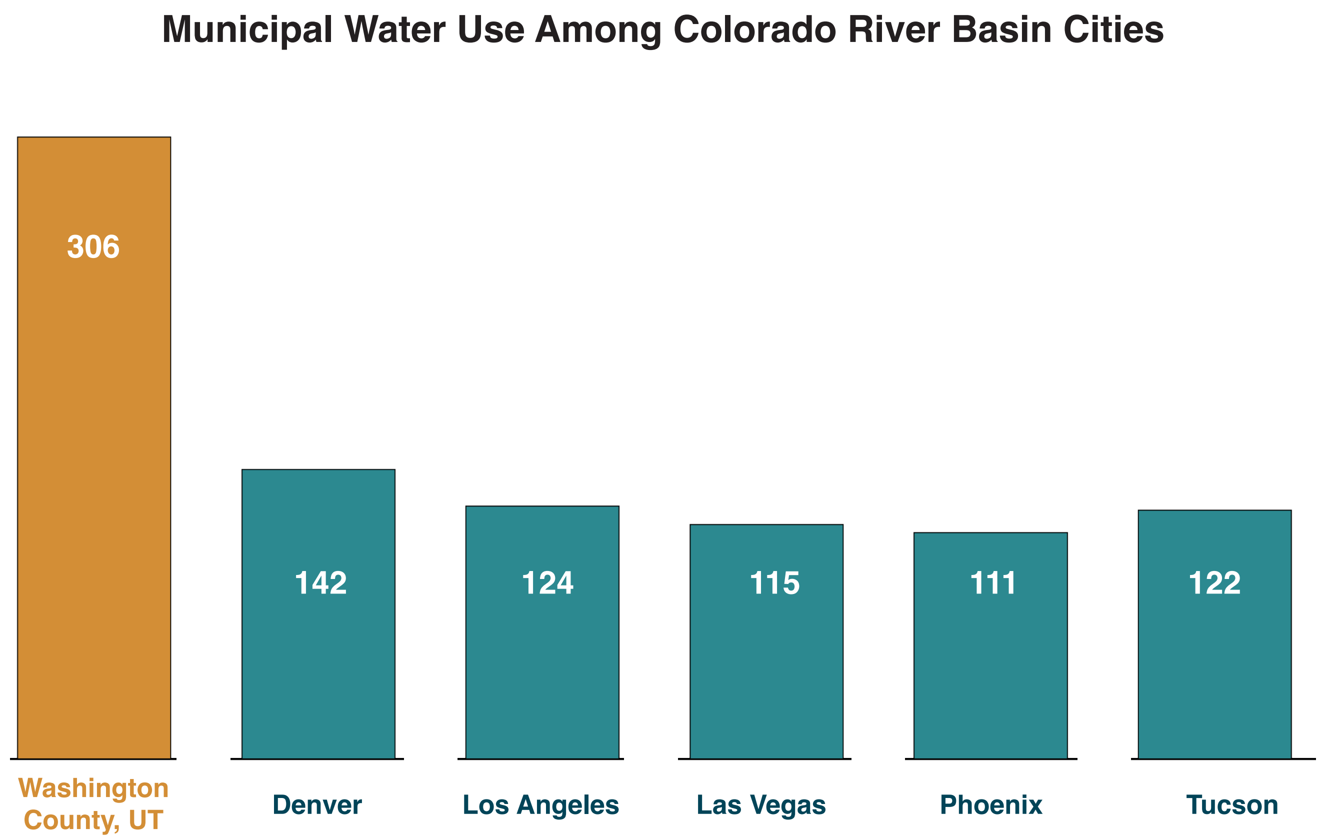


Figure 8. Water users in Washington County, Utah who are slated to receive water from the proposed Lake Powell Pipeline, use 2-3 times the per person water use of other Colorado River Basin residents. Data taken from 2020 Lake Powell Pipeline DEIS, Bureau of Reclamation and individual cities.

Lesson 3. Improving Agricultural Water Efficiency is the Key to Protecting Agriculture's Future.

Agriculture uses a majority of the water in the Colorado River Basin and in virtually every Colorado River Basin state.[132] Since it is diverting the lion's share of water from the Colorado River, agriculture is facing pressure to discontinue its operations and this pressure will only increase as water flows continue to decline. New technologies and practices can greatly reduce agricultural water use,[133] but are typically too costly for independent operators to implement on their own.[134]

Capital-sharing programs must be advanced where farmers can update archaic canal systems in exchange for water-sharing agreements. These agreements should be created through the leadership of elected officials who are essential to mediating conflict among different classes of users. Trial runs of such programs have so far shown promise and generated water savings at a reasonable cost.[135] While legitimate concerns exist surrounding these programs,[136] improving irrigation infrastructure and conserving surplus water is preferable to buying and drying farmland.

This unlined irrigation canal in Southern Colorado is one example of the old infrastructure Colorado River Basin farmers rely on to produce their crops. This type of infrastructure is inefficient and, if updated, could save significant quantities of water. Photo by Jeffrey Beall

Lesson 4. Urban Water Conservation & Efficiency is the Future for Cities.

Colorado River Basin cities must find ways to make their water use more efficient in a low-flow future to ease the burdens of curtailment. With much of the urban American West constructed in relatively-new suburbs, these often-junior water rights holders will pay more for water in the future as the Colorado River Basin water supply shrinks. This is one of many reasons why cities should take proactive steps to reduce water demand through efficiency and conservation measures that are actually meaningful.

There are an array of water demand and water efficiency measures which have been well-documented by credible water suppliers and institutions across the world. Numerous studies have been conducted that evaluate the most effective methods to reduce water use,[137] including ones focused on the Upper Basin specifically.[138] These strategies provide Upper Colorado River Basin states with tools to reduce their water use, which is essential to lessening the effects of curtailment. But reducing water use should be measureable, and feel-good marketing campaigns may not substitute for transparency when it comes to demonstrating water use reductions through conservation and efficiency programs.

Systemic water waste in Salt Lake City, Utah. Salt Lake City residents use roughly 100 more gallons of water than Denver residents each day. Although the marketing of water conservation to residents is a useful education tool, water efficiency programs based solely on marketing lack the effectiveness of more comprehensive programs which include pricing and incentivizes to reduce water waste. Photo by EP Kosmicki

Lesson 5. Elected Officials Need to Design & Incentivize Water-Sharing Instruments Between Water Users.

Water rights in the American West are structured in a way that incentivizes waste.[139] The "use it or lose it" principal of prior appropriation creates a disincentive to reducing water use on a farm or in a city. This provision creates a perverse incentive where water users are encouraged to waste and hoard water to protect their water rights.[140] This has led many water conservation efforts by municipal water suppliers to at-times be more marketing hype than substance. Reducing water use must be translated into sharing water supplies between users, otherwise no real water savings benefits may accrue.

These perverse incentives significantly harm the rivers and aquatic ecosystems of the Basin. Existing policies designed to protect rivers, such as instream flow laws are often weak or nonexistent, such as inside Utah.[141] A river's need for water is often ignored or considered only after all other water users have had their fill. Elected officials must solve these problems by creating incentives which encourage both urban and agricultural water hoarders to share their water supplies. Cities should share their water supplies with other cities, particularly when a municipal water right portfolio greatly exceeds the needs of its current and future population. Farmers and canal companies should be incentivized to share their water surpluses to avoid greater impacts from curtailment situations. These systems should be established to secure water for rivers and ecosystems.

Appendix A. Total Upper Basin Colorado River Water Budget

Table 12 describes the Colorado River water budget for the entire Upper Basin under different flow reduction scenarios, assuming the Upper Basin is required to deliver water to Mexico. Since the delivery to Mexico is in dispute, another analysis was run assuming no delivery to Mexico is required, the results for which are in Table 13.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Columns B.1 – B.4 describe the Upper Basin's delivery obligations as per the Law of the River, and use the following equation, which is explained on pages 25-27:

Upper Basin Allocation = Natural Flow of the Colorado River – (Delivery to Lower Basin + Delivery to Mexico + Arizona's Upper Basin Right)

This equation can also be written using the column numbers from the table, as shown below:

B.4 = A.2 – (B.1 + B.2 + B.3)

Columns C.1 – C.4 employ consumptive use data from the Bureau of Reclamation and the Ten Tribes Partnership to compare Colorado River water use amounts to expected apportionments. This is done according to the following equation, which is explained on page 29:

Upper Basin Surplus/Deficit = Upper Basin Apportionment – Upper Basin Use

This can again be written using the column numbers from the table, as shown below:

C.2 = B.4 – C.1
C.4 = B.4 – C.3

This table shows that under the 21st Century Average flow scenario, the Upper Basin is using 504,000 acre-feet more water than allowed from the Colorado River (a deficit). If Tribes in the Upper Basin fully develop their water rights, this deficit could grow to 947,000 acre-feet.

Table 12. Upper Basin Colorado River Water Budget Including a Delivery to Mexico

A. Water Flow Scenario		B. Colorado River Compact & Treaty Obligations				C. Upper Basin Use			
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Lower Basin Delivery per 1922 Compact	2. Mexico Delivery per 1944 Treaty	3. Arizona Upper Basin Right per 1948 Compact	4. Upper Basin Apportionment	1. Total Upper Basin Use	2. Surplus (Deficit)	3. Total Upper Basin Use w/ Full Tribal Rights	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2				6.900		2.308		1.865
5% Decrease	14.4				6.140		1.548		1.105
10% Decrease	13.7				5.380		0.788		0.345
15% Decrease	12.9				4.620		0.028		(0.415)
21st Century Average 19% Decrease	12.4	7.5	0.75	0.05	4.088	4.592	(0.504)	5.035	(0.947)
20% Decrease	12.2				3.860		(0.732)		(1.175)
25% Decrease	11.4				3.100		(1.492)		(1.935)
30% Decrease	10.6				2.340		(2.252)		(2.695)
35% Decrease	9.9				1.580		(3.012)		(3.455)
40% Decrease	9.1				0.820		(3.772)		(4.215)

Appendix A. Total Upper Basin Colorado River Water Budget

Table 13 describes the Colorado River water budget for the entire Upper Basin under different flow reduction scenarios, assuming the Upper Basin is not required to deliver water to Mexico. This differs from Table 12, which assumes the Upper Basin is required to deliver water to Mexico.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Columns B.1 – B.4 describe the Upper Basin's delivery obligations as per the Law of the River, and use the following equation, which is explained on pages 25-27:

Upper Basin Allocation = Natural Flow of the Colorado River – (Delivery to Lower Basin + Arizona's Upper Basin Right)

This equation can also be written using the column numbers from the table, as shown below:

B.4 = A.2 – (B.1 + B.2 + B.3)

Columns C.1 – C.4 employ consumptive use data from the Bureau of Reclamation and the Ten Tribes Partnership to compare Colorado River water use amounts to expected apportionments. This is done according to the following equation, which is explained on page 29:

Upper Basin Surplus/Deficit = Upper Basin Apportionment – Upper Basin Use

This can again be written using the column numbers from the table, as shown below:

C.2 = B.4 – C.1
C.4 = B.4 – C.3

This table shows that under the 21st Century Average flow scenario, the Upper Basin is allowed to develop an additional 246,000 acre-feet of water from the Colorado River. But, if Tribes in the Upper Basin fully develop their water rights, the Upper Basin would use 197,000 acre-feet more water than allowed from the Colorado River.

Table 13. Upper Basin Colorado River Water Budget Without a Delivery to Mexico

A. Water Flow Scenario		B. Colorado River Compact & Treaty Obligations				C. Upper Basin Use			
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Lower Basin Delivery per 1922 Compact	2. Mexico Delivery per 1944 Treaty	3. Arizona Upper Basin Right per 1948 Compact	4. Upper Basin Apportionment	1. Total Upper Basin Use	2. Surplus (Deficit)	3. Total Upper Basin Use w/ Full Tribal Rights	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	7.5	0.00	0.05	7.650	4.592	3.058	5.035	2.615
5% Decrease	14.4				6.890		2.298		1.855
10% Decrease	13.7				6.130		1.538		1.095
15% Decrease	12.9				5.370		0.778		0.335
21st Century Average 19% Decrease	12.4				4.838		0.246		(0.197)
20% Decrease	12.2				4.610		0.018		(0.425)
25% Decrease	11.4				3.850		(0.742)		(1.185)
30% Decrease	10.6				3.090		(1.502)		(1.945)
35% Decrease	9.9				2.330		(2.262)		(2.705)
40% Decrease	9.1				1.570		(3.022)		(3.465)

Appendix B. Utah's Colorado River Water Budget

Table 14 describes the Colorado River water budget for Utah under different flow reduction scenarios, assuming the Upper Basin is required to deliver water to Mexico. Since the delivery to Mexico is in dispute, another analysis was run assuming no delivery to Mexico is required, the results for which are in Table 15.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Utah Allocation = 23% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, Utah is using 151,000 acre-feet more water than allowed from the Colorado River (a deficit). If Tribes in Utah fully develop their water rights, this deficit could grow to 339,000 acre-feet.

Table 14. Utah's Colorado River Water Budget Including a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Ute, Navajo & Utah Allocation (23%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	1.59	0.981	0.110	1.091	0.496	0.188	1.279	0.308
5% Decrease	14.4	1.41				0.321			0.133
10% Decrease	13.7	1.24				0.147			(0.041)
15% Decrease	12.9	1.06				(0.028)			(0.216)
21st Century Average 19% Decrease	12.4	0.94				(0.151)			(0.339)
20% Decrease	12.2	0.89				(0.203)			(0.391)
25% Decrease	11.4	0.71				(0.378)			(0.566)
30% Decrease	10.6	0.54				(0.553)			(0.741)
35% Decrease	9.9	0.36				(0.727)			(0.915)
40% Decrease	9.1	0.19				(0.902)			(1.090)

Appendix B. Utah's Colorado River Water Budget

Table 15 describes the Colorado River water budget for Utah under different flow reduction scenarios, assuming the Upper Basin is not required to deliver water to Mexico. This differs from Table 14, which shows the Colorado River water budget for Utah but assumes the Upper Basin is required to deliver water to Mexico.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Utah Allocation = 23% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, Utah is allowed to develop an additional 22,000 acre-feet of water from the Colorado River. But, if Tribes in Utah fully develop their water rights, the state would use 166,000 acre-feet more water than allowed from the Colorado River.

Table 15. Utah's Colorado River Water Budget Without a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Ute, Navajo & Utah Allocation (23%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	1.760	0.981	0.110	1.091	0.669	0.188	1.279	0.481
5% Decrease	14.4	1.585				0.494			0.306
10% Decrease	13.7	1.410				0.319			0.131
15% Decrease	12.9	1.235				0.144			(0.044)
21st Century Average 19% Decrease	12.4	1.113				0.022			(0.166)
20% Decrease	12.2	1.060				(0.031)			(0.219)
25% Decrease	11.4	0.886				(0.205)			(0.393)
30% Decrease	10.6	0.711				(0.380)			(0.568)
35% Decrease	9.9	0.536				(0.555)			(0.743)
40% Decrease	9.1	0.361				(0.730)			(0.918)

Appendix C. The State of Colorado's Colorado River Water Budget

Table 16 describes the Colorado River water budget for Colorado under different flow reduction scenarios, assuming the Upper Basin is required to deliver water to Mexico. Since the delivery to Mexico is in dispute, another analysis was run assuming no delivery to Mexico is required, the results for which are in Table 17.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Colorado Allocation = 51.75% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, Colorado is using 377,000 acre-feet more water than allowed from the Colorado River (a deficit). If Tribes in Colorado fully develop their water rights, this deficit could grow to 489,000 acre-feet.

Table 16. The State of Colorado's Colorado River Water Budget Including a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Southern Ute, Mountain Ute, & Colorado Allocation (51.75%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	3.571				1.078			0.966
5% Decrease	14.4	3.177				0.685			0.573
10% Decrease	13.7	2.784				0.292			0.179
15% Decrease	12.9	2.391				(0.101)			(0.214)
21st Century Average 19% Decrease	12.4	2.116	2.245	0.247	2.492	(0.377)	0.113	2.605	(0.489)
20% Decrease	12.2	1.998				(0.495)			(0.607)
25% Decrease	11.4	1.604				(0.888)			(1.001)
30% Decrease	10.6	1.211				(1.281)			(1.394)
35% Decrease	9.9	0.818				(1.675)			(1.787)
40% Decrease	9.1	0.424				(2.068)			(2.180)

Appendix C. The State of Colorado's Colorado River Water Budget

Table 17 describes the Colorado River water budget for Colorado under different flow reduction scenarios, assuming the Upper Basin is not required to deliver water to Mexico. This differs from Table 16, which shows the Colorado River water budget for Colorado but assumes the Upper Basin is required to deliver water to Mexico.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Colorado Allocation = 51.75% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, Colorado is allowed to develop an additional 11,000 acre-feet of water from the Colorado River. But, if Tribes in Colorado fully develop their water rights, the state would use 101,000 acre-feet more water than allowed from the Colorado River.

Table 17. The State of Colorado's Colorado River Water Budget Without a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Southern Ute, Mountain Ute, & Colorado Allocation (51.75%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	3.959	2.245	0.247	2.492	1.467	0.113	2.605	1.354
5% Decrease	14.4	3.566				1.073			0.961
10% Decrease	13.7	3.172				0.680			0.567
15% Decrease	12.9	2.779				0.287			0.174
21st Century Average 19% Decrease	12.4	2.504				0.011			(0.101)
20% Decrease	12.2	2.386				(0.107)			(0.219)
25% Decrease	11.4	1.992				(0.500)			(0.612)
30% Decrease	10.6	1.599				(1.893)			(1.006)
35% Decrease	9.9	1.206				(1.286)			(1.399)
40% Decrease	9.1	0.812				(1.680)			(1.792)

Appendix D. New Mexico's Colorado River Water Budget

Table 18 describes the Colorado River water budget for New Mexico under different flow reduction scenarios, assuming the Upper Basin is required to deliver water to Mexico. Since the delivery to Mexico is in dispute, another analysis was run assuming no delivery to Mexico is required, the results for which are in Table 19.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-32:

New Mexico Allocation = 11.25% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, New Mexico is using 41,000 acre-feet more water than allowed from the Colorado River (a deficit). If Tribes in New Mexico fully develop their water rights, this deficit could grow to 184,000 acre-feet.

Table 18. New Mexico's Colorado River Water Budget Including a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Navajo, Jicarilla & New Mexico Allocation (11.25%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	0.776	0.447	0.054	0.501	0.275	0.143	0.644	0.133
5% Decrease	14.4	0.691				0.190			0.047
10% Decrease	13.7	0.605				0.104			(0.038)
15% Decrease	12.9	0.520				0.019			(0.124)
21st Century Average 19% Decrease	12.4	0.460				(0.041)			(0.184)
20% Decrease	12.2	0.434				(0.067)			(0.209)
25% Decrease	11.4	0.349				(0.152)			(0.295)
30% Decrease	10.6	0.263				(0.238)			(0.380)
35% Decrease	9.9	0.178				(0.323)			(0.466)
40% Decrease	9.1	0.092				(0.409)			(0.551)

Appendix D. New Mexico's Colorado River Water Budget

Table 19 describes the Colorado River water budget for New Mexico under different flow reduction scenarios, assuming the Upper Basin is not required to deliver water to Mexico. This differs from Table 18, which shows the Colorado River water budget for New Mexico but assumes the Upper Basin is required to deliver water to Mexico.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

New Mexico Allocation = 11.25% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. Columns G.1 – G.2 use data from the Bureau of Reclamation and the Ten Tribes Partnership to estimate the state's Colorado River water use with full development of Tribal water rights, and Column H.1 compares that use to expected allocations, as is described on pages 34-35.

This table shows that under the 21st Century Average flow scenario, New Mexico is allowed to develop an additional 44,000 acre-feet of water from the Colorado River. But, if Tribes in New Mexico fully develop their water rights, the state would use 99,000 acre-feet more water than allowed from the Colorado River.

Table 19. New Mexico's Colorado River Water Budget Without a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Navajo, Jicarilla & New Mexico Allocation (11.25%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	0.861	0.447	0.054	0.501	0.360	0.143	0.644	0.217
5% Decrease	14.4	0.775				0.274			0.131
10% Decrease	13.7	0.690				0.189			0.046
15% Decrease	12.9	0.604				0.103			(0.040)
21st Century Average 19% Decrease	12.4	0.544				0.044			(0.099)
20% Decrease	12.2	0.519				0.018			(0.125)
25% Decrease	11.4	0.433				(0.068)			(0.211)
30% Decrease	10.6	0.348				(0.153)			(0.296)
35% Decrease	9.9	0.262				(0.239)			(0.382)
40% Decrease	9.1	0.177				(0.324)			(0.467)

Appendix E. Wyoming's Colorado River Water Budget

Table 20 describes the Colorado River water budget for Wyoming under different flow reduction scenarios, assuming the Upper Basin is required to deliver water to Mexico. Since the delivery to Mexico is in dispute, another analysis was run assuming no delivery to Mexico is required, the results for which are in Table 21.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Wyoming Allocation = 14% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. According to data from the Bureau of Reclamation and the Ten Tribes Partnership there are no tribes in Wyoming with claims to Colorado River water. This makes Columns G.1 – G.2 effectively irrelevant for Wyoming.

This table shows that under the 21st Century Average flow scenario, Wyoming is allowed to develop an additional 64,000 acre-feet of water from the Colorado River.

Table 20. Wyoming's Colorado River Water Budget Including a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Wyoming Allocation (14%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	0.966	0.441	0.067	0.508	0.458	0.000	0.508	0.458
5% Decrease	14.4	0.860				0.352			0.352
10% Decrease	13.7	0.753				0.245			0.245
15% Decrease	12.9	0.647				0.139			0.139
21st Century Average 19% Decrease	12.4	0.572				0.064			0.064
20% Decrease	12.2	0.540				0.033			0.033
25% Decrease	11.4	0.434				(0.074)			(0.074)
30% Decrease	10.6	0.328				(0.180)			(0.180)
35% Decrease	9.9	0.221				(0.287)			(0.287)
40% Decrease	9.1	0.115				(0.393)			(0.393)

Appendix E. Wyoming's Colorado River Water Budget

Table 21 describes the Colorado River water budget for Wyoming under different flow reduction scenarios, assuming the Upper Basin is not required to deliver water to Mexico. This differs from Table 20, which shows the Colorado River water budget for Wyoming but assumes the Upper Basin is required to deliver water to Mexico.

Columns A.1 and A.2 use the Bureau of Reclamation's natural flow data to derive different Colorado River flow scenarios, as is described on page 24. Column D.1 uses the water sharing methodology described in the 1948 Upper Colorado River Compact to find the state's Colorado River allocation. This is done according to the following calculation, which is explained on pages 33-34:

Wyoming Allocation = 14% X Upper Basin Allocation

Columns E.1 – E.3 employ consumptive use data from the Bureau of Reclamation to find each state's current Colorado River water use, and column F.1 compares that water use to the expected allocation, as is described on pages 34-35. According to data from the Bureau of Reclamation and the Ten Tribes Partnership there are no tribes in Wyoming with claims to Colorado River water. This makes columns G.1 – G.2 effectively irrelevant for Wyoming.

This table shows that under the 21st Century Average flow scenario, Wyoming is allowed to develop an additional 169,000 acre-feet of water from the Colorado River.

Table 21. Wyoming's Colorado River Water Budget Without a Delivery to Mexico

A. Water Flow Scenario		D. Allocation	E. Current Use			F. Remaining Allocation w/ Current Use	G. Future Additional Use		H. Remaining Allocation w/ Future Use
1. Flow Reduction of the Colorado River at Lee Ferry	2. Naturalized Flow at Lee Ferry	1. Wyoming Allocation (14%)	1. Current Use per BOR	2. Share of Reservoir System Losses	3. Total Current Use	4. Surplus (Deficit)	1. Unused Tribal Depletion Rights	2. Total Current Use + Future Additional Use	4. Surplus (Deficit)
20th Century Average (1906-1999)	15.2	1.071	0.441	0.067	0.508	0.563	0.000	0.508	0.563
5% Decrease	14.4	0.965				0.457			0.457
10% Decrease	13.7	0.858				0.350			0.350
15% Decrease	12.9	0.752				0.244			0.244
21st Century Average 19% Decrease	12.4	0.677				0.169			0.169
20% Decrease	12.2	0.645				0.138			0.138
25% Decrease	11.4	0.539				0.031			0.031
30% Decrease	10.6	0.433				(0.075)			(0.075)
35% Decrease	9.9	0.326				(0.182)			(0.182)
40% Decrease	9.1	0.220				(0.288)			(0.288)

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69 The phrase “compact call” is not written anywhere in the 1922 Colorado River Compact. Yet, it is colloquially used to refer to Lower Basin’s ability to “call” or demand that the Upper Basin deliver the water agreed to in Article III(d) (i.e. 75 million acre-feet over 10 years), should the Upper Basin ever fail to meet that obligation. This report uses “compact call” in this same sense.

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71 The term “allocation” has many uses and meanings in the context of the Law of the River. This report uses it to refer to the specific amount of water afforded to each individual Upper Basin state by the provisions of the Law of the River.

72 This analysis looks at the flows of the Colorado River at one specific point, Lee Ferry, because that is the location where many important Law of the River provisions are measured. Lee Ferry (the compact point) is a location one mile below the confluence of the Paria and Colorado Rivers. It is often confused with Lees Ferry, a point above the confluence of the Paria and Colorado Rivers where the USGS has a stream monitoring gauge. We do our best to specify that “Colorado River flows” refer to flows at Lee Ferry this throughout the report, but where we fail to do so, it can usually be assumed that we are referring to Lee Ferry.

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