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The First Step in Repairing the Colorado River's Water Budget: Technical Report

Colorado River Research Group

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THE FIRST STEP IN REPAIRING THE COLORADO RIVER'S WATER BUDGET:

TECHNICAL REPORT[1]

December, 2014

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An independent, scientific voice for the future of the Colorado River

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[1] This technical report provides information in support of "The First Step in Repairing the Colorado River's Water Budget: Summary Report." These are the first products of the Colorado River Research Group, a "self-directed group of veteran Colorado River scholars assembled to provide a non-partisan, academic voice on matters pertaining to science, law and policy on the Colorado River, helping all those with a stake in the river identify, justify and implement actions consistent with long-term sustainable management."

Table on Contents

Tables and Figures

I. Introduction

The Colorado River is a critically important resource for the Southwest. It is at least a partial water supply for nearly 40 million people, a source of irrigation water for 5.5 million acres, the driver of 4,200 megawatts of hydropower generating capacity, and the lifeblood for 22 tribes, 7 National Wildlife Refuges, 4 National Recreation Areas, and 11 National Parks.[2] It is also, however, an incredibly overworked and threatened resource, and virtually all research to date suggests that the situation is likely to worsen without significant management changes. In short, water users collectively consume too much from the river and, moving forward, should plan to use less if the water budget is to be balanced. But that is neither the observed trend nor the future envisioned by dozens of water development proponents. This issue is explored in the following pages. In Section II, the nature of the supply/demand imbalance is reviewed, highlighting both the basin-wide imbalance that threatens the long-term sustainability of the resource, and the more immediate Lower Basin imbalance (the so-called "structural deficit"). This is followed in Section III by a review of some proposals to increase consumption on the river, a trend that threatens to further stress the regional water budget. Some implications of this mismatch between water availability and growth proposals are noted in Section IV, followed by some general conclusions in Section V.[3]

II. Diagnosing the Problem

The massive storage capacity on the Colorado River provides the system with an incredible ability to buffer year-to-year fluctuations in inflows (mostly snowmelt) and outflows (demands and losses). Keeping water in storage provides a host of regional benefits, including water supply reliability, hydropower generation, and recreational opportunities. These attributes are

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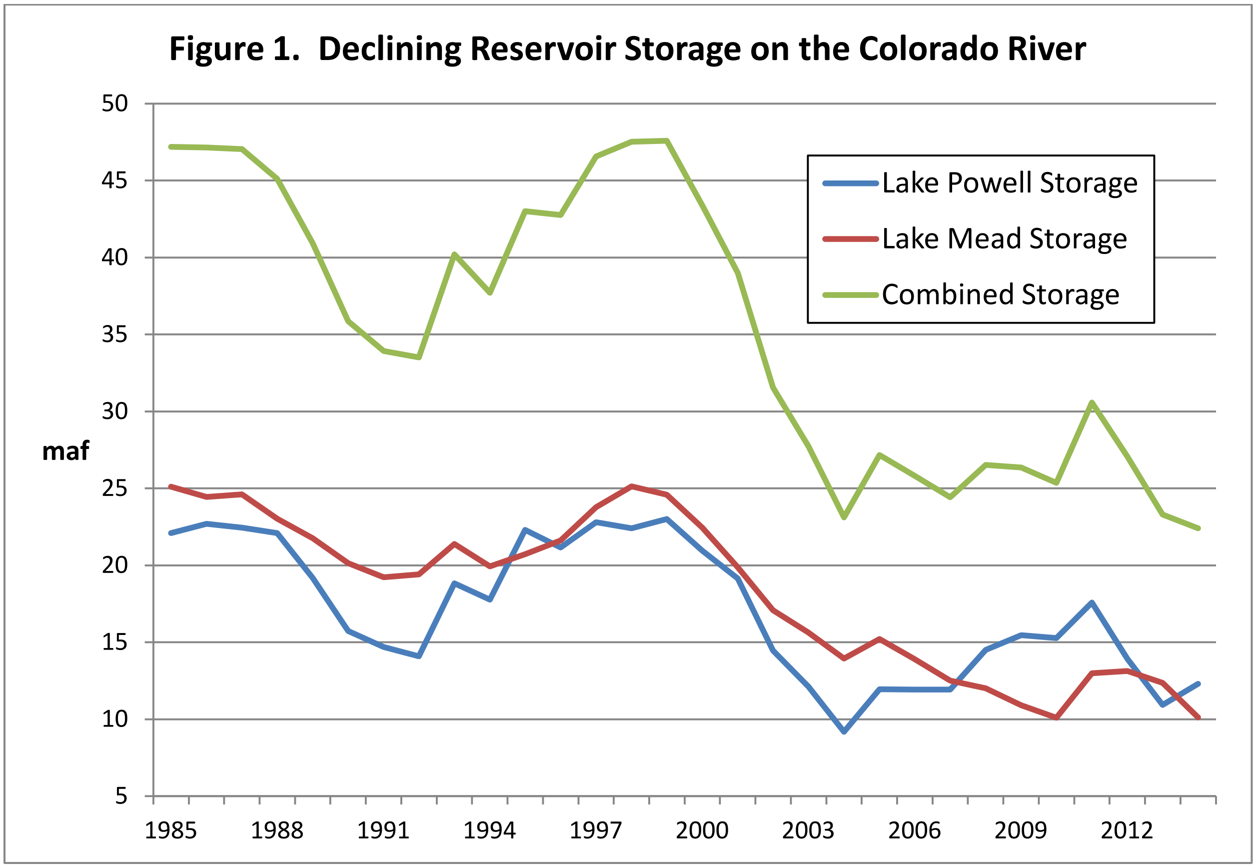
[2] The primary source of information on current uses of water is the *Colorado River Basin Water Supply and Demand Study* (hereafter "*Basin Study*") (DOI, 2012). Reports are available at http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html.

[3] As a technical report, this document is geared toward readers that have a working knowledge of the Colorado River system, including the collection of laws and agreements known as the Law of the River. The elements of the Law of the River that have a significant influence on matters of apportionment and river management include the Colorado River Compact (1922), Boulder Canyon Project Act (1928), Treaty between the US and Mexico (1944), Upper Colorado River Basin Compact (1948), Colorado River Storage Project Act (1956), *Arizona v. California* (1963), Colorado River Basin Project Act (1968), Criteria for Long-Range Operation of Colorado River Reservoirs (1970), Minute 242 of the US-Mexico Treaty (1973), Colorado River Basin Salinity Control Act (1974), Grand Canyon Protection Act (1992), Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007), and Minute 319 of the US-Mexico Treaty (2012). Collectively, the framework assumes sufficient water to consumptively use 7.5 million acre-feet (maf)/year of water in the Upper Basin, 7.5 maf in the Lower Basin, and 1.5 maf in Mexico, for a total of 16.5 maf/year. Once evaporation, system losses, and extra deliveries to Mexico (to meet water quality and environmental requirements) are considered, close to 2 maf/year of additional water is implicated. The upper limit of actual water availability, however, is approximately 15 maf—much less than the framers of the Compact assumed. Reconciling the promises codified in law with the physical realities of the system is at the heart of the political conflicts in the Colorado River basin, as discussed throughout this report.

all threatened by the rapid decline in shortage observed in recent years, shown below in Figure 1.[4]



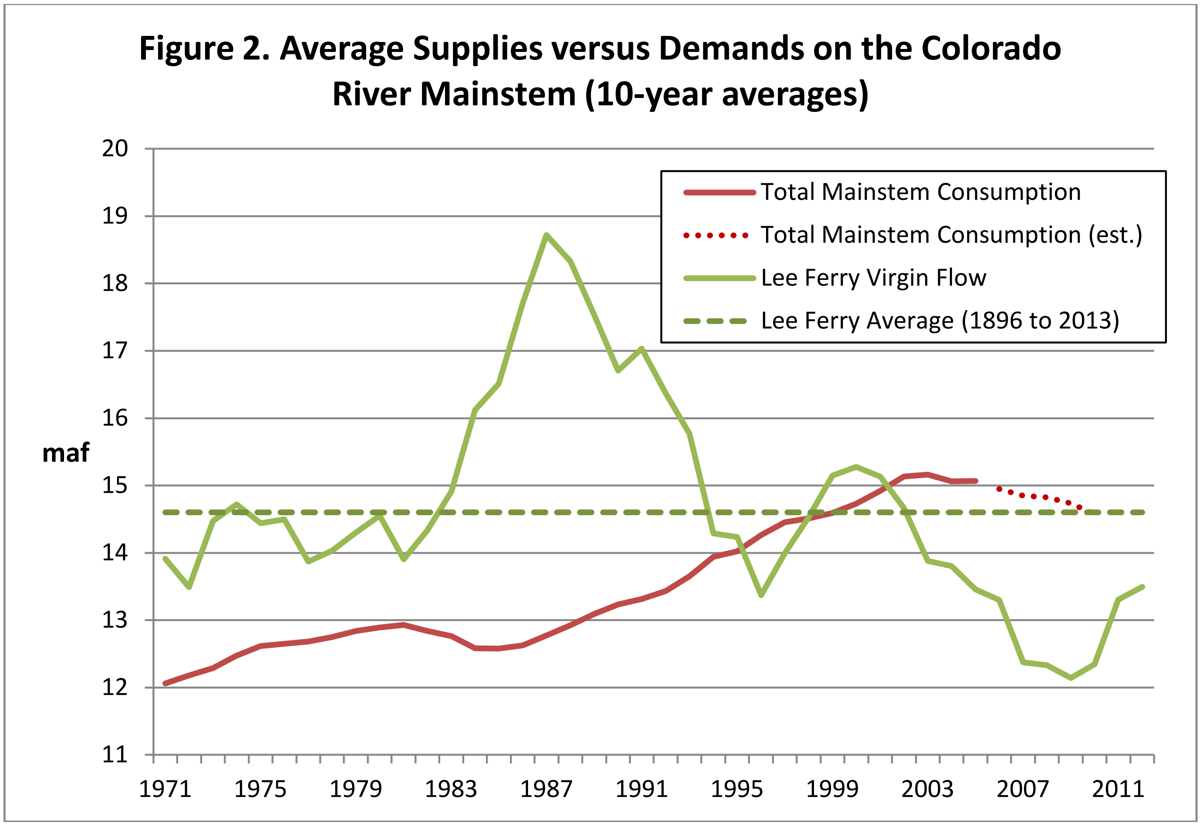
Compounding this problem is the largely unseen crisis of groundwater depletion. Recent satellite-based studies from NASA's GRACE mission indicate that from March 2005 to June 2013 (a 100-month study period), the basin lost over 38 million acre-feet (maf) of groundwater—roughly 38% in the Upper Basin, and 62% in the Lower Basin. This is a staggering sum—far in excess of the roughly 200,000 acre-feet lost from Lakes Powell and Mead in this period—leading the authors to "observe that groundwater is already being used to fill the gap between Basin demands and the annual renewable surface water supply" (Castle et al., 2014: 5909).[5]

Unlike the groundwater crisis, the sharp declines in reservoir storage have received considerable attention. However, many parties fail to understand that the declines are the product of two very different phenomena: demands, which can be actively managed; and

[4] Data compiled from the U.S. Bureau of Reclamation, Lower Colorado River (http://www.usbr.gov/lc/) and Upper Colorado Region (http://www.usbr.gov/uc/).
[5] The results are discussed at http://www.circleofblue.org/waternews/2013/world/nasas-grace-satellites-show-colorado-river-basins-biggest-water-losses-are-groundwater-during-current-drought/.

drought, which cannot. Understanding the contribution of each phenomenon to the current crisis is an essential first step in identifying appropriate solutions.

As shown below in Figure 2, average demands (i.e., consumption) on the river have, predictably, climbed steadily over time as the Southwest developed, finally surpassing average flows in the late 1990s.[6] This milestone went largely unnoticed, but has proven to be incredibly salient, as it created vulnerability to the drought that was just around the corner.



[6] This figure is based on consumption data compiled from the *Consumptive Uses and Losses Reports*, (1971 through 2005) published by the Bureau of Reclamation and available online at: http://www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html. Upper Basin consumption data for 2006 through 2010 (shown as the dotted line) is from the provisional report; Lower Basin data for those years is from Reclamation's *Colorado River Accounting and Water Use* reports, available at http://www.usbr.gov/lc/region/g4000/wtracct.html. Lower Basin evaporation and system losses post 2006 are estimated by the authors. The estimate of average Lee Ferry virgin flow from 1896 to 2013 (of 14.6 maf/year) is taken from the *Sixty-Fifth Annual Report of the Upper Colorado River Commission* (UCRC, 2013: 24). Many investigations, including the *Basin Study*, use a shorthand estimate of 15 maf/year average, which is consistent with a shortened time series (1906 to 2007). In some cases, these numbers may deviate slightly from those of the *Basin Study* due to different accounting methodologies.

This interplay of these two factors is different for the two reservoirs.[7] As shown below in Figure 3, the close relationship between inflows and storage is particularly clear upstream in Lake Powell, with storage immediately increasing in wet years and declining in dry years.[8] But the situation for Lake Mead (Figure 4) is more complex and illuminating.[9] Unlike Lake Powell, inflows to Lake Mead are remarkably consistent, as planned, as they come from precisely scheduled Lake Powell releases. But since the turn of the century, the consistent releases between 2000-2009—averaging slightly above the 8.23 maf/year standard that is the *de facto* long-term management target[10]— did nothing to stabilize Mead, which lost more than half its storage in this period. Why? After accounting for reservoir evaporation and system losses (over 1 maf/year), and mandated deliveries to Mexico (1.5 maf/year), when the Lower Basin states use their full 7.5 maf/year consumptive use apportionment, net storage in Lake Mead declines over 1 maf/year at this level of Lake Powell releases. This is the so-called "structural deficit."[11]

[7] Of course, since the reservoirs are operated in a coordinated way, any factor that influences one reservoir ultimately impacts the other.

[8] Data compiled from the Bureau of Reclamation, Upper Colorado Region (http://www.usbr.gov/uc/). Reservoir volumes can be found in many locations, including the *Colorado River Accounting and Water Use* reports, available at http://www.usbr.gov/lc/region/g4000/wtracct.html.

[9] Data compiled from the U.S. Bureau of Reclamation, Lower Colorado River (http://www.usbr.gov/lc/) and Upper Colorado Region (http://www.usbr.gov/uc/). Reservoir volumes can be found in many locations, including the *Colorado River Accounting and Water Use* reports, available at http://www.usbr.gov/lc/region/g4000/wtracct.html.

[10] Whether or not the Upper Basin has a "delivery obligation," and if that obligation is actually 8.23 MAF/year, are complex and contested legal issues (*see* Robison and Kenney, 2013). Historically, water supplies have been sufficient to allow these underlying legal issues to go unchallenged. By providing a schedule of releases tied to reservoir levels, the Interim Guidelines reinforce 8.23 MAF/year as the operational target for normal conditions. That agreement expires in 2026.

[11] The period 2008 to 2012 is illustrative. In that period, releases from Lake Powell averaged roughly 9.5 MAF/year, allowing Lake Mead to exit the period with the same amount of storage as immediately prior (roughly 12.4 MAF). Lake Mead was stable due to the high releases. But take away high Lake Powell releases—either due to drought, growing Upper Basin consumption, or some combination of both—and Lake Mead declines sharply.

Figure 3. Relationship Between Lake Powell Storage and Lee Ferry Virgin Flows

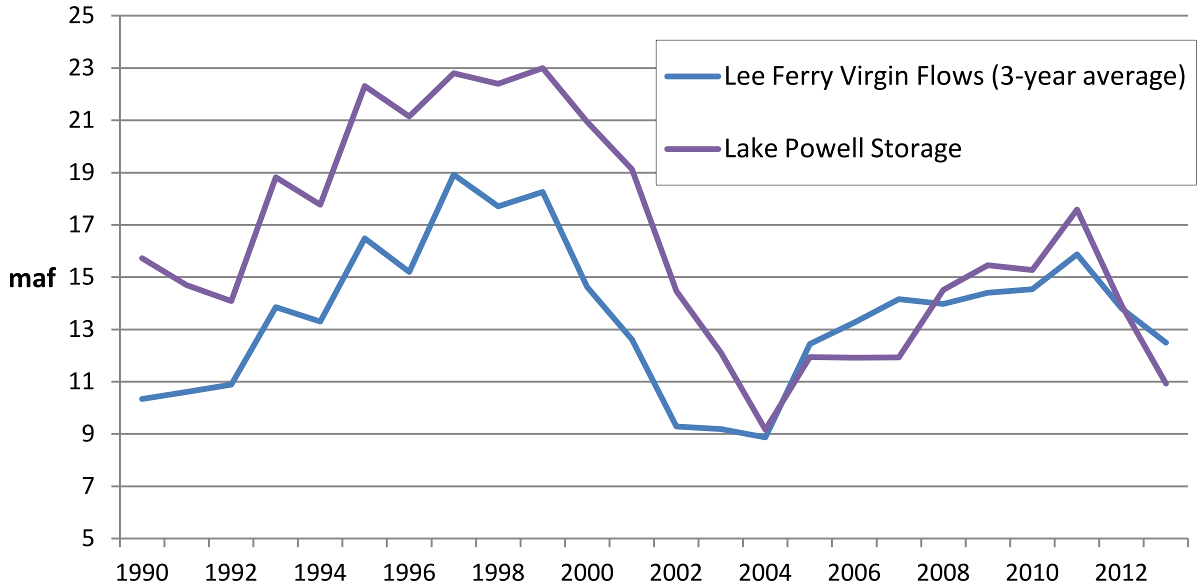
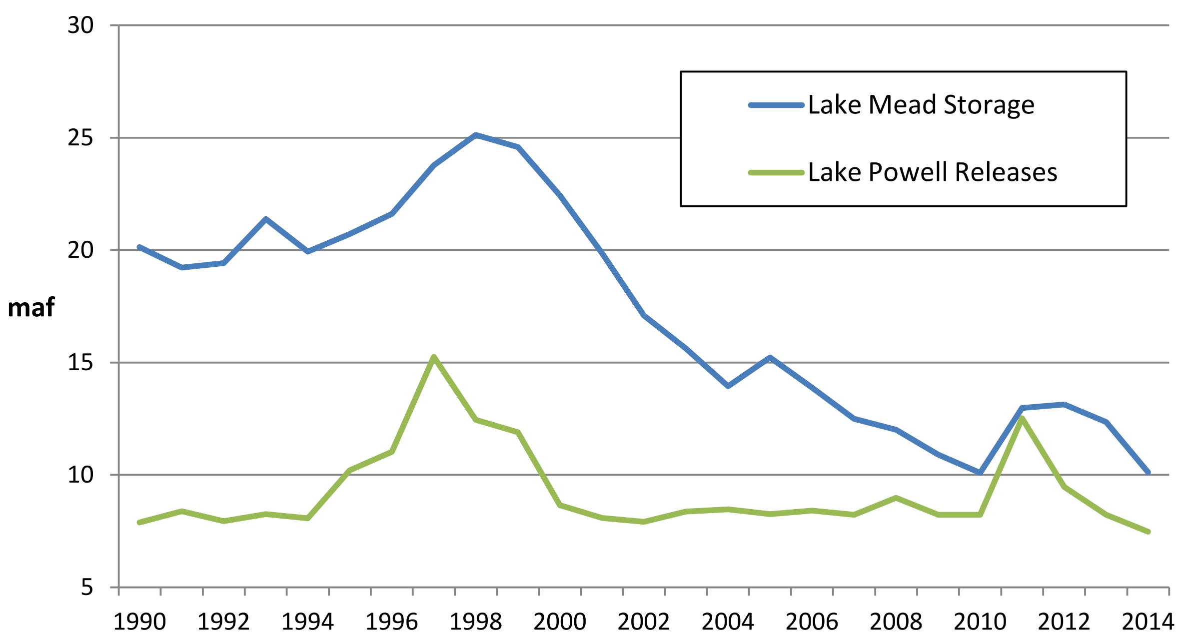


Figure 4. Relationship Between Lake Powell Releases and Lake Mead Storage



The unusually hot drought that has gripped the region since 2000 is truly exceptional, and some loss of reservoir storage was both expected and appropriate—a purpose of reservoir storage is to act as a drought buffer. However, to characterize the "crisis" on the river as simply a drought problem that ends when "normal" snowfall levels return is overly simplistic. A string of wet years could mean a quick recovery for Lake Powell, and a recovered Lake Powell would quickly trigger those high downstream releases that are currently necessary to stabilize or recover Lake Mead. But remember: remove hydrologic variability (both dry and wet years) from the equation and problems still exist for the simple reason that *average* demands on the system now equal or slightly exceed *average* supplies. Average runoff results, at best, in a period of "fragile" stability that remains highly vulnerable to both drought and/or a continued growth in demands.

There is reason to believe that so-called "average" conditions—typically assumed to be roughly 15 maf/year—are unlikely to reappear. The vast majority of research on the Colorado Basin's climatology points to significantly reduced flows in coming decades. All recent studies have predicted significant flow reductions; the latest synthesis of that work indicates declines in the range of 5 to 35 percent by midcentury (Vano et al., 2013)[12], and barring any successful international effort to curb greenhouse gas emissions dramatically, conditions would likely deteriorate further past that time. The projections used in the climate change scenario (labeled "Downscaled GCM Projected") in the *Basin Study* feature an average drop of roughly 9 percent by 2060 (about 1.3 maf/year) (DOI, 2012). The region has already warmed by approximately 2^{o} Fahrenheit in three decades. Additionally, recent research by Ault et al. (2014) indicates that the risk of future multidecadal droughts (or "megadroughts") in the coming century are more substantial than previously realized—e.g., a 20 to 50 percent chance for a drought in excess of 35 years, and a 5 to 10 percent probability for an event lasting 50+ years. The science cannot tell us definitively what will happen—there is little hope of science ever settling on the "right" numbers to use in planning—but it does strongly suggest that conditions are likely to become more challenging, and that maintaining a buffer between supplies and demands will be critically important.

Given this alarming snapshot of the region's hydrologic water budget both today and in a future that may very well feature further reductions in streamflow occurring against a backdrop of depleted buffers (reservoir storage and groundwater), it is understandable why some individual water users see this as a reason for racing to expand their individual water supply systems. But much like the classic "tragedy of the commons," what is in the best interest of individuals can collectively overwhelm the system to everyone's long-term detriment. This is the subject explored in Section III.

[12] Vano et al. (2013) indicate a flow decline of 6.5 percent (plus or minus 3.5 percent) per every 1^{o}C of warming.

III. Plans to Increase Use of Basin Water

A. Overview

All of the basin states project increased demands for uses of basin water in the future. Projected population increases—and resulting spikes in M&I (municipal and industrial) demand—are the primary driver. Depending upon the scenario used, the *Basin Study* estimated population in areas served by water from the Colorado basin to grow from 40 million (in 2015) to anywhere from 49 million to 77 million (by 2060).[13] As a result, projected M&I demand across the basin increases from about 27 percent (of total consumption) in 2015 to 33 to 38 percent by 2060, mostly due to Lower Basin growth. This occurs despite projected improvements in water use efficiency resulting in declining per capita use for all states except Wyoming.[14] Overall, the *Basin Study* finds that consumptive use from the mainstem is expected increase "between 1.2 and 3.4 maf, with the Lower Basin making up about 60 percent of the increase" (DOI, 2012: C22). Yet there is little likelihood these amounts of water will be physically available.

This section examines projected uses on a state-by-state basis in the Upper and Lower Basins and also looks at projected tribal uses. It relies primarily on the information gathered as part of the *Basin Study* but also provides information about pending claims (permits and conditional water rights) where available in state water rights records to use basin water in the future. It also uses figures from Reclamation's *Consumptive Uses and Losses* reports, state and regional planning documents, hydrologic determinations, and other research reports. That the numbers are not entirely consistent is a function of differing methodologies and accounting assumptions (including the treatment of evaporation and other losses), and reflects that water consumption varies significantly from year-to-year and projection-to-projection. No effort is made to somehow identify the "best" numbers; it is sufficient simply to note that the number of

[13] The *Basin Study's* (DOI, 2012) demand estimates are found in Technical Report C, available at: www.usbr.gov/lc/region/programs/crbstudy/finalreport/techrptC.html.

[14] The states use significantly different estimates regarding per capita water use trends. For example, in the "rapid growth" (C1) scenario, per capita usage is projected to decrease most significantly in Nevada (-20%), followed by Utah (-14%), California (-13%), New Mexico (-11%), Colorado (-9%), and Arizona (-5%). Per capita usage is expected to increase slightly in Wyoming (+4%), although this has little effect on the basin-wide water budget given the very low population numbers. The states also have very different baseline per capita use values, make different assumptions about relevant demographic trends (e.g. the number of rural residents that will relocate to cities), and use different assumptions about the role of Colorado River water in meeting these demands. Taken together, population growth in different states affects water demands in very different ways. For example, the rapid growth (C1) scenario in California suggests a population increase of 14.2 million, boosting M&I demand by 289,000 acre-feet. Meanwhile, the same scenario for Arizona projects a population increase of 8.5 to 9.3 million residents, resulting in new M&I demands of 1.3 million acre-feet (maf). Thus, as far as the Colorado River water budget is concerned, *how* a region grows can be much more important than *how much* it grows. (This information is contained with the relevant state water demand technical appendices, available at: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/techrptC.html.)

proposals, and the total volume of water they represent, is significant. In sidebars, a few of the most active proposals for additional water development are noted.

B. Upper Basin States

1. Colorado

According to the *Basin Study*, "Colorado River demand [in Colorado] increases from about 2.4 maf in 2015 to between 2.5 and 3.0 maf in 2060 (or 6 to 27 percent) depending on the scenario."[15] At present, agricultural uses account for about 79 percent of demands for Colorado River system water, with M&I accounting for about 15 percent. Agricultural use is expected to decrease, while M&I use will increase. Most of the projected demand growth will occur in the South Platte basin on Colorado's Front Range, primarily due to expected population growth.

The State of Colorado is currently engaged in a planning process primarily intended to identify new projects to meet growing M&I demands while minimizing agricultural-to-urban water transfers. *Basin Study* numbers suggest a growth in M&I demands from 2015 to 2060 of 290,000 to 752,000 acre-feet, with roughly two-thirds of that being Colorado River demand. The extent to which transmountain diversions of Colorado River water will be featured in future water management is the key policy issue hanging over planning efforts. Thus far, for the three water divisions in the Colorado River Basin, the Colorado Water Plan process has identified 54 projects with the potential to develop more than 500,000 acre-feet from the Colorado mainstem, 37 projects yielding 32,000 acre-feet from the tributaries in the southwest (San Juan) region, and 211,000 acre-feet of new projects from the Yampa, White, and Green region in the northwest of the state.[16] Additionally, as mentioned later in the Wyoming summary, Front Range water providers in Colorado are also pursuing a major diversion to the Front Range from the Green River Basin in Wyoming, a depletion that would count against Colorado's apportionment.

A very different indicator of intentions to develop and use additional Colorado River basin water in Colorado can be found by looking at the number of conditional water rights that have been decreed for the planned use of water from either the Colorado River mainstem or its

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[15] The State of Colorado is currently engaged in a statewide planning process. For information, see http://coloradowaterplan.com/. This process is using somewhat different numerical information. Unless noted otherwise, we have chosen to stay with the information provided in the *Basin Study* to be consistent with information presented respecting other states. The *Basin Study* presents Colorado information in appendix C2: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix2_FINAL.pdf. The quote is from page C2-7.

[16] This information is pulled from the working draft of the Colorado Water Plan, available at http://coloradowaterplan.com/. The official first complete draft is due in December, 2014; a second draft is due in July, 2015; and a final version is scheduled for December, 2015.

tributaries in western Colorado.[17] A recent study by Podolak and Doyle (2014) identified approximately 70 million acre-feet of conditional water rights in the Colorado River system. While most of these claims will never actually be developed, their amount indicates a wildly ambitious view of anticipated demand for the use of Colorado River system water in Colorado, a view that in no way takes account of the remaining water legally available for development in the State or of the physical realities of the basin's water supply.

Windy Gap Firming Project

The Municipal Subdistrict of the Northern Colorado Water Conservancy District proposes to build 90,000 acre-foot Chimney Hollow Reservoir to hold water from the Colorado River and enable a more secure water supply for 14 Front Range water suppliers. Water currently stored in Granby Reservoir would move to the Front Range, allowing additional west slope storage. Flows in the Colorado River below Granby would be reduced an estimated 9,000 acre-feet annually.

Dry Gulch Reservoir

The Pagosa Area Water and Sanitation District and the San Juan Water Conservancy District plan to build the Dry Creek Reservoir, with water diverted from the San Juan River in southwest Colorado and pumped into the storage site. Originally proposed to be a 35,000 acre-foot storage system, Colorado water court review of foreseeable demand resulted in a reduction of the storage right to 11,000 acre-feet.

2. New Mexico

The population in that part of New Mexico that relies, at least in part, on use of water from the Colorado River basin is about 1.5 million.[18] It is expected to grow to between 2 and 3 million by 2060. At present, New Mexico uses about 600,000 acre-feet of basin water annually. By 2060 that use is estimated to be between 683,000 and 979,000. While M&I demands are likely to increase during this period, the largest source of increased demand is expected to be from tribal water uses. These projected uses will be discussed below in the section summarizing tribal uses. Interviews with water officials in New Mexico indicate that no new permits for appropriation of Colorado River basin water have been issued since the 1960s.[19]

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[17] Under Colorado law, a conditional water right is established when a user files their intention to develop and use water in the future, and satisfies a court-review of due diligence every six years toward completion of the necessary project. Upon project completion, the right can become an absolute water right, and will feature the priority date associated with the initial filing.

[18] The *Basin Study* presents New Mexico information in appendix C3: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix3_FINAL.pdf.

[19] Interview with Shawn Williams, Water Master for the San Juan River, Oct. 15, 2014.

Steps are being taken to build the Navajo-Gallup project under which water would be diverted from the San Juan and moved via pipeline to users on the Navajo Reservation, including in Windrock, Arizona, the Jicarilla Apache Reservation, as well as users in Gallup, NM. The project's two branches will divert about 37,000 acre-feet per year at full capacity, depleting more than 35,000 acre-feet per year.

The State of New Mexico is considering the construction of a water supply project that would take water from the headwaters of the Gila River in that State (WRA, 2014). Authorized under the 2004 Arizona Water Rights Settlement Act, the project would enable New Mexico to consumptively use an additional 14,000 acre-feet per year of water.

Navajo-Gallup Water Supply Project

Authorized by Congress in 2009 as part of a water rights settlement bill, this Bureau of Reclamation project will divert about 38,000 acre-feet annually from the San Juan River. With an estimated cost of $870 million, the project will deliver water to portions of the Navajo and Jicarilla Apache reservations and to the City of Gallup.

3. Utah

About 2.4 million people currently live in that portion of Utah that relies, at least in part, on use of water from the Colorado River basin.[20] This population is expected to reach from 3.7 to 6.2 million by 2060. While agricultural uses of basin water are expected to remain stable during this period, M&I uses are expected to increase from 236,000 acre-feet to between 274,000 and 409,000 per year, while Tribal uses are expected to grow from about 200,000 to between 259,000 and 337,000 acre-feet per year. Overall, the *Basin Study* estimates Utah's demands on the Colorado to increase from roughly 960,000 acre-feet/year to 1.1 to 1.3 maf/year.

An examination of the Utah Division of Water Rights data base indicates the existence of approved permits authorizing the development of a total of more than 4.3 maf of water from the Colorado River system in Utah, including about 1.1 maf of water for irrigation use and 242,000 acre-feet for municipal use. The State of Utah is pursuing the construction of the Lake Powell pipeline, a project that would carry about 86,000 acre-feet per year of Colorado River water to the St. George area of southwest Utah.

Lake Powell Pipeline

To provide water to the growing population in the St. George area of southwest Utah, the State of Utah is planning a 120 mile pipeline from Lake Powell. The pipeline would deliver 86,000 acre-feet of water annually to users in Kane and Washington counties.

[20] The *Basin Study* presents Utah information in appendix C4: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix4_FINAL.pdf.

4. Wyoming

There are about 310,000 people living in the area of Wyoming that relies, at least in part, on use of water from the Green and Little Snake rivers, tributaries to the Colorado.[21] That number is expected to increase to between 370,000 and 440,000 by 2060. At present Wyoming consumptively uses about 511,000 acre-feet of basin water annually. The *Basin Study* projects that use will increase from between 576,000 to 769,000 acre-feet in 2060.

Colorado interests are exploring the construction of a pipeline that would carry as much as 250,000 acre-feet of water annually from Flaming Gorge Reservoir and the Green River to the Colorado Front Range.

Flaming Gorge Pipeline

A Colorado developer has proposed the construction of a 560 mile pipeline that would carry water from the Green River in Wyoming to users in southeastern Wyoming and along the Colorado Front Range. The pipeline would deliver 250,000 acre-feet per year for use.

C. Lower Basin States

1. Arizona

Arizona's population is currently about 7 million.[22] By 2060, the population is estimated to be between 9.8 and 16 million. Virtually the entire State of Arizona is within the Colorado River basin. Traditionally, the Bureau of Reclamation has only reported on the uses of water from the mainstem Colorado River, currently estimated at nearly 3.0 maf in Arizona. These uses are expected to increase to between 3.1 to 4.2 maf by 2060. Agricultural uses of Colorado River water are projected to decline while both M&I and tribal uses are expected to increase during this period. A small portion of Arizona is included in the Upper Basin. Demands in this area are expected to increase from at least 40,000 acre-feet to as high as 73,000 acre-feet. The *Basin Study* did not include demand for uses of water from the Gila Basin, the major river system within the State, or from other tributaries. Its analysis of consumptive uses in the tributaries in 2000 suggests uses of about 3.25 maf/year from the Gila system, with an additional 215,000 acre-feet from other tributaries in the State.[23]

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[21] The *Basin Study* presents Wyoming information in appendix C5: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix5_FINAL.pdf.

[22] The *Basin Study* presents Arizona information in appendix C6: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix6_FINAL.pdf.

[23] The Basin Study contains annual consumptive use and loss figures for the Little Colorado River, Virgin River, and Bill Williams River for the 2001 to 2005 period, but these figures are apparently being investigated and likely contain data as well as methodological inconsistencies. Lower Basin tributaries are discussed in appendix C11: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix11_FINAL.pdf.

2. California

The current population in the area of the State served, in part, with water from the Colorado River is 20.4 million, or roughly half all municipal users in the entire Basin.[24] Agriculture, however, remains the largest (and most senior) user, accounting for 65% of California's Colorado River consumption, mostly in the Imperial Valley. By 2060, estimates show the population to be anywhere from essentially unchanged to nearly 35 million. Existing demand for Colorado River water is nearly 5 maf, with demand projected to increase to between 5.2 and 5.3 maf. These numbers reflect a small decline in agricultural demand and a somewhat larger increase in M&I demand.

3. Nevada

Population in that portion of Nevada served, in part, by water from the Colorado River—essentially, the Las Vegas area—is estimated to range from 2.3 to 2.6 million in 2015, and is expected to increase to between 4.2 and 5.1 million by 2060.[25] Virtually all water demand is for M&I, with a small portion for tribal use. Water use from the Colorado River at present is 300,000 acre-feet, with demands expected to grow to from between 490,000 and 600,000 acre-feet by 2060. An examination of Nevada's water rights data base reveals the existence of permits that would enable the additional development of about 2,800 cubic feet per second within sub-basins of the Colorado River.[26]

D. Tribal Demands

Tribes with reservations in the basin are estimated to hold quantified rights to divert approximately 2.9 maf/year.[27] Of this total, about 1.4 maf is for tribes in the Upper Basin and 1.5 maf for tribes in the Lower Basin. Many of these rights have not yet been placed to use. In addition, there are unquantified tribal rights still outstanding.

Some existing and projected demands for tribes in the Upper and Lower Basins are summarized below in Tables 1 through 3: [28]

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[24] The *Basin Study* presents California information in appendix C7: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix7_FINAL.pdf

[25] The *Basin Study* presents Nevada information in appendix C8: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix8_FINAL.pdf.

[26] We have not attempted to convert these claims into acre-feet or to estimate the associated depletions.

[27] The *Basin Study* presents tribal water demand information in appendix C9: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20C%20-%20Water%20Demand%20Assessment/TR-C_Appendix9_FINAL.pdf.

[28] These figures, and those in the following tables, come from the *Basin Study* (specifically Appendix C9, tables C9-3 to C9-5 and supporting text). The magnitude of tribal water rights is a highly contested matter; the numbers

Table 1. Tribal Water Rights/Demands: Upper Basin		
Tribe/State	**Present Rights/Demands** (diversions in acre-feet)	**2060** (diversions in acre-feet)
Jicarilla Apache/NM	37,000	46,000
Navajo (San Juan)/NM	506,000	613,000
Navajo/AZ	49,000	49,000
Southern Ute/CO	137,000	* included in CO estimates
Ute Indian/UT	481,000	481,000
Ute Mountain/CO	88,300	* included in CO estimates

Table 2. Tribal Water Rights/Demands: Lower Basin Mainstem		
Tribe/State	**Present Rights/Demands** (diversions in acre-feet)	**2060** (diversions in acre-feet)
Chemehuevi/CA	11,340	11,340
Cocopah/AZ	10,800	10,800
Colorado River Indian/AZ	662,000	662,000
Colorado River Indian/CA	57,000	57,000
Fort Mojave/AZ	103,000	103,000
Fort Mojave/CA	17,000	17,000
Fort Mojave/NV	12,500	12,500
Hopi/AZ	4,300	4,300
Quechan/AZ	6,300	6,300
Quechan/CA	71,600	71,600

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provided herein are one interpretation of a complex legal landscape. Additional discussion and updated figures are available from the Colorado River Governance Initiative, *Cross-Boundary Water Transfers in the Colorado River Basin: A Review of Efforts and Issues Associated with Marketing Water Across State Lines or Reservation Boundaries, Appendix A* (CRGI, 2013); available at: http://www.waterpolicy.info/docs/CrossJurisdictionalWaterMarketingCRBJune2013.pdf.

Table 3. Tribes Served by Central Arizona Project (CAP) Water		
Tribe	**2015** (acre-feet)	**2060** (acre-feet)
Ak Chin	75,000	75,000
Fort McDowell Yavapai	18,233	18,233
Gila River	208,200	328,800
Pascua Yaqui	500	500
Salt River Pima-Maricopa	35,300	35,300
San Carlos Apache	43,500	43,500
Tohono O'odham	54,800	74,000
Tonto Apache	128	128
White Mountain Apache	2,031	25,000
Yavapai-Apache	1,200	1,200
Yavapai-Prescott	500	500

While most tribes in the basin now hold quantified water rights, a few settlements are still in progress. For example, the Navajo Nation and the State of Utah are negotiating an agreement to quantify rights associated with reservation lands located in that state. A proposed settlement awaiting Congressional approval would establish a diversion right of about 315,000 acre-feet.[29] In addition, according to a recent study completed by the Colorado River Governance Initiative, "[t]he Hualapai, Havasupai, Kaibab Band of Paiutes, Ute Mountain Ute, Yavapai-Apache, Tonto Apache, Pascua Yaqui, and Hopi Tribes are among the federally recognized tribes that have unsettled claims to federal reserved rights within the Colorado River Basin" (CRGI, 2013: 38).

IV. Reconciling Fantasy with Reality

Aspirations for the additional development of basin water exist within a highly constrained system. As noted in Section II, annual depletions of basin water now meet or exceed their replacement. Balance is being temporarily maintained by drawing from savings, the basin's enormous storage systems of reservoirs and mostly non-renewable groundwater supplies. But these savings are no longer being replenished; instead they are diminishing. In this context, plans for increased water development and its associated increased depletions make little sense and draw effort and attention away from efforts to adapt to the hard realities already apparent in the basin.

[29] UTAH CODE ANN. § 51-9-702. Depletions could not exceed 81,500 acre-feet per year.

A. Upper Basin

Under the 1922 Compact, the Upper Basin is authorized to consume up to 7.5 maf annually—an amount apportioned for use among the states on a percentage basis. At present, depletions (consumption plus losses) in the Upper Basin are about 4.5 maf each year, and each state contends it has the legal right to increase existing uses. But the 1922 Compact also obligates the Upper Basin "not to cause" less than 75 maf to pass into the Lower Basin on a running ten-year average. Moreover, the Upper Basin is typically regarded as having an obligation to make available half of the 1.5 maf of the water committed to Mexico annually under the 1944 Treaty. These obligations mean that 8.25 maf must flow from the Upper Basin to the Lower Basin each year. Adding the existing 4.5 maf of depletions to the 8.25 of downstream flow obligation leaves little water for additional use in the Upper Basin. To take into account these limitations on the Upper Basin, the Bureau of Reclamation has optimistically estimated that total Upper Basin consumption can reach about 5.7 maf annually—about 75% of the amount allocated under the Compact.[30] The very limited amount of water potentially still available for consumptive use raises difficult matters of who gets to claim its use.[31] And it highlights the potential insecurity of any such new water supply in extended periods of drought.

How does this affect individual states in the Upper Basin? Under the assumption of a total of 7.5 maf of consumption, Colorado's share (compact entitlement) would be about 3.86 maf. As adjusted by Reclamation, Colorado's share, in reality, would be about 2.95 maf (see Table 4). Without considering its share of reservoir evaporation and channel losses (now totaling about 490,000 acre-feet per year), Colorado currently consumes about 2.3 maf.[32] So how much, if any, is left to develop in Colorado? It's a critically important question, so Colorado commissioned a study to evaluate more closely how much Colorado River basin water remains for development.[33] The study produced a range of possible answers that went from zero to as much as 900,000 acre-feet, depending on hydrological assumptions. Obviously, making wise decisions against this range of uncertainty is a significant challenge.

The other Upper Basin states face the same uncertainty, as summarized below in Table 4. Based on the latest *Consumptive Uses and Losses Reports* (Reclamation, 2013), New Mexico is currently consuming about 413,000 acre-feet annually. Its adjusted allocation is about 640,000 acre-feet. Utah's adjusted allocation is about 1.3 maf, compared to present consumption of

[30] This review is known as the Final Hydrologic Determination 2007, and was prepared as part of the analysis of the Navajo Gallup Water Supply Project (see DOI, 2007). This analysis did not consider effects on Upper Basin hydrology associated with climate change. The 5.7 maf value is consumptive use annually available to the four Upper Basin states after subtracting out evaporation losses and the modest 50,000 acre-feet apportionment of Upper Basin water to Arizona.

[31] These issues are reviewed in detail by Robison and Kenney (2013), among many others.

[32] This estimate comes from the *Consumptive Uses and Losses Report*, 2006-2010 (page v); available at: http://www.usbr.gov/uc/library/envdocs/reports/crs/pdfs/cul2006-2010prov.pdf (cited herein as Reclamation, 2013). The *Basin Study* estimate, as noted earlier, is slightly higher (2.4 maf).

[33] This is an ongoing (multi-phase) investigation under the name "Colorado River Water Availability Study." More information is available at http://cwcb.state.co.us/technical-resources/colorado-river-water-availability-study/Pages/main.aspx.

about 908,000 acre-feet. And Wyoming's adjusted expected total consumptive use is about 800,000 acre-feet while its current consumption is about 382,000 acre-feet. Thus, even under adjusted assumptions, all of the Upper Basin states have Colorado River basin water that is potentially legally available to them for development. But like most Colorado River matters, the math is not that simple.

Table 4. Water Use and Availability in the Upper Basin

State	Compact Allocation	Adjusted Allocation	Current Consumptive Use	Projected Use in 2060
Colorado	3.86	2.95	2.27	2.53 – 3.03
New Mexico	0.84	0.64	0.41	0.68 – 0.98
Utah	1.71	1.31	0.91	1.08 – 1.28
Wyoming	1.04	0.80	0.38	0.58 – 0.77

All values in maf/year. As noted in the text, the "adjusted allocation" is derived by multiplying each state's percentage allocation (from the Upper Basin Compact) to the estimate of physically available water provided in Reclamation's Final Hydrologic Determination (DOI, 2007). The present consumptive use values are the 2006-2010 averages (provisional data) from the *Consumptive Uses and Losses Report* (Reclamation, 2013), and do not include evaporation losses (estimated at 491,000 acre-feet/year). The estimates for Colorado and Utah match closely with those in the *Basin Study*, while the New Mexico and Wyoming values are significantly less.

As shown in the table, Colorado's projected 2060 uses are generally in line with the adjusted allocation, New Mexico's are slightly higher, and Utah's and Wyoming's are slightly lower. At first glance, that is encouraging. However, there are three significant caveats that undermine this assessment. First, the adjusted allocation does not consider the very real possibility of reduced streamflows due to climate change or multidecadal drought. As noted earlier, virtually every modern study of the Colorado projects streamflow reductions by 2060 (Vano et al., 2013). Given the legal obligations of the Upper Basin to deliver a fixed minimum value of water downstream, any future reduction in average streamflow primarily comes out of water allocated to the Upper Basin—the adjusted allocation—and can very quickly eliminate any opportunities for new consumption. Second, as noted earlier, in some states—particularly Colorado and Utah—conditional and permitted rights far exceed consumption considered by the Basin Study. And third, the Upper Basin adjusted allocation is a value estimated to be sustainable (without climate change) in terms of maintaining downstream releases no more than 8.23 maf/year. As noted in the earlier discussion (Section II) of the "structural deficit" in the Lower Basin, releases at this level are devastating to Lake Mead, resulting in a net loss in storage of more than 1 maf/year.

B. Lower Basin

The Colorado River Compact authorized the consumptive use of 7.5 maf per year in the Lower Basin and allowed for an additional 1.0 maf per year of consumptive use if required. The details of this apportionment were reviewed in *Arizona v. California*,[34] where the Court decided that Congress had allocated 4.4 maf/year of mainstem water to California, 2.8 maf/year to Arizona, and 300,000 acre-feet/year to Nevada, not including evaporation and river losses (now totaling roughly 1.5 maf/year) (MacDonnell, 2013).[35] Additionally, the Court seemed to indicate that the Lower Division states (including New Mexico and Utah) through which Lower Basin tributaries pass were free to consume the water in these tributaries. The Court said nothing about the status of the Compact's additional 1.0 maf/year.

The states of Arizona, California and Nevada are all currently using their full apportionments, and extensive consumptive use of tributaries (primarily in Arizona) ensures little additional inflows to the mainstem. Considering evaporation and system losses (roughly 1.5 maf/year) and the delivery obligation to Mexico (1.5 maf/year), well over 10 maf/year is needed from Lake Mead—an amount only sustainable if Powell is making high releases, an increasingly unlikely prospect given projected Upper Basin growth and climate change pressures. But this "structural deficit" is only part of the problem. In reality, the *Basin Study* (as noted earlier) estimates the states of Arizona, California, and Nevada to be consuming roughly 8.3 maf/year from the mainstem—before accounting for evaporation and other system losses—with an additional demand of 0.5 to 1.9 maf/year projected by 2060. In short, the Lower Basin water budget is badly out of shape. Additional depletions are simply not possible; reduced depletions appear necessary. That is the reality.

V. Conclusions

It is difficult to imagine a river where more is expected than the Colorado. We are in an era where average consumptive use demands on the river have caught up with average supplies, leaving us highly dependent upon buffers—reservoir storage and groundwater—which are eroding rapidly. Already, we have seen how vulnerable this delicate balance is to drought. Looking ahead, we see additional threats from climate change and a continued growth in consumptive uses. In this report, we have focused on this projected growth in demands, based on the simple notion that it is the only major stressor that society can actively manage, and is the component of the water budget where the greatest opportunities for solutions are found.

In future reports of the Colorado River Research Group, we will explore many of those solutions. But for now, it is sufficient to observe that every state (and many tribes within those states) project increased Colorado River demands in the future. Based on *Basin Study* scenarios going to 2060, demands on the mainstem are expected to increase anywhere from 1.2 to 3.4 maf/year. Certainly that vision cannot become reality; the numbers will simply not add up.

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[34] *Arizona v. California*, 373 US 546 (1963).

[35] The accounting for these losses is a factor for the Secretary of the Interior to consider when making annual determinations about deliveries to these states.

Attempting to achieve that future will only shatter a water budget that is already showing cracks.

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