RETHINKING THE FUTURE OF THE COLORADO RIVER

Draft Interim Report of the Colorado River Governance Initiative

December, 2010

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List of Tables [in main report only]

List of Figures [in main report only]

I. Introduction

The Colorado River is one of the most thoroughly studied, debated and contested natural resources in the world, and for good reason. For residents of the seven basin states and northwestern Mexico, it is both an economic lifeline and a cultural marker, massively engineered to provide a steady flow of water and hydropower for cities, farms and industry, while retaining enough wildness to showcase a stunning diversity of physical, environmental and recreational amenities. By almost any standard, it is the jewel of the American Southwest—and it is in trouble. Of all that is expected of the river, the primary focus of the struggles and investments—of a political, legal, economic and engineering nature—has been to utilize the river as a water supply source, even when this has meant sacrificing other values and uses. But the ability of the physical and institutional system to fulfill this central function is increasingly in doubt and, for a variety of reasons, is likely to become further compromised should we continue along the current management pathway.

The Colorado River Governance Initiative (CRGI), based at the University of Colorado Law School, is a research project inspired by several decades of research on Colorado River issues, all culminating in the belief that significant institutional reforms must be an essential component of any strategy to effectively address the region's water management challenges of today and tomorrow. Inevitably, this means reexamining the structure and functioning of the "Law of the River," the suite of laws and policies governing water allocation and river management, all built upon the Colorado River Compact (the "Compact") of 1922.[1] It is worth explicitly noting that the CRGI is *not* based on the premise that the Compact must be "thrown out" or "renegotiated"; those actions are not politically viable, and ignore the fact that the core principles articulated in the Compact are appropriate and highly valued. But the way in which those core principles are translated into river management and water allocation will need to be revisited, and undoubtedly will be. This, of course, is nothing new. On many occasions—the latest being the negotiation of the "Interim Guidelines" in 2007[2]—such discussions have occurred, and incremental reform has resulted. What is different now is that we are at a point in which incremental reform along the "traditional" pathway has reached a point of diminishing returns, and may in fact be stifling efforts to consider different, and better, future pathways. It is the aim of the CRGI to show the shortcomings of the current trajectory and, therefore, the

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[1] This paper is designed for individuals with a working familiarity with the basin and its management, including the Law of the River. For those desiring more background information, Appendix A provides a general review.
[2] USBR, 2007. *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.* Department of the Interior. http://www.usbr.gov/lc/region/programs/strategies.html
[3] Much of this discussion draws from the CRGI white paper: "Stressors and Threats to the Water Budget of the
[2] USBR, 2007. *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead.* Department of the Interior. http://www.usbr.gov/lc/region/programs/strategies.html

value of considering significantly different approaches, and to inspire and cultivate the new ideas that will allow basin leaders to more effectively address the challenges that lie ahead.

In this Interim Phase 1 Report, we summarize research and analysis conducted in Year 1 of the CRGI, focused primarily on articulating the argument for significant reform. In the Phase 1 Comprehensive Report due in draft form at the completion of Year 2 (December 2011), this discussion will be expanded to include a more detailed discussion of specific reform options.

II. The Argument for Significant Institutional Reform

The Broken Water Budget[3]

The argument for change on the Colorado River begins with a simple, and largely irrefutable, observation: as a water supply source, the river is already stretched to its limits. There are several indicators of this reality. First, significant flows have not consistently reached its terminus in the Colorado River delta for half a century, as shown in Figure 1.[4]

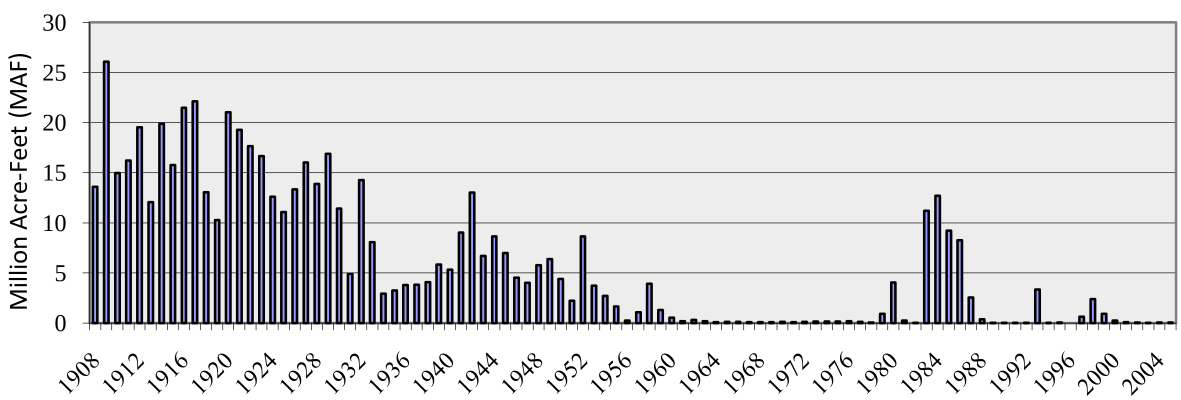

Figure 1. Colorado River Flows to the Delta

[3] Much of this discussion draws from the CRGI white paper: "Stressors and Threats to the Water Budget of the Colorado River Basin" by John Berggren, Doug Kenney, and Anne Bensard (2010). That report is attached here as Appendix B.

[4] Figure 1 is adapted from data compiled by Kevin Wheeler. At one time, the Delta was among the most ecological diverse wetlands in North America; today, it receives roughly 1 percent of the river's natural (i.e., pre-development) flows. As a result, the delta has shrunk to less than a tenth of its original 728,000 hectares (Glennon and Culp, 2002). Nonetheless, it remains an important ecological resource supporting "more than 160,000 shorebirds, 60,000 waterfowl, and a dozen threatened or endangered species of animals, fish, and plants" (Clark et al., 2001: 3). It was named a Ramsar site in 1996. For a review of delta-related environmental issues, see Getches (2003), Luecke et al. (1999), and Pitt (2001).

Obviously, this has had significant ecological ramifications for the Colorado River delta, as both baseline and pulse flows that previously provided important ecological functions have been redirected to build (and rebuild when necessary) the immense reservoir storage that has provided Colorado River users with abundant and highly reliable water supplies.[5] As recently as the late 1990s, Colorado River reservoirs stored nearly 4 years of flow, with the majority of this volume in Lakes Powell and Mead (Figure 2).

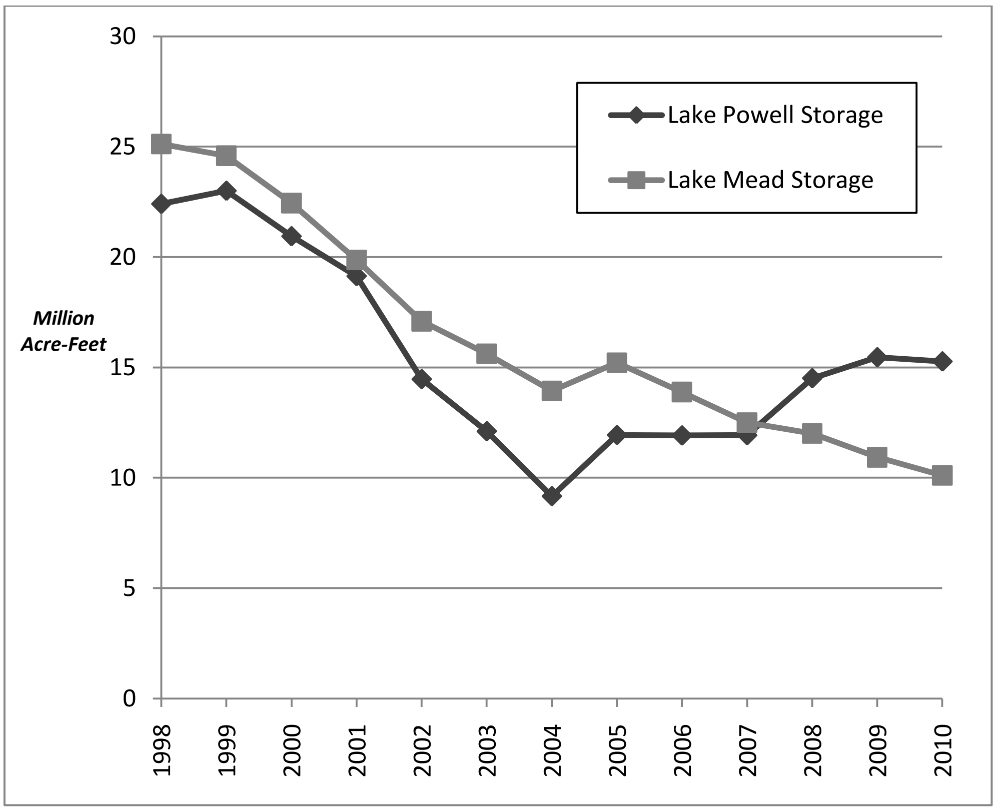

Figure 2. Storage on Lakes Powell and Mead, 1998 to 2010 (September 30th values). (USBR Data).

Finding water to maintain or rebuild storage, however, has recently become unattainable, in part due to the onset of drought conditions. Flows in 9 of the 11 "water years" this century have been below the average of the preceding 30 years (1971-2000) (USBR, 2010). Not surprisingly, this period has seen a precipitous decline in reservoir storage, but it would be dangerous to attribute this reality to drought conditions alone. Perhaps the more salient

[5] The loss of delta flows has also had a tremendous impact on the native peoples, the Cocopah and Cucapá, that have lived in the region for centuries.

contributor is that demands on the system have now caught up with (and likely exceed) long-term supplies on the system *even without drought conditions*, as shown below in Figure 3.

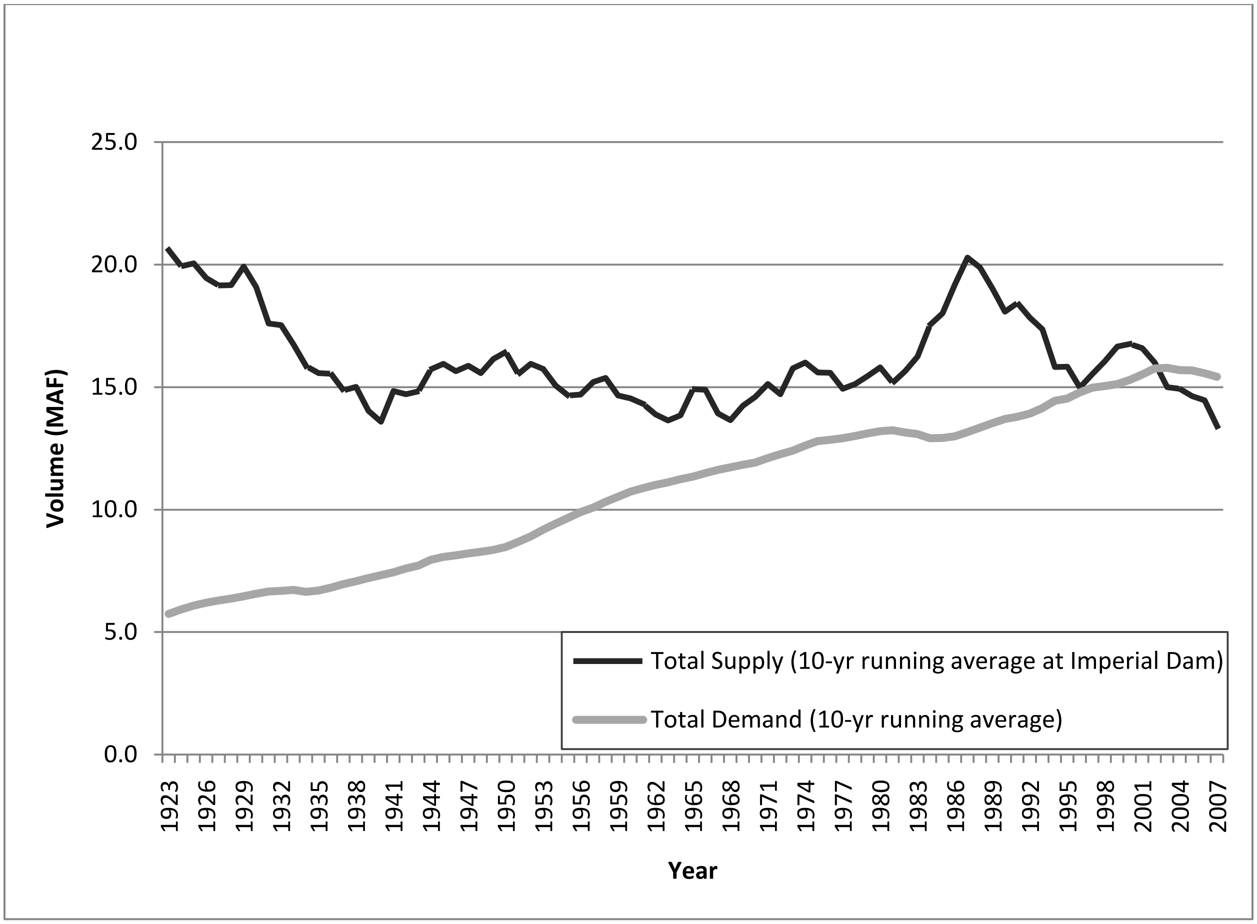

Figure 3. System-wide Supplies and Demands.[6]

As discussed in detail by Kenney et al. (2010), and summarized (in part) in Appendix B, the declining reservoir storage in Lakes Powell and Mead best illustrates the interaction of drought and the growth in demands. Figures 4 and 5 (below) show the relationship of reservoir storage to inflows, which in the case of Lake Powell (Figure 4), is largely influenced by drought—i.e., as

[6] Data and methodology for this figure was provided by the U.S. Bureau of Reclamation. In this figure, supplies are the sum of natural (undepleted) mainstem flows originating upstream of Lake Mead, plus Lower Basin tributary flows that actually reach the mainstem above Imperial Dam. Demands are the official accounting of consumptive uses of mainstem water. Note that water originating in Lower Basin tributaries that is consumed before reaching the mainstem is neither included as either supplies or demands. Thus, the supply line and demand line are both a little low (if the intent were to truly describe total surface water supplies and demands in the Colorado River System), but the spread between them is accurate, which is the primary purpose of this figure.

natural flows have declined, reservoir storage has followed. But Lake Mead (Figure 5) is more complicated, as inflows in the early 1990s and the 2000s are nearly identical, but while that resulted in a stable reservoir in the first period, it results in storage losses—of roughly 1 million acre-feet (MAF)/year—in the modern era.[7] What changed? Lower Basin demands have grown to a level that are only sustainable if the Upper Basin makes releases beyond its Compact and Treaty obligations.[8] A complex operational schedule, based on relative volumes of Lakes Powell and Mead, is established to determine when such releases—termed "balancing" or "equalization" (based on the conditions)—will occur. Releases from Powell of greater than 8.23 MAF should occur in 2011, which will provide some temporary relief for the Lower Basin, but only at the expense of reduced storage upstream in Lake Powell (USBR, 2010).[9]

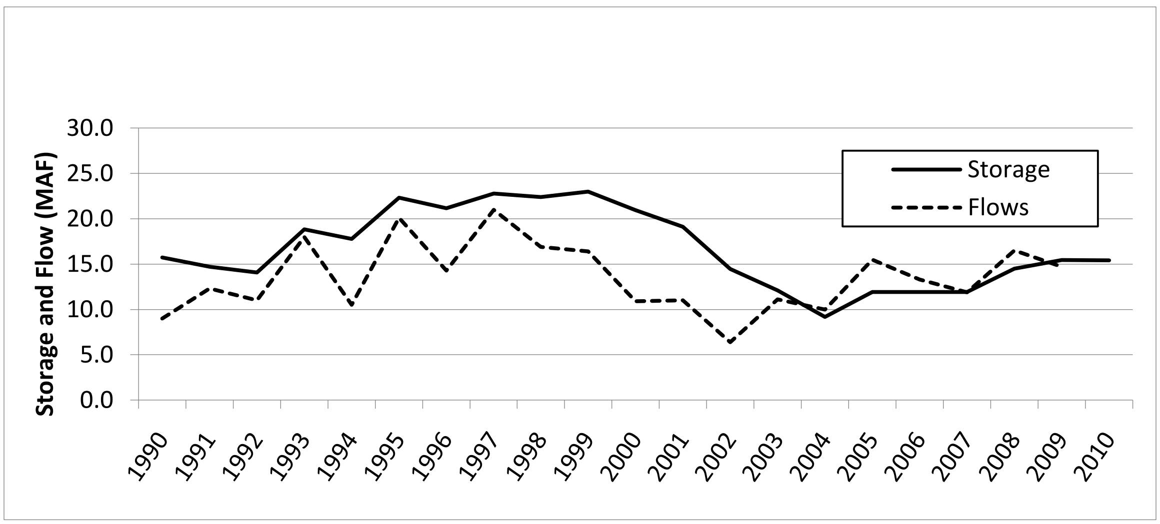

Figure 4. Storage in Lake Powell as a Function of Natural Inflows

[7] It should be noted that Lake Mead's elevation recently dropped to its lowest level, 1,083 feet above sea level, since the reservoir began filling in the late 1930's. See: http://www.azcentral.com/arizonarepublic/news/articles/2010/10/19/20101019lake-mead-water-level-new-historic-low.html

[8] Presumably, the minimum objective release of 8.23 MAF/year is sufficient to cover the Upper Basin's obligation to deliver 75 MAF/10-years (or 7.5 MAF/year) under Article III(d) of the Compact, and half of the Upper Basin's minimum obligation of 1.5 MAF/year to Mexico. (The 20,000 acre-foot difference is comprised of inflows from the Paria River, downstream of Lake Powell but upstream of Lee Ferry.) Many interests contend that the Upper Basin does not currently have any obligation to contribute to the Mexican delivery, as that water is supposed to come from surpluses that, arguably, are currently being consumed in the Lower Basin. For more information, see Carlson and Boles (1986) and Kuhn (2007).

[9] As of September 2010, it was expected that Lake Powell elevations would climb high enough to trigger "equalization" releases in 2011, resulting in an annual release of approximately 11.3 MAF (USBR, 2010). However, due to an unexpectedly dry Fall, it is now more likely that Powell will remain in the lower tier—the Upper Elevation Balancing Tier, rather than the Equalization Tier—resulting in a "balancing" release of approximately 9 MAF.

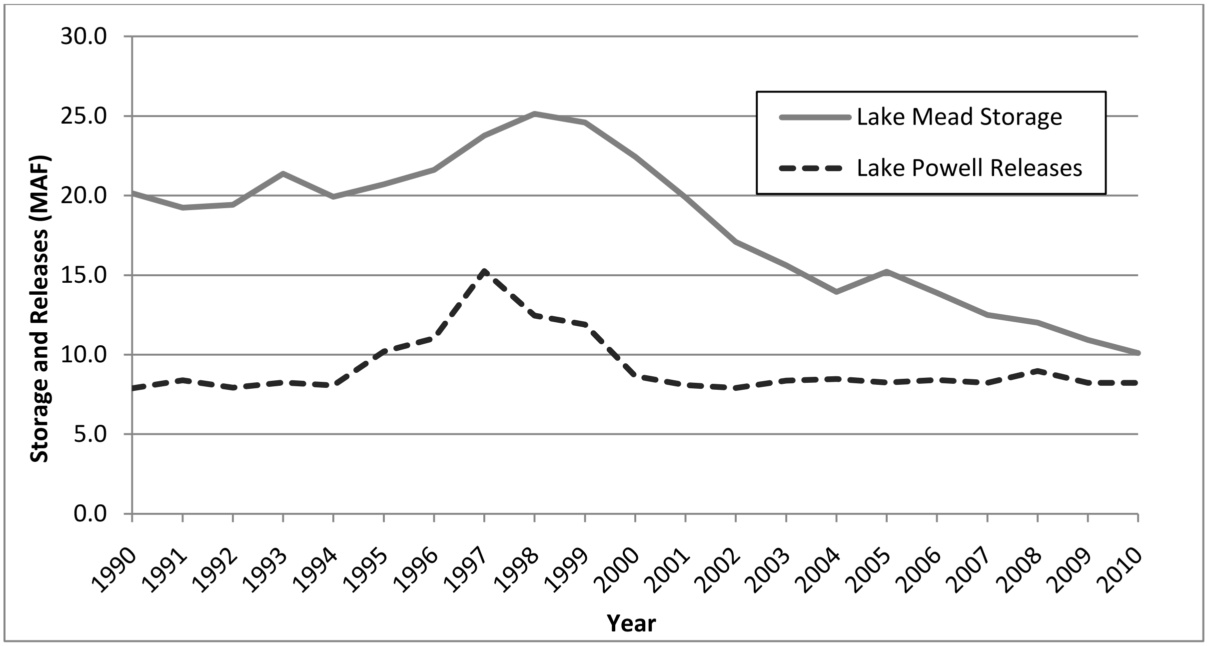

Figure 5. Storage in Lake Mead as a Function of Lake Powell Releases[10]

Looking long-term, is there reason to believe that storage in Lake Powell will grow, thereby allowing "extra" water to consistently be released from Powell for the benefit of Lake Mead? To answer this question, one must look at what is happening upstream of Powell, regarding both demands and supplies. For both variables, the trend lines are not encouraging. As shown below in Table 1, Upper Basin depletions are projected to grow significantly over the next half century.[11] Counting evaporative losses, Upper Basin depletions in 2055 are estimated at 6.1 MAF/year, roughly 2.1 MAF higher than 2005, although still well below the 7.5 MAF/year allocated to the Upper Basin by Article III of the Compact.[12]

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[10] Adapted (and updated) from Kenney et al (2010), figure 4.

[11] Data provided by the U.S. Bureau of Reclamation. Data for 2005 are actual use (provisional data); other years are from the updated Upper Basin Depletion Schedule. Future evaporation losses are estimated at a constant 560 KAF/year. Estimated losses to native vegetation are not included.

[12] A great deal of skepticism has always surrounded the Depletion Schedules, as some view the data as wishful thinking or political posturing more so than sound water planning. This is one of several thorny issues that are being confronted in the Colorado River Basin Water Supply and Demand Study (or simply the "Basin Study"), which is a two year effort led jointly by the Bureau of Reclamation and the basin states. The $2 million study will identify water supply and demand imbalances in the basin between now and 2060, and will include a review of potential adaption and mitigation strategies to address those imbalances. The Basin Study will be complemented by another study conducted by the United States Geological Survey called the Colorado River Basin Geographic Focus Study. The USGS study will be conducted over a three-year period and will attempt to identify how much water is demanded from the Colorado River Basin, including water to support ecosystems. For additional information, see the Basin Study website and Department of Interior press release: http://www.usbr.gov/lc/region/programs/crbstudy.html

Table 1. Projected Upper Basin Depletions (KAF/year)						
Water Year	**2005**	**2015**	**2025**	**2035**	**2045**	**2055**
Colorado	1,856	2,819	2,867	2,905	2,937	2,955
New Mexico	466	574	622	639	642	642
Utah	853	931	994	1,075	1,141	1,163
Wyoming	405	591	670	727	743	757
Arizona (UB apportionment)	37	50	50	50	50	50
Upper Basin Total	3,618	4,965	5,203	5,396	5,513	5,567
Total Upper Basin Consumption (including evaporation)	4,012	5,525	5,763	5,956	6,073	6,127

The assessment of future supplies is even more fraught with uncertainty. If the current dry period is, in fact, just a temporary drought that will eventually subside, then a return to “normal” or “above-normal” flows could bring significant relief to the basin—although it is worth remembering that *average* demands on the system already equal *average* (non-drought) supplies, even before additional Upper Basin growth is considered. But is a return to “average” reasonable in an era of climate change? As discussed in detail in Appendix B, the overwhelming majority of research suggests a decline in future flows due to climate change, coupled with a likely increase in drought frequency and intensity. Projections vary significantly regarding the magnitude of flow declines, however, a review by Milly et al. (2005) found that greater than 90% of the climate models project decreases of 10-30% for the time period 2041-2060. Assuming a long-term average annual flow of roughly 15 MAF (at Lee Ferry), this translates to annual future flows in the range of 10.5 - 13.5 MAF.

Even if operating on an assumption of no growth in demands and no decline in supplies, the current system is operating at full capacity (as shown by Figure 3), and is unstable during drought years (as shown by Figures 2 and 5). A future with increased demands and decreased flows is untenable. As evidence, Figure 6 (below) extends the Figure 3 snapshot into the future, plotting demands based on official depletion schedules, and utilizing an unusually modest

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http://www.doi.gov/news/pressreleases/Secretary-Salazar-Launches-New-Regional-Climate-Science-Center-and-Water-Census-at-Meeting-of-Colorado-River-Basin-Water-Leaders.cfm projection of supply declines (roughly 7%).[13] Additionally, rather than focus on total system-wide demands (as done in Figure 3), Figure 6 focuses only on those supplies (and the demands on those supplies) that enter the mainstem at or above Lake Mead, as the modern operating rules (as described by the Interim Guidelines) largely hinge on storage in, and withdrawals from, Lake Mead. This is done to foreshadow later discussions about the challenges facing the Law of the River and issues of interbasin management.

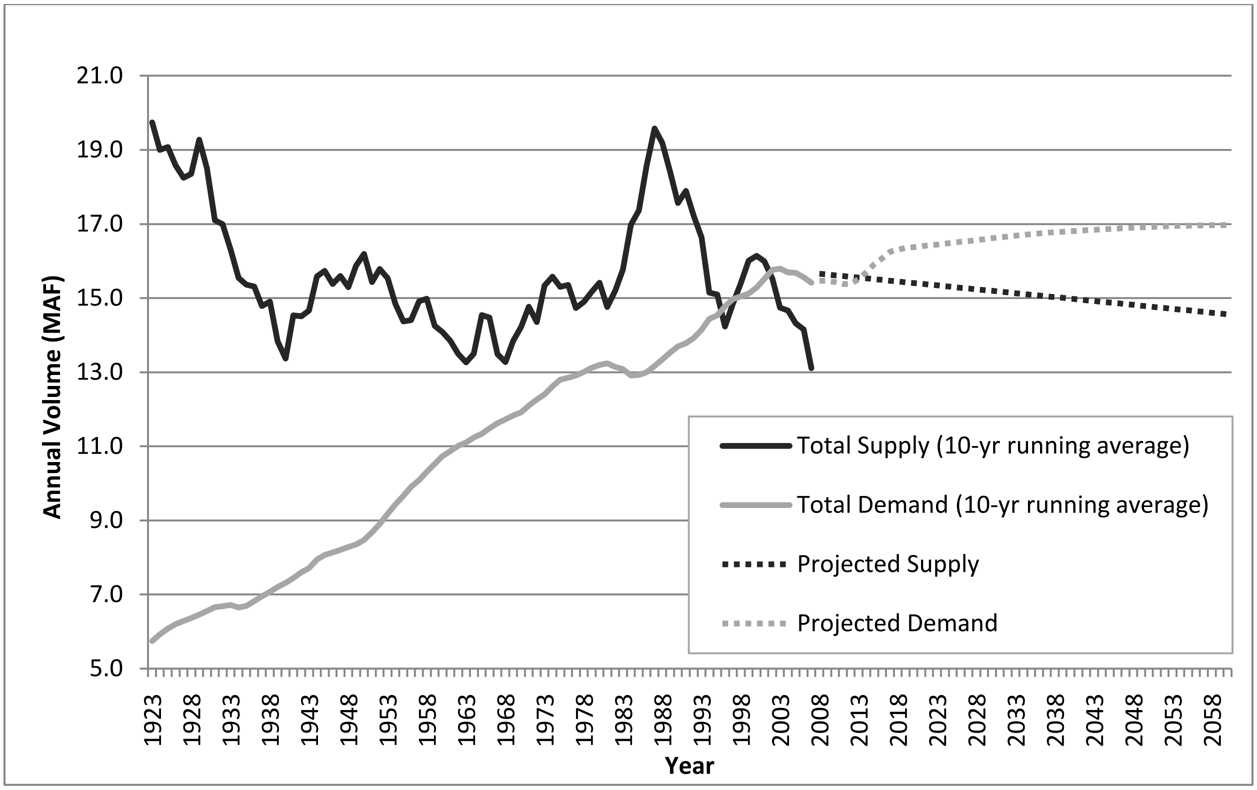

Figure 6. Supplies and Demands of Mainstem Water[14]

[13] Among the most sophisticated and modern of the highly regarded climate change studies on the Colorado, this level of decline is the lowest cited (by Christensen and Lettenmaier, 2006). Thus, this may be a best-case scenario in terms of supplies.

[14] Specifically, the demand line includes consumptive uses (from the mainstem) by both Upper Basin and Lower Basin users, plus minimum treaty deliveries to Mexico, plus ET losses. Projections are based on the assumption of "full use" (7.5 MAF) in the Lower Basin, and the Upper Basin depletion schedules (starting in 2008). These projections do not include uses (or contributions) of tributaries downstream from Lake Mead or overdeliveries (including spills) to Mexico. The supply line is Lees Ferry natural flow, plus the "intervening" flows between Powell and Mead (roughly 860 KAF/year). While those intervening flows are not officially part of the primary interbasin apportionment, under the current operating (and water accounting) regime, they currently provide a significant source of supply that is used to provide Lower Basin deliveries from Lake Mead. (All data from is from Reclamation.) The future supply line, as indicated above, is simply a linear decline of roughly 7%.

In summary, the water budget on the Colorado River is currently at its breaking point, and while an easing of drought conditions would undoubtedly provide short-term relief[15], the long-term trajectory points to an unsustainable situation. Of course, ultimately, the laws of physics will win out, and average demands will be limited to the level of average supplies. That is not in doubt. It is also not in doubt that the manner in which supplies and demands are balanced will vary significantly from state to state, as the Law of the River does not treat all states equally in terms of allocations and priorities. The question before water leaders is what pathway will be utilized to achieve the inevitable reconciliation of the water budget. This issue is discussed in the next section.

The Current Pathway to Reconciliation

"Governance" is a general term used to describe the various activities of government relating to decision-making and management. The reason for the CRGI is called a "*governance initiative*" is that the mechanisms and approaches traditionally used to "govern" the Colorado River not only shape existing law and policy, but greatly influence the boundaries of what is, and is not, possible in the future. Two aspects of the approach used in the Colorado are particularly noteworthy. First is the tradition of reactive policy-making—i.e., major negotiations and policy initiatives generally occur when prompted by crisis, such as the recent Interim Guidelines arising from the sharp decline in reservoir storage. And second, most negotiations and resulting policy initiatives closely follow a model that emphasizes (a) further interpreting and defining rights, and (b) then enforcing those rights. Again, the Interim Guidelines provide an excellent example, as the rules clarify (in a quantitative way) the manner in which Central Arizona Project (CAP) rights are junior to California's apportionment, and provide a process and schedule for implementing the necessary curtailments. Neither or these qualities of Colorado River governance are particularly novel—incremental, crisis-based management describes activities in many sectors and by many governments. These qualities are nonetheless worth acknowledging, in that they not only shape the current trajectory of management, but can also be an impediment to considering other approaches.

Figure 7 (below) illustrates three possible pathways to dealing with Colorado River issues. These categories are obviously quite general and are not exhaustive or mutually exclusive, but they do capture the majority of conversations focused on the future of the river, and do help frame the remaining discussions about solution options. As mentioned earlier, the governance process typically begins when a triggering event (e.g., drought) creates a management dispute

[15] The recent shift in ocean temperatures from El Nino to La Nina conditions suggests the next couple years could remain unusually dry in the Southwest, although conditions in the critical source-water watersheds in Colorado and Wyoming may be unaffected. http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/

that hinges on some contested element of the Law of the River. As noted on the figure, the Law of the River, while complex and detailed, has numerous omissions and ambiguities that provide the basis for argument.[16] While litigation is always an option in such disputes—the *Arizona v. California* (1963) experience being the obvious example—a more common approach is to either negotiate a solution (perhaps a temporary solution) among the basin states, or for a state to simply make assumptions about how the issue is likely to eventually "play out" in the future, and base present day management decisions accordingly.

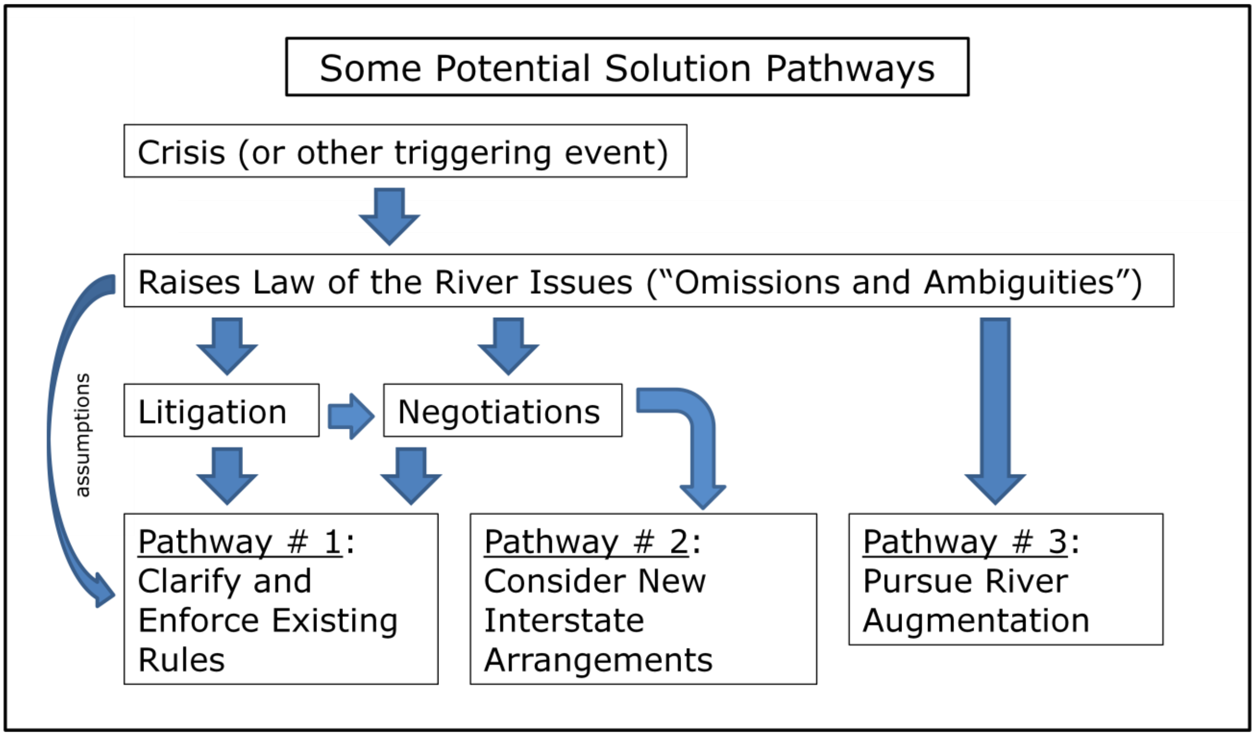

Figure 7. Potential Pathways for Addressing Colorado River Issues

But regardless of the stimuli involved and the dispute resolution process utilized, this series of events is most notable in that it leads to a pathway distinguished by a core set of ideas about how best to deal with Colorado River disputes. Pathway # 1 is the "traditional" pathway; i.e., this is the best description of how problems are typically framed and actually addressed on the Colorado. In this pathway, the goal of decision-making is to inject further detail and clarity into the Law of the River about the magnitude and/or priority of allocations to each state (and Mexico), to devise river management regimes to ensure compliance with those allocations, and to then defer to each state the responsibility to devise internal water management strategies. It is an approach that derives from the philosophy of water allocation compacts more generally, in that it is state-centric, and is based on the assignment of permanent rights rather than

[16] Several of these "omissions and ambiguities" are mentioned in the Law of the River summary in Appendix A.

dynamic or needs-based allocations.[17] At the other end of the spectrum is Pathway # 3, which is based on the premise that the best way to avoid or solve water supply disputes on the river is to augment supplies through mechanisms as diverse as cloud seeding, desalination, trans-basin imports, phreatophyte removal, and so on.[18] The remaining approach, Pathway # 2, is the least defined at this point, but is the area that best describes the focus of the CRGI. Pathway # 2 is a catch-all for approaches that are institutional and "interbasin" in nature—i.e., that focus on the rules governing the relationship between the Upper and Lower Basin—and that look to cultivate new agreements and governing processes that retain the intent and core values of the existing framework, but through new rules and arrangements that, in some cases, constitute more significant departures from current management and legal interpretations than what is seen in Pathway # 1.[19] The remaining pages primarily compare the merits of Pathways 1 and 2; augmentation-based solutions (Pathway # 3) are mentioned in a few instances, but are largely outside the institutional focus of the CRGI.

Shortcomings of the Current Approach

Analysts who contend the current approach (Pathway # 1) is "unworkable" or "unsustainable" have good reasons to be critical, but the full and aggressive application of this approach is certainly possible and, if no intervention occurs, is inevitable. The question is whether the "costs" of this approach to reconciling the Colorado's broken water budget are needlessly high—or stated differently, could those costs be reduced by considering ideas that currently lie outside the typical framing of problems and solutions? To answer this question requires considering how the current trajectory will play out. As discussed below, doing that thought exercise identifies several deficiencies of the current pathway that not only violate the intent of the Compact, but may undermine its long-term viability. Two issues are of particular concern: the Upper Basin climate change squeeze, and the role of compact calls in basin administration.

[17] It is worth noting that this "compacts model" is very different than either the equitable apportionment model or the approaches most typically seen in other countries, which tend to be more "needs based" and subject to periodic adjustment. As Wolf (2005: 150) notes: "What one notices in the global record of water negotiations is that several of those surveyed begin where many western United States issues are now, with parties basing their initial positions in terms of rights…. In almost all of the [transboundary] disputes globally which have been resolved, however, particularly on arid or exotic streams, the paradigms used for negotiations have not been 'rights-based' at all … but rather 'needs-based.' Similarly, successful frameworks in the international experience are flexible; flexibility in agreements is almost more critical than the initial agreements themselves."
[18] The Southern Nevada Water Authority recently funded a review of potential options entitled "Study of Long-Term Augmentation Options for the Water Supply of the Colorado River System" (Colorado River Water Consultants, 2008).
[19] It is readily acknowledged that a number of innovative arrangements have been crafted in recent decades among the Lower Basin states. However, a similar level of activity has not been as the interbasin scale, nor among the Upper Basin states. As explained in the following pages, these are the scales at which future institutional innovation appears most urgent.

The Upper Basin Climate Change Squeeze

The so-called “Upper Basin climate change squeeze” refers to the observation that the Upper Basin apportionment is essentially the last priority on the river, and as average flow volumes decline, this apportionment bears the full brunt of the “squeeze” of reduced water availability. The categorization of the Upper Basin apportionment as being the last priority is a delicate issue[20], but is based on the workings of Article III(d) that requires “the States of the Upper Division [to] 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 is a *de facto* delivery obligation, and while the Compact was initially pursued as a mechanism to ensure that the priority system was not implemented across state lines, it essentially does just that as it pertains to the three major classes of Colorado River allotment holders: the Lower Basin, the Upper Basin, and Mexico. Many efforts have been made over time (and are still ongoing) to ensure that the Lower Basin and Mexico (pending[21]) will, except in surplus periods (if any), be limited to their stated apportionments. This is shown below in Table 2. In no year since 2003 has total (pre-evaporation) Lower Basin consumption from the mainstem exceeded the 7.5 MAF threshold, and is not projected in the Depletion Schedules to ever do so again.[22]

[20] There is a significant literature reviewing how the Law of the River prioritizes allocations. For example, see MacDonnell et al. (1995), Clyde (1960), Grant (2003), and Saunders (1998). As noted, most categorize the Upper Basin as having a delivery obligation (and thus a junior priority) to the Lower Basin. A somewhat contrary argument is offered by Kuhn (2007), who argues that the Upper Basin would not be responsible for increased river depletions associated with climate change. The distinction hinges on whether or not the Upper Basin has a “delivery obligation” or an obligation “not to deplete.” While the Compact uses the latter language, other Law of the River documents, including the Upper Basin Compact, use both terms.

[21] Negotiations with Mexico regarding triggers and curtailment schedules for the Mexican apportionment are underway, and quite possibly will be concluded shortly. The 2007 EIS contains a Mexican apportionment curtailment schedule, but that was hypothetical (i.e., was not based on any agreement with Mexico).

[22] This conclusion is based on provisional supply and demand data provided by the U.S. Bureau of Reclamation. The key to this achievement has been the accelerated (and voluntary) implementation of California’s plan to reduce consumption to 4.4 MAF, a goal achieved in 2003. When evaporation is considered, 8.735 MAF of Lake Mead water is actually consumed to achieve the 7.5 MAF of consumptive use.

Table 2. Efforts to Clarify and Enforce Existing Water Allocation Rules (Pathway # 1)				
	Party	**Process / Rule**	**Outcome**	**Timing**
Lower Basin	California	Interim Surplus Guidelines (2001) et al. (QSA, 4.4 Plan)	From ~ 5.2 MAF to 4.4 MAF	Early 2000s
	Arizona (CAP), Nevada	Interim Guidelines	Staged curtailments as needed	2007 to 2026
	Mexico	Ongoing negotiations	Staged curtailments as needed	Pending
Upper Basin	All upper basin	Acknowledgement of over-allocation	7.5 MAF to ~ 6 MAF	Clarified in 1940s–60s
	All upper basin	"Climate Change Squeeze"	~ 6 MAF to Present Perfected Rights (perhaps 2.2 MAF)	Coming decades

While limiting the Lower Basin to its 7.5 MAF mainstem apportionment is frequently viewed in the Upper Basin as a policy victory that protects the Upper Basin apportionment, it may actually have the opposite impact, as it further reinforces the "define and enforce" approach (Pathway # 1) that now points directly at the Upper Basin—and to a much lesser extent, Mexico—as the next target for belt-tightening. Of course, as every Colorado River scholar understands, the Upper Basin apportionment of 7.5 MAF described in Article III(d) of the Compact has long been understood as being unrealistic, as the over-apportionment of the river by Compact negotiators due to flawed estimates of average flows have long forced Upper Basin planners to assume a "practical" apportionment no higher than 6 MAF.[23] Given climate change estimates, this figure now seems unrealistically high. In fact, it is now possible to foresee a situation in which Upper

[23] The story of the over-apportionment has been told by many authors; the classic account is by Hundley Jr. (1975). Among the first prominent studies to articulate a reduced Upper Basin apportionment was the report by Tipton and Kalbach Inc. (1965). That report examined a variety of different scenarios, based on different Upper Basin storage capacities, delivery requirements, and evaporative losses, and estimated Upper Basin water availability to range from 4.7 to 6.3 MAF.

Basin users could be curtailed to a point of present perfected rights (PPRs)—i.e., those uses already in existence when the Compact was signed. As noted in Appendix A, the magnitude of Upper Basin PPRs are contested, but are likely in the range of 2.2 MAF.

The potential impact of the climate change squeeze on the Upper Basin is shown in Figure 8, which plots available water to the Lower Basin, Upper Basin, and Mexico under a variety of climate change scenarios (defined in terms of average annual flows at Lee Ferry). The figure is based on a host of highly debatable assumptions and simplifications; thus, it should be viewed as a starting point for discussion, rather than a formal projection or legal interpretation. Specifically, in scenarios where the long-term average Lee Ferry flow is 14.5 MAF/year or higher, it assumes that the Upper Basin will be required to maintain a minimum delivery schedule of 8.23 MAF/year in order to satisfy the Compact and Treaty, and that the Lower Basin will be required to pass 1.5 MAF/year of this water to Mexico, with the remainder available for use by the Lower Basin. In scenarios where the long-term average Lee Ferry flow is 14.0 MAF/year or less, it assumes the Upper Basin will be required to maintain a minimum delivery schedule of 8.18 MAF/year in order to satisfy the Compact and Treaty, and that the Lower Basin will be required to pass 1.4 MAF/year of this water to Mexico.[24] All values are maximum water available for use before subtracting evaporation or other losses.

[24] The Depletion Schedules project constant future deliveries to Mexico of 1.574 MAF/year, so capping the delivery at a maximum of 1.5 MAF assumes no wastes or overdeliveries. Limiting these deliveries to 1.4 MAF translates to a further reduction of roughly 7 percent (from 1.5 MAF), with half of the 0.1 MAF curtailment being removed from the Upper Basin's 8.23 MAF delivery obligation (leading to a minimum delivery schedule of 8.18 MAF). Again, these numbers and approach are highly debatable, but are based on assumptions that are believed to be consistent with plausible interpretations of the Law of the River. A very similar exercise is done by MacDonnell et al. (1995: Table 1 on page 830), in which deliveries to the Lower Basin are held stable at 8.23 MAF (and thus do not anticipate any curtailments to Mexico, or any reduction in the Upper Basin's contribution to the Mexican delivery). Presumably, that is a worse-case scenario for the Upper Basin. A best case scenario for the Upper Basin would be based on the argument that the Upper Basin has no obligation to deliver water for Mexico as long as the Lower Basin is using more than 1 MAF of tributary flows (for a discussion, see Carlson and Boles, 1986; Kuhn, 2007; and others). Figure 8, thus, is a "middle-ground" scenario. Regardless of the scenario chosen, all show a precipitous decline in Upper Basin supplies under climate change.

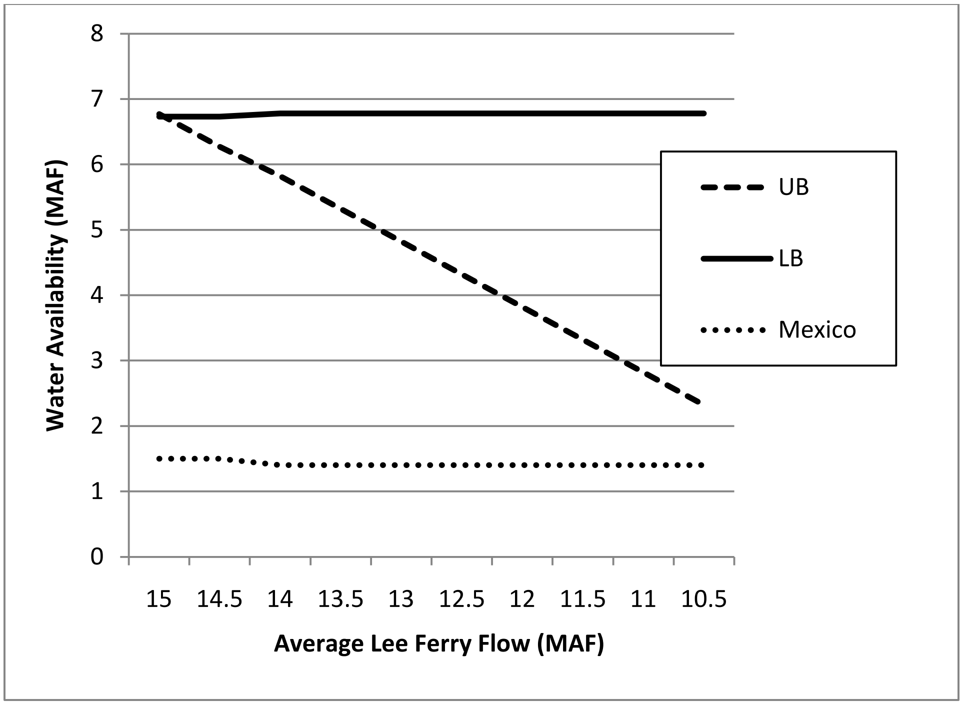

Figure 8. Water Availability (by sub-basin) as a Function of Long-Term Average Flows

Again, while the assumptions and simplifications inherent to this figure are important and are certainly worth debating, the overarching point is that the Law of the River (as implemented by the Interim Guidelines) provides a remarkably equal sharing of water between the Upper and Lower Basins, which was the intent of the Compact (Carlson and Boles, 1986). At an average Lee Ferry flow of 15 MAF (the long-term gauged average), neither basin is afforded the 7.5 MAF described in Article III(d) (especially once evaporation and system losses are considered), but the burden of over-apportionment is shared equally—except, of course, that the Lower Basin retains exclusive rights to Lower Basin tributary flows.[25] Thus, as noted earlier, the existing trajectory (assuming a roughly 15 MAF/year future of Lee Ferry flows) calls for some Lower Basin curtailments, but they are of a manageable scale.[26]

The bigger lesson of Figure 8, however, is to illustrate the extreme vulnerability of the Upper Basin to climate change. In no region of the United States are climate models as consistent in

[25] Between Lee's Ferry and Imperial Dam, tributary flows are likely in the range of 1 to 3 MAF/year, with spikes from 6 to 9 MAF/year. (This conclusion is based on preliminary paleohydrology research being conducted by the Western Water Assessment.) As noted elsewhere, the defining of Lower Basin tributary flows as outside the basic interbasin apportionment is still a sore and contested point among many Upper Basin interests. While this matter was mostly settled by the *Arizona v. California* litigation, it is still argued that tributary flows in excess of 1 MAF are surplus flows and, as such, are the intended supply for the Treaty deliveries.

[26] "Manageable," of course, is a relative term. For irrigators reliant on Central Arizona Project (CAP) deliveries, projected Lower Basin curtailments could be a serious and chronic problem. The point is that Lower Basin curtailments would be "capped" (no pun intended) at a level somewhere around 1 MAF/year, even if significant climate change reshapes the hydrologic character of the region.

their predictions of future conditions as they are in the Southwest. In a review of the 19 GCMs (global circulation models) used in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Seager et al. (2007: 1) note that "there is a broad consensus amongst climate models that this region will dry significantly in the 21st century and that the transition to a more arid climate should already be underway." In fact, 18 of the 19 GCMs project a dryer climate by 2021-2040.

The decreased future flows associated with a "modest" climate change scenario are problematic; they are a disaster at high levels of climate change. As noted earlier (and discussed further in Appendix B), Milly et al. (2005) found that most climate change studies project a mid-century decline in Lee Ferry flows of 10 to 30 percent, which translates to an average flow of 13.5 and 10.5 MAF, respectively. At a flow of 13.5 MAF (the 10% scenario), Upper Basin water availability is estimated in Figure 8 as falling to 5.3 MAF (counting evaporation). According to the Upper Basin depletion schedules, this threshold has already been surpassed (at 5.4 MAF), although as noted earlier, those schedules are assumed to be high; Reclamation estimates for the period 1998-2007 (which includes provisional data from 2001-2007) suggested an annual average of 4.3 MAF (not counting losses to native vegetation), which according to Figure 8, is roughly what the Upper Basin could expect under a 12.5 MAF Lee Ferry scenario (roughly a 17% reduction from 15 MAF). Thus, a relatively modest climate change scenario suggests that by mid-century, the Upper Basin apportionment could be roughly equal to Upper Basin uses a half-century earlier. The more extreme scenario (30%) restricts the Upper Basin to about 2.3 MAF, roughly equivalent to estimates of the basin's Present Perfected Rights (PPRs)—i.e., the amount of water in use by the basin in the 1920s. While flow reductions on this scale may sound implausible, it's worth observing that Lee Ferry flows in the first decade of this century has thus far averaged 12.1 MAF (19% below 15 MAF) (UCRC, 2009). According to the Figure 8 calculation, this would translate to a long-term Upper Basin water availability of approximately 3.9 MAF, a figure matched or exceeded in actual Upper Basin consumption every year since 1980.

The Potential Role of Compact Calls in Future Basin Administration

As a practical matter, we will never know the extent of climate change in the basin until it happens (or fails to happen); even the most confident climate scientist will concede that their projections are almost certain to be wrong to some extent. Consequently, despite the cautionary tone of the preceding discussion, it is safe to assume that some Upper Basin utilities, water districts, and other individuals, perhaps encouraged by their state governments, are likely to continue to advocate a course of continued water development.[27] Much like a stream governed by prior appropriation, this is likely to continue until reaching a point in which calls on the river make further development unattractive to even the most optimistic water developer, or to those developers that have the ability to utilize highly intermittent supplies. At the scale of the Colorado River, this suggests that the Upper Basin may continue development until stopped by interbasin Compact calls, as this in the only way to ensure that the Upper Basin gets its maximum possible allotment—albeit still way below the 7.5 MAF promised in Article III(d).

Although it has never happened, it is generally surmised that a call would entail at least three contentious and phased efforts (MacDonnell et al., 1995). First, a call between the Upper and Lower Basin would require an assessment of the magnitude and timing of downstream deliveries required to bring the Upper Basin back in compliance with the Compact. Second, a system of reservoir releases and user curtailments would need to be allocated among the Upper Basin states, presumably using the rules featured in the Upper Colorado River Basin Compact, as overseen by the Upper Colorado River Commission (Hobbs, 2009). And third, state water officials would need to devise and enforce curtailments within each state. Every aspect of every stage figures to be filled with bitterness, data deficiencies, legal challenges, and perhaps most importantly, a likely unrealistic expectation that Upper Basin water officials will ultimately take actions that they will feel to be unjustified given the fact that Lower Basin uses—especially when considering tributary uses—would likely be 2 to 3 times higher than those in the Upper Basin. Just navigating the first phase of a Compact call could take years, as omissions and ambiguities in the Law of the River—many summarized in Appendix A—could overwhelm current means of governance and conflict resolution.[28] Not only might the Law of the River prove unmanageable, but it may actually collapse under the weight of the situation. As evidence, consider the fact that Compacts are, legally, contracts (as well as statutes), and that the Colorado River Compact was a contract based on a factual error (about average flow volumes), an expectation of equal sharing, and an ignorance of climate change. If the agreement can be shown to be severely deficient in those or other areas, then it may be subject to a fundamental reinterpretation or restructuring by the Supreme Court (e.g., *see* Getches, 1985; Grant, 2003; and Adler, 2008). While this seems unlikely, the potential interbasin

[27] One such water development project is a proposed pipeline from the Green River at Flaming Gorge Reservoir in Wyoming to the Front Range in Colorado. The 560-mile pipeline would pump approximately 250,000 acre-feet per year; capital costs are estimated to be over $7 billion with annual operating costs around $123 million. The pipeline, which is being proposed by Colorado entrepreneur Aaron Million, would bring significant amounts of water to the Front Range, but has garnered opposition in Wyoming, Utah, and even Colorado (see: http://trib.com/news/state-and-regional/article_c2c3dbeb-1f1c-5ca7-a432-077a0ff43c39.html).

[28] It's worth noting that the Secretary of the Interior is, essentially, the river master for the Lower Basin, but likely does not have the same breadth of legal authority over the Upper Basin (Hobbs, 2009). This conclusion is based on the *Arizona v. California* litigation. Likewise, the unanimity rule that surrounds existing mechanisms of interstate negotiation is likely to be poorly suited to such an obvious zero-sum conflict. For more information on the resolution of interstate river conflicts, see Schlager and Heikkila (2009).

allocation inequities shown in the scenarios of Figure 8 may be too extreme to ignore; a precedent for this type of action already exists: in *Texas v. New Mexico* (467 U.S. 1238 (1984)), the Supreme Court used contract law to change the flawed allocation formula in the Pecos River Compact.

Moving beyond the formidable legal and governance challenges, river management via Compact calls also raises a host of water management issues. For example, management via Compact calls all but ensures that major reservoirs are perpetually low (or empty), which will result in chronic Lower Basin curtailments (as Lake Mead would never receive surplus flows), a greatly enhanced drought vulnerability, few opportunities (or ability) to maintain environmental flows or recreational resources, reduced (or eliminated) hydropower production, and so on.[29] Additionally, it means that the newest developers of Colorado River water in the Upper Basin would often be imposing these, and related, costs and vulnerabilities on existing users. Under the current incentive and management structure, how is a current water user—in either sub-basin—expected to insulate themselves from these impacts? Undoubtedly, a variety of clever coping mechanisms could be developed[30], but they would likely be complicated and costly, and to the extent that efforts are designed merely to *cope with* rather than *prevent* a Compact call, they are a limited and partial solution to administrating water scarcity. Accepting a future of river management via Compact calls is, at best, a missed opportunity; at worst, it is a policy failure that abandons the cooperative interbasin spirit of the Law of the River, while largely invalidating the benefits of river development and reservoir storage for which basin residents have paid a high economic and environmental price.

III. Understanding the Resistance to Change

The shortcomings of the current trajectory of river management suggest that, at a minimum, fundamental modifications of inter-basin arrangements should be a subject of exploration and discussion among basin leaders. In bits and pieces, this occasionally happens; the research and negotiations associated with the 2007 EIS and the ongoing Basin Study are examples. Other, quieter discussions continue among basin leaders. But fears about the possible directions of change, and substantive misunderstandings about the need for innovation, often combine to

[29] Chronically low reservoirs could have some benefits. Most obviously, losses to reservoir evaporation would be reduced. Also, low storage levels in Lake Powell would open up some flooded canyons to "rediscovery." However, it is difficult to imagine benefits that would offset the negative impacts.

[30] For example, one idea under development is a water bank in Colorado that would operate during a Compact call. The arrangement would encourage holders of Present Perfected Rights (mostly West-slope agricultural users) to offer water for lease to holders of curtailed (junior) rights, primarily Front Range municipalities.

discourage intensive discussions of the merits of significant reform. Both factors are important to acknowledge and understand.

Fear of Change

Politically, talking about institutional reform is a dangerous topic, especially if one of the "taboo phrases" of Colorado River politics is mentioned. As an example, consider the gaffe made in 2008 by presidential candidate John McCain, who commented that "the compact that is in effect, obviously, needs to be *renegotiated* over time amongst the interested parties" [emphasis added].[31] The reaction was swift, passionate, and predictable. Colorado Senator (now Interior Secretary) Ken Salazar said that we could renegotiate the compact "over my dead body," a sentiment echoed by many Upper Basin political leaders.[32] A Denver Post editorial page editor, commenting on McCain's "politically suicidal ramblings," succinctly explained the outcry: "When lower basin states talk about "renegotiating" the compact, that's their code for a process of give and take – in which Colorado, Utah, New Mexico and Wyoming give and California, Arizona and Nevada take."[33]

The Upper Basin's fear of significant institutional change is rooted, at least in part, on past reform proposals emphasizing interstate water marketing—another of the taboo topics. Past proposals, as the Denver Post editorial suggests, have largely been motivated by a desire to convert Upper Basin apportionments (either used or unused) to Lower Basin ownership and use.[34] The arguments in favor of such proposals are primarily economic and environmental. For example, in one analysis published in 1994, the potential economic gains of an interstate water market on the Colorado are estimated at $140 million per year, largely due to the instream benefits (e.g., hydropower, salinity reduction) associated with moving more water downstream (Booker and Young, 1994).[35] Arguments in opposition are often focused on legal issues, including whether or not private interests or public bodies would/could be

[31] Ashby, Charles. 2008. "McCain: Renegotiate 1922 Western water compact." The Pueblo Chieftain, August 15. At: http://www.chieftain.com/news/local/article_24df1115-8bc1-5b54-bb04-27f9b39d479b.html.
[32] http://www.chieftain.com/editorial/article_cbee4097-f3f2-5308-8b0c-309abe6a553c.html
[33] http://www.denverpost.com/opinion/ci_10218277 Even the English newspaper, *The Guardian*, commented on the gaffe; see http://www.guardian.co.uk/world/2008/aug/20/johnmccain.water.
[34] Howe (2005a, 2005b) summarizes a variety of past interstate marketing proposals. Some of the early proposals—such as those of the Galloway Group in 1994 and the Resources Conservation Group in 1990—were designed by private interests; however, most subsequent approaches originated in government (e.g., *see* State of California, 1991; and Ten Tribes Proposal, 1992). Somewhat surprising is the large number of schemes developed by Upper Basin interests, including separate proposals from Colorado by Representative Ben Nighthorse Campbell and Governor Roy Romer (circa 1991), and the State of Utah (in 1995).
[35] Specifically, this is composed of gains of $74 million for consumptive uses, $35 million for hydropower generation, and a reduction in salinity damages of $31 million (in 1989 dollars). Note that $140 million in 1989 dollars is roughly $246 million in 2010 dollars.

sellers/buyers, whether states have the ability to regulate such transactions, and whether or not this violates the perpetual allocation concept that is at the core of the Compact (e.g., *see* Lochhead, 2001; and Landry, 1985).

These legal issues are significant, but ultimately, they are a surrogate for concerns that are political. In a nutshell, for the Upper Basin, "protecting" water supplies is viewed as the more valuable objective than receiving payments for water that would be "lost." There is nothing to suggest that this has changed or is likely to change, which is perhaps why the flurry of interbasin marketing proposals that was seen in the 1980s and 1990s has disappeared and has not returned.[36] If the Lower Basin wants some assurance of enhanced or more reliable flows coming from the Upper Basin, then the compensation will need to take the form of something other than cash. Given that reality, the past reform proposals focused on interstate marketing are best viewed as being politically off-target, and serve only the negative role of discouraging the consideration of new proposals that potentially could have more universally desirable trans-basin benefits.

The reluctance to discuss institutional reform in the basin reflects lingering concerns about the "ground-rules" that might be associated with such conversations. Reflecting on the region's political history, some useful ground-rules seem obvious and have already been articulated in this report, starting with the idea that the focus must not be on "renegotiating" or "throwing out" the Compact, but on finding more effective ways of achieving the core principles that were the inspiration and basis of the agreement. Two ideas are paramount: allocation rules that emphasize *equity*, and operational rules that maximize water supply *certainty*. The procedural principles that likely require reiterating are the notions that any changes should be designed by the states and enacted only by unanimous agreement; any approach that is imposed by another level of government, or by an advocacy or academic institution, is unlikely to enjoy much support.[37]

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[36] Interestingly, where the action has been on interstate water marketing is among the Lower Basin states. Several deals—typically described using the language of "water banking" rather than water marketing—between Arizona and Nevada are particularly noteworthy, as is the recently authorized (2007) Intentionally Created Surplus (ICS) program that allows "marketing" of conserved water across state lines in the Lower Basin. (Many of the relevant documents can be accessed through Reclamation's periodic reports on "Colorado River Accounting and Water Use Report: Arizona, California, and Nevada"; e.g., see http://www.usbr.gov/lc/region/g4000/4200Rpts/DecreeRpt/2007/2007.pdf.)

[37] Ironically, these ground-rules were actually part of the highly contentious McCain quote mentioned earlier, but were buried by the initial gaffe. Specifically, he said: "[T]he compact that is in effect, obviously, needs to be renegotiated over time amongst the interested parties. I think that there's a movement amongst the governors to try, if not, quote, renegotiate, certainly adjust to the new realities of high growth, of greater demands on a scarcer resource. Conditions have changed dramatically, so I'm not saying that anyone would be forced to do anything because I'm a federalist and believe in the rights of states. But at the same time there's already been discussion amongst the states, and I believe that more discussion amongst the governors is probably something that

Substantive Misunderstandings

Another factor discouraging a discussion of institutional reforms is that the current state of the river, and the trajectory of current management, is poorly understood by many Colorado River stakeholders—especially those just outside the inner circle of decision-making. Some indication of this comes from a survey, conducted by the CRGI in 2010, of members of the Colorado River Water Users Association (CRWUA). (Full survey results are presented as Appendix C.) For example, of the survey respondents, only 18.4% (34/185) estimated the probability of a least one Central Arizona Project (CAP) curtailment (question 1) between now and 2026 at more than 90%, even though modeling done by the U.S. Bureau of Reclamation (as part of the 2007 EIS) suggests this is virtual certainty.[38] Similarly, only 39.5% (73/185) of respondents think average demands have caught up with supplies (question 4); however, as discussed earlier, data from the Bureau of Reclamation indicates this has already happened. Additionally, while the scientific community is nearly unanimous in projecting future flow declines for the Colorado River by mid-century (see Appendix B), a large number of survey respondents, 42.9% (79/184), remain unconvinced (question 3).

Not surprisingly, those survey respondents that view the current and future water availability situation as most serious (questions 1-4) are also most likely to suggest that the Law of the River is most in need of significant or fundamental reforms (questions 5-6), and similarly, are most interested in discussing both institutional reforms or non-institutional options that promise augmented river flows (question 6). Who are those individuals? The survey is a far from perfect means to answer that question, as it sampled only a cross-section of anonymous stakeholders; nonetheless, the results appear consistent with observations and informal interviews. Specifically, those that see the situation as most dire, the need for reform as most serious, and with the greatest willingness to discuss change are from the Lower Basin, and specifically, from Nevada. At the opposite end of this spectrum, on all counts, are respondents

everybody wants us to do." http://www.chieftain.com/news/local/article_24df1115-8bc1-5b54-bb04-27f9b39d479b.html

[38] This is a question that was addressed in the modeling associated with the 2007 Final EIS in Figure N-15 of Appendix N (page N-23). Using the DNF (Direct Natural Flow) hydrology (i.e., the 1906-2005 record) and the PA (Preferred Alternative) rules that has since been adopted (i.e., the "Interim Guidelines"), the trace shows the probability of shortage in any given year. Curtailments begin when Lake Mead elevation falls below an elevation of 1075 feet. By multiplying these annual values together over a selected time frame, a cumulative probability is easily calculated. *The probability of having at least 1 CAP curtailment over the 2010-2025 period (assuming the DNF-PA scenario) is calculated to be roughly 98%.* Furthermore, this estimate is likely conservative (i.e., a "best case" scenario), for at least three reasons: first, the Preferred Alternative proposed limits for ICS (Intentionally Created Surplus) storage in Lake Mead that were utilized are twice the level ultimately adopted; second, Upper Basin demand assumptions have since been increased; and third, this modeling does not assume any climate change induced streamflow reductions. More recent Bureau of Reclamation modeling considers these, and other, factors, and further reinforces the conclusion that the occurrence of at least one CAP curtailment over the 2010-2025 period is a virtual certainty.

from the Upper Basin. This is shown in Table 3.[39] Similar trends, shown in Table 4, exist between those expecting reduced future flows versus those that do not.

Table 3. Perceptions, by Sub-Region, of the Severity of Problems and the Need for Action

Measures of Concern (defined below)	**Nevada**	**Lower Basin without Nevada**	**Upper Basin**
Supplies, Demands, and Water Availability			
A (CAP curtailments)	72.0% (18/25)	52.7% (49/93)	35.0% (21/60)
B (Compact call by 2026)	47.8% (11/23)	37.0% (34/92)	32.8% (19/58)
C (Compact call by 2050)	68.0% (17/25)	53.2% (41/77)	38.9% (21/54)
D (Reduced Future Flows)	64.0% (16/25)	59.8% (55/92)	50% (30/60)
E (Demands Catching Supplies)	60% (15/25)	37.6% (35/93)	30.0% (18/60)
Assessment of the Law of the River			
F (Need for change)	68.0% (17/25)	24.7% (23/93)	23.3% (14/60)
G (Priority of change)	75.0% (18/24)	52.2% (48/92)	56.7% (34/60)
Desire to Act			
H (Institutional reforms)	1.93	0.73	0.70
I (Non-inst. Reforms)	3.12	1.78	1.45
J (All reforms)	2.57	1.20	1.12

Definition of the "Measures of Concern." See survey for exact phrasings.
A = Expect CAP curtailment by 2026 ("very likely" or "probable") (question 1)
B = Expect compact call by 2026 ("very likely" or "probable") (question 2a)
C = Expect compact call by 2050 ("very likely" or "probable") (question 2b)
D = Expect future reduction in flows (question 3)
E = Believe demands have already caught supplies (question 4)
F = Respondents saying Law of River requires "significant" or "fundamental" change (question 5)
G = Respondents saying that revisiting Law of River is a "high" or "medium" priority (question 6, Law of River option)
H = Ratio of total "High Priority " to "Not a Priority" responses for the six options that are highly institutional in nature (i.e., additional studies, planning and coordination; pricing incentives, non-structural measures; refined operation of Lakes Powell and Mead; interstate water markets; resolving Law of River issues; and river basin organization) (question 6)
I = Ratio of total "High Priority " to "Not a Priority" responses for the five options that are not primarily institutional in nature (i.e., technology to reduce waste; desalination; infrastructure updates and expansions; augmentation (e.g., cloud seeding and vegetation management); and imports from other basins) [Note: "improved intra-state management" could not be classified as either institutional or non-institutional, as it likely means both] (question 6)
J = Ratio of total "High Priority " to "Not a Priority" responses for all twelve options (question 6)

[39] Note that it was not our original intent to divide the respondents into these three groupings: the Upper Basin, Nevada, and the Lower Basin (without Nevada). However, doing this appears useful in illustrating important trends, while still retaining relatively high sample sizes (the lowest population being the 25 respondents from Nevada).

Table 4. Perceptions of Problem Severity and the Need for Action by Belief in Future Flow Reductions		
Measures of Concern (defined below)	**Those Whom Expect Lower Future Flows***	**All Others** $^{\beta}$
Supplies, Demands, and Water Availability		
A (CAP curtailments)	62.5% (65/105)	34.2% (27/79)
B (Compact call by 2026)	45.7% (48/105)	23% (17/74)
C (Compact call by 2050)	63.7% (58/91)	32.4% (23/71)
D (Reduced Future Flows)	*100% (105/105)*	*100% (79/79)*
E (Demands Catching Supplies)	45.7% (48/105)	31.6% (25/79)
Assessment of the Law of the River		
F (Need for change)	35.6% (37/104)	21.5% (17/79)
G (Priority of change)	57.7% (60/104)	52.6% (41/78)
Desire to Act		
H (Institutional reforms)	0.99	0.70
I (Non-inst. Reforms)	1.67	1.71
J (All reforms)	1.40	1.11

Definition of the "Measures of Concern." See survey for exact phrasings.

* = This column shows answers for that sub-set of the total survey population (105 of 184 respondents) whom, on question 3, expressed a belief that future flows would be lower than the previous century.

$^{\beta}$ **=** This column shows the responses (79 of 184) of the people whom, on question 3, answered "roughly the same as the past century", "higher than the previous century", or "don't know".

Based on response to question 3. The "other answers" included those whom expected future flows to be the same, higher, or don't know. (Note that in the entire survey population, 105/184 (57.1%) expected a reduction in future flows.)

A = Expect CAP curtailment by 2026 ("very likely" or "probable") (question 1)

B = Expect compact call by 2026 ("very likely" or "probable") (question 2a)

C = Expect compact call by 2050 ("very likely" or "probable") (question 2b)

D = Expect future reduction in flows (question 3)

E = Believe demands have already caught supplies (question 4)

F = Respondents saying Law of River requires "significant" or "fundamental" change (question 5)

G = Respondents saying that revisiting Law of River is a "high" or "medium" priority (question 6, Law of River option)

H = Ratio of total "High Priority " to "Not a Priority" responses for the six options that are highly institutional in nature (i.e., additional studies, planning and coordination; pricing incentives, non-structural measures; refined operation of Lakes Powell and Mead; interstate water markets; resolving Law of River issues; and river basin organization) (question 6)

I = Ratio of total "High Priority " to "Not a Priority" responses for the five options that are not primarily institutional in nature (i.e., technology to reduce waste; desalination; infrastructure updates and expansions; augmentation (e.g., cloud seeding and vegetation management); and imports from other basins) [Note: "improved intra-state management" could not be classified as either institutional or non-institutional, as it likely means both] (question 6)

J = Ratio of total "High Priority " to "Not a Priority" responses for all twelve options (question 6)

Placing Tables 3 and 4 side-by-side is done, in part, to further reinforce the observation that how a stakeholder views the seriousness of the water issues and the need for reform is largely shaped by two variables: geographic location, and whether or not one expects future flow reductions. This relationship is complex. As explained earlier in the discussion of the so-called "Upper Basin climate change squeeze," Upper Basin interests have much to fear given the current trajectory of water management and the traditional approach used (Pathway # 1) to resolve interbasin disputes, *but only if climate change occurs*. As shown in Table 3, Upper Basin interests were the least likely to expect future flow reductions, albeit by a small margin. (On this question, the Upper Basin respondents were evenly split.) Should the case for climate change become more universally accepted in the Upper Basin, then it might be expected that Upper Basin stakeholders would be the most—rather than the least—concerned about the trajectory of management and problem-solving.

The salience of climate change science in shaping Upper Basin strategy is perhaps best highlighted by noting how climate change affects three of the most deeply held (and interrelated) strategic assumptions in the Upper Basin regarding Colorado River politics, namely: (1) enforcement of the Law of the River reserves water for Upper Basin development; (2) the Upper Basin could never get a better deal; and (3) changes in the Law of the River would only benefit California. Each assumption is readily defensible without climate change; but under climate change, these assumptions begin to fall apart and, in fact, may be completely contradictory from reality. After all, under climate change, the only water that may practically be "reserved" for Upper Basin use are those Present Perfected Rights that pre-date the Compact (as shown in Figure 8 and the discussion of the climate change squeeze); all other post-Compact Upper Basin water rights are effectively junior to those (of any seniority date) downstream. Is this really the best arrangement the Upper Basin could ever hope to achieve? And is any deviation from the *status quo* likely only to benefit California? True, in any deal-making, California is likely to want to improve its position; but the reality is that none of the eight parties (the seven states and Mexico) has an apportionment that is better protected under the *status quo* than California. Looking back, it is undoubtedly true that the Compact, as administered, has served the Upper Basin well and (generally) as intended. The manner in which the Compact put an enforceable cap on Lower Basin development remains vitally important. But looking forward, achieving the goals and principles of the Compact may require something much different than an approach based on simply enforcing the letter of the law (Pathway # 1).[40]

[40] It is worth revisiting the Upper Basin's specific goals for the Compact, summarized by Lochhead (2001) based largely on the writings of Delph Carpenter, the "father" of the Compact. Those goals were: (1) to reserve water, in perpetuity, for later Upper Basin development; (2) to block application of the prior appropriation doctrine over state lines; (3) to preserve state autonomy over intrastate water management; (4) to avoid interstate litigation;

IV. Conclusions: Looking Forward

The purpose of this Interim Report is not to suggest that the "sky is falling" or that the current management approach is beyond repair, nor is it intended as an indictment of past decisions or decision-makers. Rather, it is merely to acknowledge that the Colorado River faces formidable challenges, and that the best approach for protecting past accomplishments in the basin may be to recognize and embrace the need to devise significantly different approaches for accomplishing longstanding goals. Our interactions with basin leaders suggest that many understand and accept this analysis; however, many do not, and are hesitant to support discussions of this nature.

Establishing a need for significant change, and articulating accepted ground-rules for the subsequent discussions, would go a long way in stimulating a new breed of proposals for institutional reform. Year 2 of the CRGI will focus on this stage of activity, encouraging basin leaders to think (and talk) about comprehensive and stable long-term solutions. Conceptually, this effort should begin with basin leaders identifying the substantive objectives upon which potential new arrangements should be based. Given the uncertainties associated with climate change, some of the best ideas might come from the field of risk management, and may feature strategies based on limiting exposure and spreading vulnerabilities. That might suggest substantive objectives such as:

- Spreading the risk of climate change to parties other than just the Upper Basin;
- Better protecting existing users from system vulnerabilities exacerbated by new developments;
- Providing incentives for limiting new Upper Basin development at a level that maintains reservoir storage (and all its associated interbasin benefits);
- Providing mechanisms for flexibility and short-term deals, including the strategic application of market forces, to deal with crises;
- Providing enhanced means and/or forums of interbasin study, negotiation, and dispute resolution to facilitate more proactive management;
- Removing the threat of Compact calls, interstate litigation, and other eventualities that could potentially result in catastrophic failure of the Law of the River.

Approaching the challenges from a different perspective may yield a very different list. The point here is not whether or not these are the "right" substantive objectives, but rather, is to suggest that a conversation that happens at this level is likely to lead to bigger ideas, broader

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and (5) to establish a foundation for comprehensive river development and management. In a future featuring climate change and Compact calls, several of these goals (specifically, items 1, 2 and 4) are directly threatened.

innovations, and better outcomes than what our current trajectory of management and decision-making can produce.

It is, indeed, a challenging time on the Colorado River. Significant institutional change may not be essential, but it is likely beneficial, and while the political risks of discussing major reforms remain high, the risks of incrementalism—or worse yet, inaction—are likely greater. Problems continue to mount: reservoir storage remains at historically low levels; Lower Basin curtailments may only be a couple years away; and proposals for new water projects continue to move forward, further stressing the river, and likely limiting the flexibility for pursuing new management approaches. Of course, at the highest political levels, most of these problems are understood, some quiet conversations among high-level basin leaders are ongoing, and joint fact-finding efforts such as the Basin Study are providing a valuable mechanism for facilitating ongoing interaction among a larger group of stakeholders and researchers. It is time to build upon the existing momentum, the assembled data, and the short window of opportunity that remains.

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Appendix A: An Overview of Law of the River Issues, Omissions and Ambiguities

The following pages provide a general overview of the Law of the River, including a description of the key elements, and a consideration of some of the legal issues that remain contested. It is preceded by a brief overview of the physical setting, as it is difficult to understand the legal and policy issues related to river operations without a basic understanding of the system infrastructure.

I. Physical Setting

The Colorado River and its tributaries originate from snowmelt high in the Rocky Mountains, and flow southwest through the states of Colorado, Wyoming, Utah, New Mexico, Nevada, Arizona and California, and then briefly across the international border into Mexico (Figure A-1) (Gleick, 2002; Pontius, 1997). The drainage basin covers approximately 244,000 sq. miles, of which over 95% is in the United States. Officially, the river channel extends over 1,450 miles from high in the Colorado mountains to the Gulf of California, but the river rarely makes it to the ocean. In most years, the flow is completely exhausted soon after the river crosses into Mexico.

Along its path, the Colorado is controlled by approximately two-dozen significant storage and diversion projects, including Lake Powell (formed by Glen Canyon Dam) and Lake Mead (formed by Hoover Dam). Collectively, these two reservoirs can hold over 3 years of flow; overall, the structures on the river allow for storage of 4 years of flow. These reservoirs have transformed the region and the river in countless ways, including altering the river from an unpredictable and sediment-heavy warm-water stream to an elaborate plumbing system of relatively clear and cold water (Fradkin, 1981; Carothers and Brown, 1991).

Figure A-1. Colorado River Basin.

II. Basics of the "Law of the River"

The legal tangle that is colloquially called the "Law of the River" governs use and management of Colorado River water. [41] It comprises interstate compacts, treaties (with Mexico and Indian tribes), Congressional legislation, and numerous court decisions. The seminal document is the Colorado River Compact, signed in 1922. The seven basin states are legally bound by its quantitative apportionments, which are allocated in perpetuity (Hundley Jr., 1975; Tyler, 2003). Despite the intentions of its drafters, the Compact has been the subject of highly contentious litigation and numerous supplemental agreements. Additionally, there remain numerous ambiguities and omissions in the Law of the River.

The primary purposes of the Compact were the division of the river's flow between the states of the Upper Basin and Lower Basin[42], the elimination of current and future interstate disputes, and the promotion of orderly river development and management. Some of the key provisions—discussed later in more detail—include:

- Article III(a) allocates 7.5 million acre-feet (MAF)/year to each Basin, while Article III(b) reserves an additional 1 MAF/year for the Lower Basin.
- Article III(c) provides for administration of any later apportionment to Mexico. (Similarly, Article VII anticipates, but does not otherwise address, future apportionments to Indian tribes.)
- Article III(d) calls for a minimum flow volume at Lee Ferry (the dividing point between the two basins) of 75 MAF over all 10-year periods.
- Article VIII describes water rights already being exercised (so-called Present Perfected Rights) as being "unimpaired" by the Compact apportionment.

The Compact achieved congressional ratification as part of the Boulder Canyon Project Act of 1928, which also authorized the construction of the Boulder (now Hoover) Dam and All-American Canal, as well as providing the three-state division of the Lower Basin apportionment. As later confirmed in *Arizona v. California* (1963), the apportionment annually provides 4.4 MAF

[41] The Law of the River is the subject of a vast body of literature. Legal overviews are provided by many authors, including Getches et al. (1995) and Lochhead (2001, 2003). Excellent historical reviews of key events and institutional innovations are provided by Hundley Jr. (1966, 1975, 1986), Reisner (1986), Fradkin (1981), and many others.

[42] The Compact uses the terms "Division" and "Basin" to distinguish between the two groups of states. "Basin" encompasses drainage areas, while "division" is limited to political jurisdictions. However, for the purpose of this paper, the terms will be used synonymously. For this paper, Upper Basin will mean the states of Colorado, Wyoming, Utah, and New Mexico, and Lower Basin will mean the states of Arizona, California, and Nevada.

to California, 2.8 MAF to Arizona, and 0.3 MAF to Nevada. A Treaty with Mexico in 1944 provides the downstream nation with a minimum apportionment of 1.5 MAF annually. The broad contours of the interstate apportionment were finalized in 1948 in the Upper Colorado River Basin Compact, which allocates the Upper Basin apportionment by percentages: 51.75% for Colorado, 23% for Utah, 11.25% for New Mexico, and 14% for Wyoming.[43] As tribal rights are quantified in court cases (e.g., *Arizona v. California*, 1963) and negotiated settlements, these allocations come out of the apportionment of the state in which the reservation is located.

The Law of the River also includes several acts of Congress relating to water project authorization and operation, including the Colorado River Storage Project Act (1956) (which provided an Upper Basin development plan and authorized the construction of Glen Canyon Dam (Lake Powell)), and the Colorado River Basin Project Act (1968) (which authorized several projects, including the Central Arizona Project (CAP)[44]). Problems with salinity led to the enactment of the Colorado River Basin Salinity Control Act (1974) and Minute 242 (1973) amending the treaty between the United States and Mexico. A variety of national and region-specific environmental laws also are part of the Law of the River.

Reservoir Operations

Implementation of the interstate (and international) apportionment is largely implemented by the policies for reservoir operations, and specifically, the management of Lakes Powell and Mead. Since these reservoirs are located on opposing sides of Lee Ferry, the point of division between the Upper and Lower Basin, the coordinated operation of the reservoirs is closely tied to Compact administration. As mandated by the Colorado River Basin Project Act (1968) and further defined in 1970 legislation, the Secretary of Interior is required to prepare both long-range and annual plans for reservoir operations. Section 602(a) of the 1968 legislation is of particular importance in these efforts, as it provides guidance on when water is retained upstream in Lake Powell, and when it is released downstream to the Lower Basin. As expected, Upper Basin users fight for policies that retain as much water as possible upstream in Lake Powell, whereas downstream interests prefer frequent releases beyond the minimum necessary to satisfy Compact and Treaty obligations.

[43] Additionally, 50,000 acre-feet is allocated to users in northeastern Arizona.

[44] The Central Arizona Project (CAP) is a multipurpose water resource development program that provides water for irrigation, municipal and industrial needs, power production, flood and sediment control, recreation, and environmental purposes. It also provides water for tribal water settlements. Water from CAP is used in Maricopa, Pima, and Pinal counties as well as the metropolitan areas of Phoenix and Tucson (USBR, 2010).

Until recently, long-range operating criteria only provided release schedules for “normal” or “surplus” conditions. However, in response to low reservoir conditions, negotiations were concluded in 2007 to also address “shortage” conditions—i.e., the “Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead” (the “Interim Guidelines”) (USBR, 2007). The Interim Guidelines not only provide a schedule of reservoir operations during shortage conditions, but include a schedule of Lower Basin curtailments when insufficient storage exists in Lake Mead to support 7.5 MAF of Lower Basin consumption from the mainstem. Curtailments are enacted in stages (based on reservoir elevations), and primarily target water delivered by the CAP, which is junior to the California apportionment and to other Arizona uses of mainstem water. The Interim Guidelines also establish the “Intentionally Created Surplus” (ICS) program, which allows water conserved in the Lower Basin through “extraordinary” measures—such as land fallowing, canal lining, desalination, and terminal reservoir construction—to be stored in Lake Mead for later use (USBR, 2007; Schiffer, 2007; Grant, 2008). The guidelines will remain in effect until 2025 for water supply determinations and until 2026 for reservoir operations.

Additional Lower Basin Arrangements

The Interim Guidelines are just the latest example of Law of the River reforms aimed primarily at better clarifying and more flexibly using the Lower Basin apportionment. Many of the other notable Lower Basin arrangements are described as “water banking” arrangements, in that they provide for storage of unused water. Most arrangements provide for underground storage of water in Arizona (by the Arizona Water Banking Authority), under arrangements negotiated with users in Nevada (the Colorado River Commission of Nevada and the Southern Nevada Water Authority) and California (the Colorado River Board of California and the Metropolitan Water District of Southern California). Major agreements, negotiated primarily between 2001 and 2009, are noteworthy not only for allowing states to store and retain ownership of apportionments not otherwise used, but for facilitating the trading of stored water across state lines (in the Lower Basin). Some additional interstate water trading (again, only in the Lower Basin) is also provided for in the ICS program.[45]

[45] A variety of studies discuss these many interrelated programs (e.g., *see* AWBA, 2009; USBR, 2007; Wash. DOE, 2004; Henley, 2002; Schiffer, 2007; Gallogly, 2003; Grant, 2008; SIRA, 2010; Colo. River Board of California, 2008; and USBR, 2010).

III. Legal Omissions and Ambiguities

Despite decades of dispute and negotiation, several "omissions and ambiguities" remain in the Law of the River, providing the potential for future conflict and litigation. Many of these issues become dramatically more pressing as reservoir levels decline and as shortages (and curtailments) become reality. A discussion of six of the most significant issues is described below—namely:

- ISSUE 1: Deliveries to Mexico
- ISSUE 2: The Interbasin Apportionment
- ISSUE 3: The Upper Basin Delivery Obligation
- ISSUE 4: Compact Rescission or Reformation
- ISSUE 5: Magnitude of Present Perfected Rights
- ISSUE 6: Administration of Compact Calls

This list is not exhaustive, and our review of these issues is not intended to be complete or authoritative. The point is to merely indicate the wealth of potential disputes that are likely to emerge as water scarcity increases.

ISSUE 1: Deliveries to Mexico

As provided by Article X of the 1944 Treaty with Mexico, the United States must annually deliver to Mexico 1.5 MAF (or 1.7 MAF in surplus years).[46] This obligation is clear and uncontroversial in years where there is an abundance of water; however, during scarcity, numerous legal ambiguities exist. Two are of particular concern and are discussed below: the Upper Basin's delivery obligation to Mexico, and the definition of extraordinary drought.

The Upper Basin's Mexican Treaty Obligation

> *Article III (c) - If….the United States of America shall hereafter recognize in the United States of Mexico any right to the use of any waters of the Colorado River System, such waters shall be supplied first from the waters which are surplus over and above the aggregate of the quantities specified in paragraphs (a) and (b); and if such surplus shall prove insufficient for this purpose, then, the burden of*

[46] Treaty with Mexico Respecting Utilization of the Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Feb. 3, 1944, 59 Stat. 1219, 1265 T.S. No. 994 (effective Nov. 8, 1945).

such a deficiency shall be equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver at Lee Ferry water to supply one-half of the deficiency…in addition to that provided in paragraph (d).

--- Colorado River Compact of 1922

According to the Colorado River Compact, deliveries to Mexico are to be made from surplus water in the "Colorado River System"[47] above the aggregate requirements of Article III(a) and III(b).[48] When there is no "surplus" water, the Upper Basin is required to bear one half of the deficiency—up 750,000 AF per year—which when combined with Compact obligations to the Lower Basin, results in a minimum delivery of 8.23 MAF/year at Lee Ferry, and perhaps more if compensation for transit losses is required.[49] In periods of scarcity, this could result in curtailment of Upper Basin users. Carlson (1989), quoting a 1979 report of The Comptroller General of the United States, summarized the dispute as follows:

The Lower Basin States contend that there is no surplus and the Upper Basin's share of the Mexican treaty delivery obligation is therefore one-half of the total obligation of 1.5 maf plus one-half of the losses incurred in delivering the water from Lee Ferry to the Mexican border. The Upper Basin States believe that surplus water exists in the Lower Basin and therefore they are not required to release any water to meet the Mexican treaty obligation. The flow and use of Lower Basin tributary water is poorly documented, but has been estimated by the Bureau of Reclamation as averaging 2.5 MAF per year (and as high as 4.5 MAF)[50] (USBR, 2004).

This dispute was nearly non-existent until the Supreme Court, in *Arizona v. California*, disregarded Arizona and Nevada tributaries when determining state allocations in the Lower Basin. The Court declared that under the scheme established by Congress in the Boulder Canyon Project Act, "the tributaries are not included in the waters to be divided..."[51] The Court

[47] The Colorado River System is "that portion of the Colorado River and its tributaries within the United States of America" (Colorado River Compact, art. II (a); 70 Cong. Rec. 324, 324-25 (1928)).

[48] This can mean either when there is more than 16 MAF in the Colorado River (the Lower Basin argument) or when there is more than 8.5 MAF in the Lower Basin (the Upper Basin argument) (Carlson, 1989; Carlson and Boles, 1986).

[49] The 8.23 MAF/year figure is a prominent element of river management, and is the typical minimum release from Lake Powell. Presumably, it is comprised of 7.5 MAF, which is the average annual delivery requirement from Article III(d), and 750,000 AF for the Upper Basin's potential share (as discussed above) of the Mexican obligation. This totals 8.25 MAF; the actual release from Lake Powell is 20,000 AF lower, which is accounted for by inflows from the Paria River, which is downstream of Lake Powell but before the official Lee Ferry point.

[50] Actually, Lower Basin tributary consumptive use was 5.2 MAF in 1981, but the 5 year average for this period (1981-1985) was only 4.4 MAF (USBR, 1991; Carlson, 1989).

[51] *Arizona v. California*, 373 U.S. 546, 559-60 (1963).

reasoned that, while the tributaries were naturally included in the Colorado River Compact under the definition of the "Colorado River System," legislative history and the alternative proposals that eventually culminated in the Boulder Canyon Project Act "consistently provided for division of the mainstream only, reserving the tributaries to each State's exclusive use."[52]

The Court's decision to disregard the tributaries is an ongoing concern in the Upper Basin. Under the plain language of the Compact, the Lower Basin's apportionment in Article III(a) is of Colorado River System water, which includes both mainstem and tributary water. Negotiation transcripts show that the Compact Commissioners certainly intended to subject the Lower Basin tributaries to future Mexican obligations.[53] Contemporaneous support for the inclusion of the tributaries in the Compact comes from the failure of amendments to the Boulder Canyon Project Act that would have exempted tributaries from the Mexican obligation. Moreover, Arizona's past conduct, in opposing ratification of the Colorado River Compact based on the inclusion of the tributaries in the Article III(c) surplus, and its argument in the 1934 *Arizona v. California* case that Article III(b) was intended to compensate Arizona for the inclusion of the Gila River and other tributaries in the Compact, illustrate that the tributaries were intended to be included in the basin allocations (Carlson, 1989; Getches, 1985).

Eliminating the tributaries from the Lower Basin's apportionment forces the Upper Basin to bear a bigger relative burden than the Lower Basin in ensuring adequate Mexican deliveries (Getches, 1985). The Upper Basin's burden will further increase if it is required to compensate for transit losses occurring between Lee Ferry and the Mexican boundary. The Lower Basin argues that the Upper Basin must deliver an amount of water equal to one half or more of the channel losses (Carlson, 1989). However, the Compact negotiations do not suggest that this was the Commissioners' intention. In two brief exchanges, Arizona Commissioner Norviel suggested to Colorado Commissioner Carpenter that the Mexican obligation be delivered at Yuma.[54] However, Carpenter and the other Upper Basin commissioners objected, because this would increase the burden on the Upper Basin states.[55] The Compact states that the Upper Basin "shall deliver at Lee Ferry" and not Yuma; channel losses are not mentioned (Carlson, 1989).

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[52] *Arizona v. California* at 569. The Court held that the Boulder Canyon Project Act effectively enacted a congressional apportionment of mainstem river water "based on congressional intent and the Act's delegation of authority to the Secretary of the Interior to allocate and distribute water through contracts."

[53] Article III(b) was inserted to placate Norviel of Arizona who unsuccessfully argued against the inclusion of tributaries in the Compact. Its inclusion conceded to the Lower Basin the right to an additional 1.0 MAF of surplus, expected to come from the tributaries, but, in exchange, subjected the tributaries to the Compact's allocations (Hundley, 2009).

[54] 1 Record, Sess. No. 16 at 26; 2 Record, Sess. No. 20 at 60.

[55] 1 Record, Sess. No. 16 at 26; 2 Record, Sess. No. 20 at 60. They would have to deliver sufficient water to ensure that 750,000 remained in the driest stretch of the Colorado River by the time it reached Yuma, Arizona.

Further complicating this issue is that the Mexican Treaty obligation is generally considered the first priority on the river (Carlson, 1989). Any shortage on the river would mean that the Mexicans have the first priority and the power to curtail both Upper and Lower Basin users. The Colorado River Basin Project Act further highlights this concept by stating that the Mexican obligation "shall be the first obligation of any water augmentation project planned according to Sec. 201."[56]

As a practical matter, the Upper Basin is not currently using its full apportionment and has not faced curtailments; therefore, there has not been a problem ensuring adequate deliveries to Mexico. However, as the Upper Basin continues to develop, and if climate change or drought further reduces flows, the chance for confrontation grows and the resolution of this ambiguity takes on increasing importance.

What is Extraordinary Drought?

The term "extraordinary drought" is not defined in the 1944 Treaty nor is it defined in any parallel agreement. Nonetheless, Article X of the Treaty provides that:

> *In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet…a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced.*

The term "extraordinary drought" is also used in Article V of the Treaty, which provides for Mexican deliveries on the Rio Grande to users in the United States.[57] During a prolonged drought in the 1990s, Mexico claimed extraordinary drought along the Rio Grande and failed to deliver sufficient water to irrigation districts in the United States. Its invocation of extraordinary drought was controversial, and similar disagreements are likely to occur should the U.S. declare extraordinary drought on the Colorado River.[58]

[56] 43 U.S.C. § 1512 (2010). Sec. 201 authorized the Secretary of the Interior to develop a long-range water supply and demand plan. It also prohibited the Secretary from pursuing importation projects.

[57] There are, however, some differences between the use of extraordinary drought in Article X and Article V. Article X says that deliveries to Mexico will be decreased in proportion to consumptive use decreases in the United States. Article V permits Mexico to deliver less water for five years, but requires it to make up delivery deficiencies in the next five-year cycle (The Treaty with Mexico, *supra*, Art. 5, Art. 10 (1944)).

[58] In the 1990s, the Rio Grande Basin in Mexico experienced a severe drought that caused Mexico to miss required deliveries. Mexico claimed extraordinary drought, and, under Article V, obtained the ability to make up deliveries in the next five-year period. Texans reliant on the water claimed the basin's growth in Mexico and Mexican storage of Rio Grande water was to blame instead of the drought (Mission 2012, 2010; U.S. Water News, 2002).

In the 2007 EIS (Appendix Q), the magnitude and timing of basinwide curtailments during periods of scarcity are discussed, including an assessment of the Mexican priority.[59] Generally, if Lake Mead elevations are low enough to trigger shortages in Lower Basin deliveries, then the Secretary of the Interior is instructed to consult with the Department of State, the USIWBC,[60] and the Basin States to determine whether and how the United States should reduce deliveries to Mexico consistent with the 1944 Treaty (USBR, 2007; Adler, 2008). While the EIS includes some assumptions about possible levels and timings of curtailments, the scenarios presented were not approved by Mexico, and await completion of ongoing international negotiations.[61]

ISSUE 2: The Interbasin Apportionment

> *Article III (a) – There is hereby apportioned from the Colorado River System in perpetuity to the Upper Basin and to the Lower Basin, respectively, the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per annum, which shall include all water necessary for the supply of any rights which now may exist.*
>
> --- Colorado River Compact of 1922

The purpose of the Colorado River Compact is to "provide for the equitable division and apportionment of the use of the waters of the Colorado River System."[62] But does "equitable" mean "equal"? Article III(a) would suggest it does, as it divides the Colorado River into equal shares, 7.5 MAF annually, between the Upper and Lower Basins "in perpetuity," purportedly to ensure that each Basin had the opportunity to develop its water without interference from the other Basin.[63] Yet despite this implication, the so-called "equal shares theory" remains a source of controversy and contention (Carlson and Boles, 1986).

The most significant effect of this ambiguity is on shortage sharing. From stream reconstructions of the Colorado River's historic flows and climate change projections of future

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[59] Current thinking on curtailment is that the Upper Basin would be curtailed first. Not until only present perfected right remained in the Upper Basin, would cutbacks begin in the Lower Basin. The Secretary would first curtail CAP, then Nevada and Arizona's non-CAP water, and finally California (Getches, 1994).

[60] The USIBWC is the United States section of the International Boundary and Water Commission (IBWC), the bi-national organization responsible for administration of the 1944 Treaty.

[61] In furtherance of this agreement, on June 17, 2010, the U.S. and Mexican representatives to the IBWC signed the *Conceptual Framework for U.S.-Mexico Discussions on Colorado River Cooperative Actions*, also known as *Minute 317*.

[62] Colorado River Compact, art. I, 70 Cong. Rec. 324, 324-25 (1928).

[63] Delph Carpenter of Colorado stated it thus, "The State of Colorado could not look with favor upon any plan which would degenerate into a mere contest of speed whereby an unfortunate, an unnatural growth would be forced in one section in order to keep pace with what might be a natural development in another section" (1 Record Sess. No. 14 at 11).

flows, it is clear that the river will rarely have sufficient volume to allow each basin to consume 7.5 MAF/year of mainstem flows (see Appendix B). Under the current operating regime, the deficiency is likely to come out of the water available to the Upper Basin (McDonald, 1997). (See the discussion of the "Upper Basin Climate Change Squeeze" in the main report.) Clearly, the result is not an "equal" division; but is it an "equitable" division?

In determining whether the Commissioners intended to "equally" divide the river, it is necessary to review the Compact negotiations, and to remember that they took place against a background of Supreme Court litigation (Tyler, 2003). These decisions framed the allocations made in the Compact. In *Kansas v. Colorado* (206 U.S. 46, 1907), the Court first announced the doctrine of "equitable apportionment," explaining that the underlying rule is "equality of right,"[64] not necessarily "equality of amounts apportioned." Accordingly, during the Compact negotiations, reference to "equitable apportionment" did not necessarily mean division of the Colorado River into equal amounts, but instead meant that the rights of each state were considered equally and the ensuing allocation was just and fair.

At the time of Compact negotiation, the future water needs of each Basin had been roughly calculated to be equal.[65] This fact, when balanced against the negotiating leverage of each party, prompted Delph Carpenter of Colorado to propose an equal division (fifty-fifty) between the basins. This would preserve the right of the Upper Basin to develop in the future, but also provide the Lower Basin with ample current supplies. Specifically, he suggested that each division receive 8.7 MAF per year from the Colorado River water, with the Lower Basin apportionment including water from their tributaries.[66] He hoped his formula would establish "a permanent and perpetual status" between the basins (Hundley, 2009; Carpenter, 1922). Response to his proposal was largely, but not universally, positive.[67] The most vehement opponent was W.S. Norviel from Arizona who disliked Carpenter's fifty-fifty allocation. He wanted half of the mainstem water for the Lower Basin as well as all of the Lower Basin tributaries. Back and forth negotiations ensued.[68] The negotiations seemed to stall as the

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[64] Each state is on the same level in the legal system as the other state, and has the same powers and rights under the Constitution and interstate disputes are settled in such a manner that recognizes "the equal rights of both and at the same time establishe[s] justice between them" (Kansas v. Colorado, 206 U.S. 46, 98 (1907)).

[65] The Upper Basin's present and future needs from the mainstem were approximately 6.3 to 6.8 MAF per year, while the Lower Basin required between 5.1 to 6.1 MAF per year. (*See* 1 Record, Sess. No. 6 at 70-79; 1 Record, Sess. No. 11, at 61; 1 Record, Sess. No. 12, at 11; 1 Record, Sess. No. 14, at 40-41; 1 Record, Sess. No. 15, at 29-30; 1 Record, Sess. No. 16, at 21-24; 1 Record, Sess. No. 17, at 7; 2 Record, Sess. No. 20, at 62.)

[66] This means the Upper Basin would deliver 6.264 MAF per year at Lee Ferry.

[67] While the commissioners of California and Nevada opposed some details, they supported the basic equal apportionment scheme. McClure from California considered the proposal to be a "fair basis for discussion." 1 Record, Sess. No. 12 at 22-23.

[68] I Record, Sess. No. 16 at 25; 1 Record, Sess. No. 17 at 2-6; 1 Record, Sess. No. 17 at 10-25.

Lower Basin, led by Norviel, insisted on receiving 82 MAF every ten years, while the Upper Basin refused to deliver more than 65 MAF every ten years[69] (Hundley, 2009).

In the face of this impasse, Herbert Hoover presented a memo compiling the basic principles of the Compact, which stated, "appropriations may be made in either division with equality of right as between them, up to a total of 7,500,000 acre-feet per annum, for each division."[70] Furthermore, in Hoover's proposal, in any future compact revisions, "an increasing amount of water to one division will carry automatically an increase in the rights of the other basin."[71] Hoover's statements, coupled with those of other negotiators, indicate that the Basins intended to share the flow equally and that these equal allocations would have equality of right—equal priority—between them. However, this exact language did not end up in the final draft.

Other language in the Compact further supports the concept of equal shares. The inclusion of Article III(b), as the sole exception to equal division, emphasizes by negative implication that the commissioners intended to equally divide the Colorado River System between the Basins.[72] Additionally, in Article III(c), the burden of Mexican delivery when surplus water proves inadequate is to be "equally borne by the Upper Basin and the Lower Basin, and whenever necessary the States of the Upper Division shall deliver….water to supply one-half of the deficiency."[73] This emphasizes that each Basin intended to bear the Mexican burden equally during non-surplus conditions, in accordance with the basic concept of equal allocation of the Colorado River. But this language is largely offset by other Compact elements that revert back to the "equitable apportionment" terminology, which suggests the intention was not equality of allocations, but is simply a recognition of the states' equal rights to the Colorado River (as articulated in *Kansas v. Colorado*). This interpretation is reinforced by Articles III(f) and III(g) concerning future appropriations of unallocated waters.[74]

In summary, it is unclear if "equitable" was intended to mean "equal," and if so, what remedies might be available to address the growing imbalance in the allocation between the Upper and

[69] The proposed delivery of 82,000,000 maf every ten years constituted a much higher delivery than the Upper Basin was willing to make due to concern that in low flow years it would be unable to meet the delivery without curtailing its own users. Stephen Davis from New Mexico pointed out that "taking the measured flow for the lowest ten years for which we have a record…it is apparent…that…any such guaranty would have been violated." 1 Record, Sess. No. 17 at 2.
[70] 1 Record, Sess. No. 17 at 23.
[71] 1 Record, Sess. No. 18 at 32.
[72] Article III(b) was included to provide an additional 1.0 MAF to the Lower Basin to offset the inclusion of its tributaries in the Compact allocations (Carlson and Boles, 1986).
[73] Colorado River Compact, art. III (c), 70 Cong. Rec. 324, 324-25 (1928).
[74] Article III(f) provides for "further equitable apportionment of the beneficial uses of the waters of the Colorado River System unapportioned by paragraphs (a), (b), and (c) may be made in the manner provided in paragraph (g)…" Article III (g) provides that future representatives making apportionments should "divide and apportion equitably between the Upper Basin and Lower Basin." Colorado River Compact, art. III (f) – (g), 70 Cong. Rec. 324, 324-25 (1928).

Lower Basins. What is clear is that this issue will only grow in importance, and that the resolution of this issue could potentially involve significant, protracted litigation.

ISSUE 3: The Upper Basin Delivery Obligation

> *Article III (d) - The States of the Upper Division 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 reckoned in continuing progressive series…*
>
> --- Colorado River Compact of 1922

At issue is whether the prohibition on the states of the Upper Division from depleting flows below 75 MAF/10 years operates as a delivery requirement and makes water rights held by the Lower Basin senior to those held by the Upper Basin, or if acts as an obligation not to deplete flows, and if so, is that practicably different than a delivery obligation.

From the language of the Compact and other Law of the River components, most commentators have adopted the working assumption that Article III(d) operates as a delivery requirement in favor of the Lower Division states, not just a division of available water (MacDonnell, 1994; Clyde, 1960). Language in the Compact is prohibitory towards the behavior of the Upper Division states. It states that the Upper Basin "will not cause the flow…to be depleted" and "shall not withhold water…" from the Lower Basin. Despite the absence of the word "guarantee," in practical terms, the Compact and related river operating rules function to ensure the Lower Basin receives at least 7.5 MAF per year (on average), giving the Lower Division a *de facto* higher priority (seniority) than the rights of the Upper Division states.[75]

The Congressional testimony of Herbert Hoover, the federal representative in the Compact negotiations, further bolsters the interpretation that Lower Division rights are senior to Upper Division rights. He testified that in the case of a Compact Call, Lower Division rights would be completely satisfied before Upper Division rights (excluding Present Perfected Rights). He stated that both the Upper and Lower Divisions were entitled to 7.5 MAF annually, but that "in the improbable event of a deficiency, the lower basin has the first call on the water up to a total of 75,000,000 acre-feet each 10 years."[76] Similarly, the language of the Upper Colorado River

[75] The language of the Colorado River Compact does not explicitly discuss water rights seniority. However, the delivery requirement in Article III(d) coupled with Article III(e)'s provision that the Upper Division States also may not withhold water that cannot be reasonably used for agriculture or domestic uses from delivery to the Lower Division suggests that the Lower Division's rights are senior to the Upper Division.

[76] 64 Cong. Rec. 2710; *see also* H.R. Doc. No. 717, 80th Cong., 2d Sess. A125 (1948). However, Hoover's testimony must be considered in context. Hoover was responding to questions from an Arizona congressman, Carl Hayden. At the time, Arizona had not ratified the compact and hostilities were developing in Arizona. Hoover was well aware

Basin Compact (UCRBC) uses both the "not to deplete" and "delivery obligation" language, but ultimately seems to accept the delivery obligation interpretation.[77] Additionally, later federal legislation about reservoir operations emphasizes a delivery obligation (MacDonnell, 1994). Several academic studies also emphasize this delivery requirement. For example, a two-phase study, entitled "Coping with Severe and Sustained Drought in the Southwestern United States," stated that "only after the full Lower Division obligation has been met can the Upper Division begin to satisfy post-1922 demands" in a time of drought (Lord, 1994).[78]

However, despite this body of evidence supporting the "delivery obligation" interpretation, the Compact does not use this terminology, and this fact may be increasingly important in an era of climate change. For example, one analyst argues that if flows are reduced by a "natural force" such as climate change rather than by Upper Basin consumption, then mitigating that decline in flows is not the responsibility of the Upper Basin, as it was not the Upper Basin that caused the flows to be depleted (Kuhn, 2007). This argument can be married to the debate about whether the Compact was intended to provide an "equitable" and/or an "equal" division of water. Under either interpretation, it can be argued that the Upper Basin should not bear the full brunt of climate change flow reductions. The fact that the 7.5 MAF/year allocation to each basin is stated "prominently and emphatically" in Article III(a) is seen by some as suggesting that this principle is superior to all other provisions, including the non-depletion language of Article III(d) (Carlson and Boles, 1986).

ISSUE 4: Compact Rescission or Reformation

The Colorado River Compact apportioned water to the Upper and Lower Divisions based on data from 1899 to 1920—an unusually wet period. This data prompted negotiators to believe the river featured an average virgin flow of (at least) 16.4 MAF per year. However, based on pre-historic tree-ring data, the actual average flow of the Colorado River is considerably less—probably no more than 15 MAF (see Appendix B for more details). As a result, the Colorado River is significantly over-allocated, a problem made worse by later commitments to apportion additional water in the Treaty with Mexico and by the Supreme Court's decision to exclude Lower Basin tributaries from the basic apportionment. As noted elsewhere, these inaccurate

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of this and had gone out of his way to campaign for its ratification. Hoover's testimony, then, may be less supportive of the delivery obligation requirement when considering the context in which it was made (Carlson and Boles, 1986; Kuhn, 2007).

[77] The UCRBC uses the "obligation not to deplete" language when describing the Yampa, but speaks of "obligations to deliver water" when referring to the Colorado mainstem.

[78] Also see Wegner (2000) and Getches (1997), among many others.

flow assumptions have serious consequences primarily for the Upper Basin states (Grant, 2003; Clemons, 2004; Erhardt, 1992).

While interstate Compacts are both statutory and contractual, courts have normally applied contract doctrine to resolve compact issues (Grant, 2003; Getches, 1985; *Kansas v. Colorado*;[79] *Texas v. New Mexico*[80] (acknowledging that a compact is statutory but applying contract doctrine)). Accordingly, there are two contract remedies available to the Upper Basin states: rescission (i.e., voiding) or reformation (i.e., altering) of the Compact based on mutual mistake. Rescission is possible only if the Upper Basin did not knowingly accept the risk of factual mistake; if they did, honoring the Compact would still be required.[81] This determination may hinge on the interpretation of Article III(d). If it is, in fact, a delivery requirement, then it seems to allocate the risk to the Upper Division. However, if it is an obligation not to deplete or is an expression of the equal shares theory, then perhaps it is less likely that this article expressly allocates the risk of mistake to the Upper Division, and rescission may thus be possible.

The second possibility that the Upper Basin bears the risk of the mistake is that it was aware that it had only limited facts at the time the Compact was made, but treated those facts as sufficient. Throughout the negotiations, data was presented to the Committee from the Bureau of Reclamation, the United States Geological Survey, and their own sub-committees.[82] The negotiations and subsequent congressional testimony illustrate that nearly all representatives believed that they had sufficient information to apportion the River, and furthermore, believed that the Colorado River had more than 15 MAF of flow.[83] While the Upper Basin Commissioners treated their knowledge as sufficient, the fact that they were unaware that it was so biased brings into question if they knowingly accepted the risk of mistake in apportioning the Colorado River's flow in the Compact. Given these facts, there is certainly a potential for arguing for rescission of the Compact based on mutual mistake; however, it is unlikely that the remedy

[79] *Kansas v. Colorado*, 533 U.S. 1, 5-8 (2001).
[80] *Texas v. New Mexico*, 482 U.S. 124, 128 (1987).
[81] Rest. (Second) of Contracts § 156 (1981).
[82] 1 Record, *supra*, Sess. No. 6.
[83] Richard Sloan, the legal advisor to Arizona's Colorado River Commission, believed that one of the major assumptions of the Compact was that "sufficient water [exists] in the river if conserved to meet all the demands for agricultural and business use, both in the upper and lower basins," and that this was illustrated by a "study of the river and of various estimates made by reclamation service and by state engineers" (H.R. Doc. No. 717, 80th Cong., 2d Sess. A66 (1948)). Delph Carpenter (Colorado) said that, "the twenty-year record that we had will not be improved by more records at this point. And the hydrographs and experts advise me that a twenty-year record on a river is adequate in its completeness and includes enough years to warrant an assumption that the average there deduced would be the average flow of the river in the future" (1 Record, Sess. No. 12 at 6). Carpenter also remarked that engineers presenting to the group had indicated that a fifty-year record would be best to determine an extreme minimum, but that general calculations could be accomplished through a twenty-year record (1 Record, Sess. No. 12 at 29).

would provide any real benefit to the Upper Basin. Since the Lower Division uses more water and has more senior water rights than the Upper Division, voiding the Compact and equitably apportioning the Colorado River may be unlikely to benefit the Upper Division more than the current Colorado River Compact (Carlson and Boles, 1986).

Reformation of the Compact to resolve some of legal ambiguities discussed may be another option for the Upper Basin if it is able to successfully argue that reformation should follow the Compact's approach of dividing the right to use water equally (Getches, 1985). Reformation due to mistake is only permitted when the mistake is to a reduction in writing or where the parties are mistaken as to the legal effect of the language used.[84] As discussed earlier, there is a strong argument that parties were mistaken as to the legal effect of certain terms used—"equitable division" being an example. More problematic is the prohibition against reformation when third parties have relied on the contract in acquiring property interests.[85] Since 1922, numerous water users in the Upper and Lower Basins have relied on the provisions in the Compact. This includes individual irrigators, municipalities, water supply companies, power companies, and recreational users, among others. Reformation to ensure equal shares would likely affect Lower Basin users more severely than Upper Basin users, and could unfairly affect the rights of third parties acting in reliance on the Compact's provisions (Carlson and Boles, 1986).

Reformation of the Compact is theoretical possible using either congressional or judicial pathways. When Congress consents to an interstate compact, it presumably retains the right to revise or interpret the agreement. However, it is unlikely to do this in the absence of demonstrable injustice. Alternatively, the Supreme Court could address, under original jurisdiction, whether the Compact should be enforced when it produces an inequitable result due to a mutual mistake. However, since the Court accepted the Compact's allocations in *Arizona v. California*, it may now be unlikely to modify the Compact (Getches, 1985).[86] The Compact's allocation to the Upper Division states may not be inequitable enough to warrant modification, and it may not be unconstitutional, in which case the Court is unlikely to allow

[84] Reformation due to mistake as to written expression may occur "where a writing that evidences or embodies an agreement in whole or in part fails to express the agreement because of a mistake of both parties as to the contents or effects of the writing" (Rest. 2d of Contracts § 155).
[85] The court can reform the contract to "express the agreement, except to the extent that rights of third parties such as good faith purchases for value will be unfairly affected" (Rest. 2d of Contracts § 155).
[86] It's worth noting, however, that *Arizona v. California* primarily focused on an intra-basin dispute, and not the inter-basin apportionment.

modification on the basis of mutual mistake. [87] Nonetheless, climate change, if severe, may ultimately prove to be a "game changer" regarding the viability of the reformation argument.

ISSUE 5: Magnitude of Present Perfected Rights

> *Article VIII - Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact. Whenever storage capacity of 5,000,000 acre-feet shall have been provided on the main Colorado River within or for the benefit of the Lower Basin, then claims of such rights, if any, by appropriators or users of water in the Lower Basin against appropriators or users of water in the Upper Basin shall attach to and be satisfied from water that may be stored not in conflict with Article III.*
>
> --- Colorado River Compact of 1922

Present Perfected Rights (PPRs) are the most senior water rights in the Colorado River Basin, and not subject to curtailment during shortages. As discussed below, two issues surround the precise quantification of Present Perfected Rights.

Are Present Perfected Rights Determined as of 1922 or 1929?

It is unclear if PPRs are those with a priority date prior to the signing of the Colorado River Compact (November 24, 1922), or prior to the effective date of its ratification in the Boulder Canyon Project Act (June 25, 1929). The Upper Colorado Basin Compact (1948) states that rights in the Upper Basin must have been perfected prior to November 24, 1922.[88] However, the Supreme Court in *Arizona v. California*, held that the PPRs in the Lower Basin include water appropriated prior to the adoption of the Boulder Canyon Project Act on June 25, 1929.[89]

The Court's adoption of 1929 as the date of PPRs is binding on the states—Arizona, California, Nevada, New Mexico, and Utah—involved in the *Arizona v. California* litigation. Colorado and Wyoming are presumably not bound by this litigation and, accordingly, continue to use the date

[87] In *Texas v. New Mexico I*, the Court held that "unless the compact to which Congress has consented is somehow unconstitutional, no court may order relief inconsistent with its express terms" (Texas v. New Mexico, 462 U.S. 554, 564 (1983)). In that case, the Pecos Compact was found to be based on a flawed allocation formula that lead to a variety of water delivery problems, leading the Court to enact a new allocation formula, but not relieving New Mexico from the obligation of remedying the past failures under the initial agreement.
[88] Upper Colorado Basin Compact, CRS 37-62-101(Art. IV)(c).
[89] *Arizona v. California*, 547 U.S. 150, 154 (2006).

of the Colorado Compact not the Boulder Canyon Project Act as the basis for determining their PPRs.[90] The primary ambiguity is whether the decision in *Arizona v. California* binds New Mexico and Utah.[91] The Court states that the determinations made in the 2006 decree do not affect the "rights or priorities of water in any of the Lower Basin tributaries…in the States of….New Mexico and Utah."[92] Since New Mexico and Utah were only joined to the extent of their Lower Basin tributaries, this may suggest that their PPRs are those perfected prior to the Colorado River Compact as stated in the Upper Colorado River Basin Compact and not those perfected prior to the Boulder Canyon Project Act.

Upper Basin Present Perfected Rights

PPRs in the Lower Division, including those held by five Lower Basin tribes, are codified in the *Arizona v. California*, 2006 decree.[93] Arizona holds 1,077,971 AF of PPRs, with only 298,003 AF being non-tribal rights.[94] California has the largest amount of PPRs, totaling 3,019,573 AF, only a small fraction of which are tribal.[95] Nevada, the last Lower Basin state to develop, holds only 13,034 AF of PPRs, only 500 AF of which do not belong to the tribes.[96] The PPRs listed in the decree are unlikely to change, except for minor adjustments after final boundary determinations for some of the tribes.[97]

The magnitude of Upper Basin PPRs, however, is much more uncertain. The amount of PPRs in the Upper Basin has important implications for Upper Basin curtailments during shortages (i.e., "calls"), and future management of the river. Because the Supreme Court has not quantified PPRs for Colorado, Wyoming, Utah, and New Mexico, these states are currently in the process of internally calculating both state and tribal PPRs. In lieu of better information, perhaps the best estimate for PPRs in the Upper Basin comes from tables presented during the Colorado River Compact negotiations.[98] Table A-1 summarizes these findings.[99] This table suggests that

[90] The recent Colorado River Water Availability Study used the 1922 date for its discussion of PPRs (CWCB, 2008).
[91] During the litigation, California had tried to join the rest of the Basin states; however, the Court permitted only Utah and New Mexico to join, and limited their participation to their Lower Basin tributary interests. The Court did not permit joinder of Colorado or Wyoming, so their PPRs are presumably those in use prior to the Colorado River Compact (*Arizona v. California,* 350 U.S. 114 (1957); Kuhn, 2007).
[92] *Arizona v. California*, 547 U.S. 150, 166 (2006).
[93] *Arizona v. California*, 547 U.S. 150, 169-181 (2006).
[94] Tribes in Arizona are entitled to 779,968 AF of PPRs. *Arizona v. California*, 547 U.S. 150, 169 (2006).
[95] California Tribes hold 156,522 AF in PPRs. *Arizona v. California*, 547 U.S. 150, 174 (2006).
[96] Tribes in Nevada are entitled to 12,534 AF of PPRs. *Arizona v. California*, 547 U.S. 150, 181 (2006).
[97] "The western boundaries of the Fort Mojave and Colorado River Indian Reservations in California and…for the boundaries of the Fort Yuma Indian Reservation in Arizona and California" are still subject to adjustment (*Arizona v. California*, 547 U.S. 150, 168 (2006)).
[98] These numbers are for circa 1920, and are very rough due to lack of adequate monitoring technology.

Upper Basin PPRs range from 2,180,750 to 2,267,000 AF.[100] Quantification of these rights and resolution of this ambiguity become increasingly important as water availability declines and the threat of a Compact call increases.

Table A-1. Estimates Used In Compact Negotiations of Upper Basin Present Perfected Rights		
State	Water Consumption (AF) (for irrigation), circa 1920	
	Table A, Bureau of Reclamation	Table C, Committee on Water Requirements
Colorado	1,110,000	1,105,000
New Mexico	68,000	99,750
Utah	538,500	376,000
Wyoming	550,500	600,000
Upper Basin Total	2,267,000	2,180,750

ISSUE 6: Administration of Compact Calls

> *ARTICLE VI - Should any claim or controversy arise between any two or more of the signatory States…(c) as to the allocation of the burdens incident to the performance of any article of this compact or the delivery of waters as herein provided… the Governors of the States affected, upon the request of one of them, shall forthwith appoint Commissioners with power to consider and adjust such claim or controversy, subject to ratification by the Legislatures of the States so affected.*
>
> --- Colorado River Compact of 1922

[99] The information in this table was presented during the Colorado River Compact Negotiations, and comes from two different tables. Table A was prepared by the Bureau of Reclamation, and Table C was prepared by the Committee on Water Requirements, a subcommittee of the Colorado River Negotiations. Both the original and "Revised" Table C have identical values for Upper Basin consumptive use. The value for "Upper Basin Total" was not included in the original tables, but is calculated from the values provided. Furthermore, the term "Present Perfected Rights" was not used in conjunction with these tables in the negotiation transcripts. It appears that the figures included in the table above were accepted as current use (as of 1920) (1 Record, Sess. No. 6 at 74).

[100] The estimate of 2.2 MAF is commonly cited in Colorado River discussions.

Under the prior appropriation system, when flows in a river are insufficient to satisfy all rights on the river, a senior appropriator will place a “call” on the river. This forces junior appropriators to stop diverting until the senior’s water right is satisfied (BLM, 2010). There are two possible types of calls on the Colorado River, neither or which has ever happened: a Lower Basin call against the Upper Basin, and an Upper Basin call against another Upper Basin state. A Lower Basin call would only occur when, due to nearly empty reservoirs and severe low flows in the Colorado River, the Upper Basin fails to meet either its Article III(d) flow requirements or its Article III(c) deliveries to Mexico (MacDonnell, 1994). In an Upper Basin call, one Upper Basin state would make a call on another Upper Basin state. This could conceivably happen when one state’s consumptive use exceeds its percentage share under the Upper Colorado River Basin Basin Compact (UCRBC) and another state is injured, perhaps as part of efforts to comply with a Lower Basin call.

Any such calls would likely be administered by the Upper Colorado River Commission. Despite the detailed language in the UCRBC and the presence of a Commission, there are still many ambiguities as to how Upper Basin curtailment rules would apply. The most common interpretation is that any of the states that used, in the ten years prior to curtailment, more water than they were entitled to use under Article III of the Colorado River Compact must supply the quantity of such an overdraft to Lee Ferry before any other state faces curtailment. If there is no overdraft, then all states must deliver to Lee Ferry an amount of water proportional to their consumptive use in the preceding water year over total consumptive use in the Upper Division. This theory is supported by the State Engineer curtailment policies of many Upper Basin states as well as contemporaneous testimony from the UCBRC consulting engineer. [101] The alternate approach is to quantify curtailments based on apportionments. Under this interpretation, each state would curtail its use based on its percentage allocation in the UCRBC, not its consumptive use in the prior water year. Gregory Hobbs, a current Colorado Supreme Court Justice, supports this interpretation (Hobbs, 2009). The Commission has yet to formally endorse either interpretation, but is “reviewing and establishing detailed procedures and policy for implementing curtailment of use in the Upper Basin”[102] (Ostler, 2009). Regardless of the approach used, the magnitude of curtailments for each Upper Basin state

[101] Pat Tyrrell, the current Wyoming State Engineer, stated that “the curtailment by each State is to be proportionate to the [consumptive use] of Upper Colorado River System water made by each State during the water year immediately preceding the year in which the curtailment becomes necessary" (Tyrrell, 2008). This testimony is similar to that of Tipton during the Compact hearings (in 1949), in which he concludes that, during curtailment, the states will take a cut in “proportion to the amount they are using, not in proportion to their apportionment” (The Upper Colorado River Basin Compact Hearing, 81st Cong. 38 (1949)).

[102] The UCRBC also specifically references curtailment procedures on the Little Snake River (Art. XI), Henry’s Fork of the Green River (Art. XII), the Yampa River (Art. XIII), and the San Juan River (Art. XIV). It is unclear how these curtailment procedures fit in with curtailment procedures in the Upper Division as a whole.

must be sufficient to result in the required delivery to Lee Ferry.[103]

During a curtailment, "it will be up to the individual states as to the particular uses that will be curtailed to take care of the obligation."[104] Since the recent drought, each state in the Upper Division has been working to promulgate curtailment rules.[105] These processes are still ongoing as there are no federal or state guidelines on how each state should implement curtailment procedures, and there is no precedent for implementing an interstate call on the Colorado. As a practical matter, the approaches that are used within and among the Upper Basin states may be impossible to fully determine without addressing many (if not all) of the other legal issues already identified.

IV. Conclusion

Perhaps the most overlooked element of the Colorado River Compact is its stated goal of producing "interstate comity" in the basin (Article I).[106] This remains a goal only partially achieved, and a goal that appears increasingly in jeopardy in the basin given growing water scarcity. The length of time normally required to resolve such omissions and ambiguities—whether this is done by litigation or negotiation—is disconcerting, and is an argument for being proactive in confronting issues before the onset of crisis.

[103] Upper Colorado River Compact, art. IV, C.R.S. 37-62-101 (2009).

[104] *The Upper Colorado River Basin Compact: Hearing on H.R. 2325, H.R. 2336, H.R. 2327, H.R. 2328, H.R. 2329, H.R. 2330, H.R. 2331, H.R. 2332, H.R. 2333, H.R. 2334 Before the H. Subcomm. on Irrigation ad Reclamation*, 81st Cong. 38 (1949) (statement of Royce J. Tipton, Consulting Engineer, Colorado Water Conservation Board).

[105] In 2007, Colorado began crafting rules for curtailment in the Colorado River Basin as part of the Colorado River Curtailment Studies. (Memo to CWCB,2007). New Mexico is currently preparing an Active Water Resources Management Initiative ("AWRM") to allow the State Engineer to create curtailment rules. (AWRM, 2005). Utah is also in the midst of quantifying its present perfected rights and examining Colorado River issues, yet it is unclear whether Utah is undertaking a comprehensive study on curtailment or whether Utah is in the process of promulgating curtailment procedures. (DNR, 2010). The Wyoming State Engineer's Office has created a new program entitled, the Colorado River Compact Administration Program, and information gathered in this program will be used in the case of curtailment necessary to fulfill obligations in the Colorado River Compact. (Tyrrell, 2008).

[106] "Comity" is a term rarely used in social settings, but in legal use, it normally refers to arrangements that yield courtesy, respect, and harmony among parties.

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Appendix B: Stressors and Threats to the Water Budget of the Colorado River

I. Introduction

The Colorado River faces many stressors which threaten the reliability of water supplies and the integrity of ecosystems. The following pages summarize the scientific, policy, and environmental literature discussing these concerns, with the aim of informing discussions about coping strategies. Most research is focused on two core threats, population growth and climate change, although the water needs of energy development are also increasingly in the conversation, as carbon emissions and national security issues could suggest rapid changes in that sector. Population growth and energy development are likely to further intensify demands, while climate change is expected to reduce average flows and increase the frequency (and intensity) of extreme events. The combined impact of these trends is highly disconcerting given the observation (shown below in Figure B-1) that average demands have already caught up with average supplies.

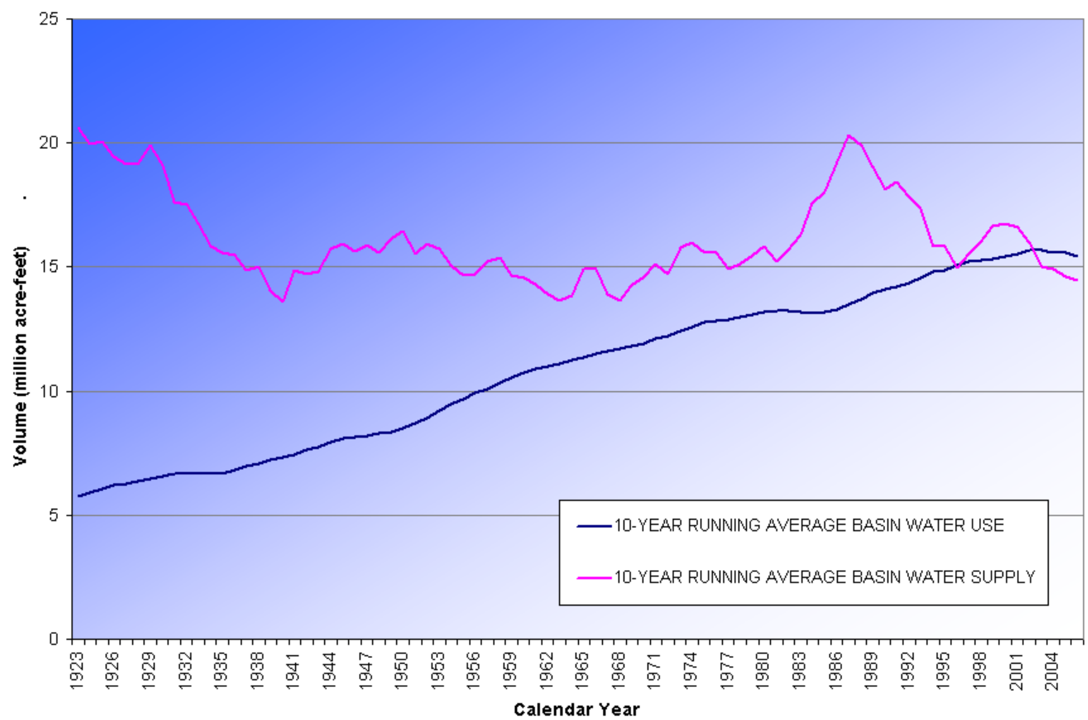

Figure B-1. Total water supplies and demands on the Colorado River System.[107]

[107] In this figure, provided by the Bureau of Reclamation, supplies are the sum of mainstem flows (from upstream of Lake Mead) plus Lower Basin tributary flows that reach the mainstem above Imperial Dam. Demands are the

II. Growing Water Demands

Population Growth

The American Southwest experienced tremendous population growth throughout the 20th Century. This trend was especially evident towards the latter half of the past century; as shown in the following figure from the U.S. Census Bureau, from 1950-2000, Colorado, Utah, Nevada, Arizona, and California all experienced population growth levels of 200% or more (U.S. Census Bureau, 2002, Figure 1-12; reprinted below as Figure B-2). This trend of substantial growth in the West has continued since the turn of the century. Since 2000, the Upper Basin states of Wyoming, Colorado, Utah, and New Mexico have increased in population by 10.2, 16.8, 24.7, and 10.5 percent, respectively, while the Lower Basin states of Nevada, Arizona, and California have increased by 32.3, 28.6, and 9.1 percent (U.S. Census Bureau, 2009).[108]

official accounting of consumptive uses of mainstem water. Note that water originating in Lower Basin tributaries that is consumed before reaching the mainstem is neither included as either supplies or demands. Thus, the supply line and demand line are both a little low (if the intent were to truly describe total surface water supplies and demands in the Colorado River System), but the spread between them is accurate, which is the primary purpose of this figure.

[108] These western states are not only ranked among the highest in terms of population growth, but also among the lowest in amounts of precipitation. Utah, Colorado, New Mexico, Arizona, and Nevada are all in the bottom ten states in terms of annual precipitation. Nevada, the fastest growing state since 2000, receives the least amount of precipitation in the entire country (less than 10 inches per year) (see: http://www.nationalatlas.gov/printable/precipitation.html#list).

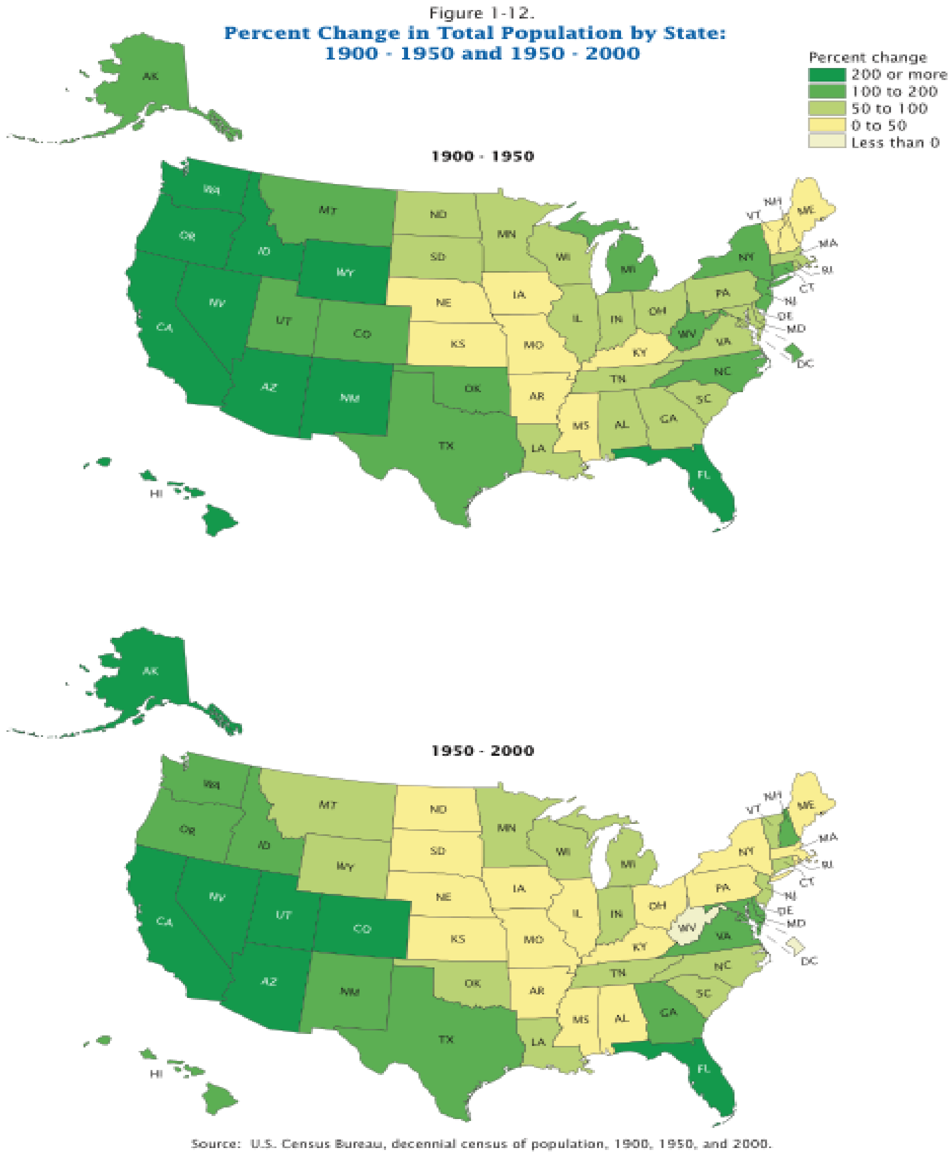

Figure B-2. Percent change in total population by state: 1900-1950 and 1950-2000. (US Census, 2002, Demographic Trends in the 20th Century, Chap. 1. Figure 1-12.)

Currently there are approximately 27 million people that receive water, at least in part, from the Colorado River. Although the Lower Basin already consumes its entire allotment each year and the Upper Basin may be reaching its Colorado River water limits, the number of people in the region is projected to increase to 38 million people by 2020 (Bates et al., 2008; WEF, 2010). An additional 11 million people will need water from a system that is already stretched near its limits (Overpeck, 2009).[109] For example, the state of Colorado is expected to grow from around 5 million people in 2010 to 7.6 million people in 2035. Most of the growth will be along the Front Range, further intensifying the call for additional trans-basin diversions from the Colorado River (Colorado State Demography Office, 2010; Williams, 2009). There are already many existing large diversion projects on the Colorado,[110] with several more being proposed (WRA, 2009; Pontius, 1997; Fradkin, 1981). For example, two pipelines are being proposed to divert water out of the Green River (a major Colorado River tributary) in southwest Wyoming and bring it to Colorado's Front Range, which is east of the Continental Divide and out of the Colorado River Basin (Coyote Gulch, 2009; Warner, 2009).

Translating projected population growth into anticipated water demand is very difficult given that the relationship is not necessarily linear; population growth does not and need not automatically mean an increase in water demand. Water efficient land use, development, and landscaping can all help reduce the amount of water needed for growth. In fact, as some specific examples have shown, an increase in population growth can sometimes be achieved with a net decrease in water consumption (NRDC, 2007; Best, 2008; National Academy of Sciences, 2007). Nonetheless, demands on the Colorado are projected to increase.

Future projections of water demand are reported in the Depletion Schedules developed by the states and compiled by the Bureau of Reclamation. As shown in Appendix C of the 2007 EIS, in the Upper Basin, Colorado, Utah, and Wyoming all expect continued consumption increases throughout the planning period (to 2060), while use in New Mexico plateaus by 2035 (USBR -

[109] In addition to the basin states populations growing, several recent water right settlements have quantified demands from Native American Tribes within the Colorado River Basin. For example, the Navajo Nation lawmakers voted in November 2010 to approve a controversial settlement that allocated 31,000 af per year from the Lower Basin (http://www.deseretnews.com/article/700079134/Navajo-lawmakers-approve-water-rights-settlement.html). The settlement also includes rights to two underground aquifers and unappropriated water from the Little Colorado River (a Colorado River tributary). Congress still needs to approve funding for infrastructure updates so the water can actually be brought to the reservation.

[110] Major transbasin projects in Colorado include the Colorado Big-Thompson Project (213,000 AF/yr) (http://www.ncwcd.org/project_features/cbt_main.asp), Denver Water Collection System (257,304 AF of total capacity) (http://www.denverwater.org/Recreation/Dillon/), and the Fryingpan-Arkansas Project (69,200 AF/year) (http://www.usbr.gov/projects/Project.jsp?proj_Name=Fryingpan-Arkansas+Project). The San Juan Chama Project in New Mexico diverts 110,000 AF/year out of the Colorado River Basin (http://www.usbr.gov/projects/Project.jsp?proj_Name=San%20Juan-Chama%20Project). In Utah, the Central Utah Project, Bonneville Unit delivers 219,160 AF/year to out-of-basin users (http://www.usbr.gov/projects/Project.jsp?proj_Name=Central%20Utah%20Project%20-%20Bonneville%20Unit). In the Lower Basin, nearly all of California's 4.4 MAF apportionment is used outside of the Colorado River Basin. The Metropolitan Water District of Southern California delivers between 550,000 AF and 1.293 MAF per year from the Colorado River to users in San Diego and Los Angeles (http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/colorado/colorado04.html). The Imperial Irrigation District diverts 3.1 MAF of Colorado River water per year out of the basin.

Appendix C, 2007).[111] The Lower Basin is already consuming its full apportionment (USBR – Appendix D, 2007). Over the next year, the methodologies used to calculate current and projected depletions will be subject to additional scrutiny as part of the Colorado River Basin Supply and Demand Study—known simply as the Basin Study. This effort, funded and managed jointly by the states and the Bureau of Reclamation, will analyze supply and demand imbalances through 2060.[112] Similar research is occurring within several of the basin states as well. One effort is the recently defunded Colorado River Water Availability Study (CRWAS), which determined that the range of additional Colorado River water available for development in the State of Colorado extends from 0 to 1.0 MAF, depending primarily on the climate assumptions utilized (CWCB, 2010).[113]

The Special Case of Energy Development

Providing energy to the residents of the Southwest is a major strain on water resources. For example, in 2005, thermoelectric power plants in Arizona, Colorado, New Mexico, Nevada, and Utah used approximately 292 million gallons of water per day. This amount of water is roughly "equal to water consumed by Denver, Phoenix, and Albuquerque, combined" (WRA, 2010: ii). Furthermore, projected population increases are expected to be matched with an increasing demand for energy, further stressing limiting water supplies. According to the Electric Power Research Institute, restraints on thermoelectric power production due to limits on water supplies will occur by 2025 in Arizona, Utah, and California (Bull, 2007). While a certain level of water use for energy development is already embedded into projections of population growth related water demand, the water consumption implications of potentially shifting to a radically new mix of energy sources in coming decades merits special attention.

Vast amounts of energy resources exist in the Colorado River Basin. Fully exploiting these extensive coal, oil, natural gas, uranium, and oil shale reserves has significant water demand implications (Pitzer, 2009; URS Corporation, 2008). Additionally, development of alternative energy sources also has water implications (DOE, 2000; Kyl, 2010; Woody, 2009). In recent years, the link between water quantity and energy development in the Colorado River Basin has become a major area of study and debate, in part because concerns over climate change and

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[111] Since 2007, the Upper Basin states have slightly revised their Depletion Schedules, showing a slightly faster rate of consumption.

[112] http://www.usbr.gov/lc/region/programs/crbstudy.html.

[113] See Figure 3-37 (page 3-45) of the Draft Phase I report; http://cwcb.state.co.us/technical-resources/colorado-river-water-availability-study/Documents/CRWAS1Task10Phase1ReportDraft.pdf. As Eric Kuhn, general manager of the Colorado River Water Conservation District, has pointed out, the effort should not be viewed as an attempt to identify the exact amount of water available, but as an exploration of the relationship between additional development and the increased risk of shortage (Jenkins, 2009).

energy independence are encouraging a new look at possible energy development futures. An extensive review of all the water-energy issues in the Colorado River Basin is beyond the scope of this paper[114], but a sampling of some of the most salient issues and questions is provided below:

- *The Future of Coal.* The majority of electricity generated and used in the Colorado River Basin comes from local coal reserves. Mining, washing and transportation of coal are all water-intensive, depending on technology and related factors, as is the burning of coal in facilities utilizing steam turbines (DOE, 2006; URS Corporation, 2008; Averyt, 2010). At the point of consumption, the major coal-fired power plants in the Colorado River Basin annually consume approximately 163,000 acre-feet from the Colorado River System (WRA, 2009). Many other plants rely on groundwater, recycled water, or surface water from other watersheds (WRA, 2009). Producing electricity from coal is cost effective, but carries a high greenhouse gas price. Even modest changes in the role of coal in generating electricity can have significant implications for the Colorado River Basin.

- *The Growing Popularity of Natural Gas*. Natural gas is enjoying increasing popularity due to its local abundance and its reputation as a cleaner burning fuel than coal or oil. Natural gas production requires water in drilling operations, pipeline transmission and treatment operations (URS Corporation, 2008). However, it can also "produce" water. Coalbed methane (CBM) development, for example, requires bringing huge quantities of groundwater to the surface, which may or may not prove locally beneficial depending on water quality, surface water-groundwater dynamics, and other considerations.[115] Additionally, like coal and uranium, natural gas is frequently used to power steam turbines, a major source of water diversions and consumption (EPRI, 2002). For example, natural gas power plants in Arizona consume approximately 3,568 AF of Colorado River water per year (WRA, 2009). The number of natural gas fueled power plants is expected to rise as well because utility companies are looking to replace coal-fired plants with cleaner burning natural gas plants.[116]

- *The Potential of Oil Shale*. Of the "new" energy sources, oil shale is among the most significant in terms of potential Colorado River demands. The Green River Formation, which is located in parts of Colorado, Utah, and Wyoming, holds the largest known oil shale

[114] The Natural Resources Law Center will publish a book on the "Water-Energy Nexus in the Western United States" in 2011 (Edward Elgar Publishing).

[115] Based on data from the USGS (2000), coalbed methane annually produces over 3,600 acre-feet in the San Juan Basin and nearly 4,000 acre-feet in the Uinta Basin. These values were calculated by the following formula: AF = (wells per basin) x (average water production (bbl/day/well)) x (365 days) x (42 gal/bbl) x (1/325,851 gal).

[116] "Xcel lays out natural-gas conversion plan for metro area". Denver Post. By Drew FitzGerald, August 14, 2010. http://www.denverpost.com/ci_15775014

deposits in the world: 1.5 to 1.8 trillion barrels. Of this quantity, approximately 500 billion to 1.1 trillion is estimated to be recoverable (Bartis, 2005). If pursued, oil shale recovery could use a very large amount of water, as water is required for refining, reclamation, dust control, on-site worker demands, and power generation (Hightower, 2008; Averyt, 2010; Pitzer, 2009). Western Resource Advocates estimates that mining the extensive oil shale reserves in northwestern Colorado could consume 280,439 acre-feet annually (WRA, 2009). Additionally, large-scale oil shale development could also have huge, but largely uncertain, impacts on population growth in the source areas (e.g., see Bartis, 2005; Oil Shale, 2009; Center of the American West, 2008).

- *A Nuclear Energy Renaissance.* Significant amounts of water are required for uranium mining and the operation of steam turbines in nuclear power plants. A renewed national commitment to nuclear energy (as urged by the Obama Administration), therefore, could have significant implications for the Colorado River Basin. Uranium mining claims located within 10 miles of the Colorado River have already increased from 2,568 in 2003 to 5,545 in 2008 (EWG, 2008).[117] Currently in the Colorado River Basin, there is only one operating nuclear power plant, the Palo Verde Nuclear Generating Station located in Arizona (NRC, 2010). This is the nation's largest nuclear power plant, consuming nearly 81,000 acre-feet per year (EPA, 2004). Additionally, a new nuclear power plant has been proposed in Southern Utah near the Green River, a main tributary to the Colorado River. It is estimated this plant would require 50,000 acre-feet of Green River water annually for cooling processes (Salt Lake Tribune, 2010).

- *Options for Solar Energy*. The most popular technology for large-scale generation of electricity from sunlight is concentrated solar power (CSP), which uses mirrors to concentrate sunlight to power steam-driven power plants. Water use is highly dependent on the cooling technology used: wet, dry or hybrid.[118] The water requirements of extensive CSP production could be significant; the Congressional Research Service has estimated that the construction of 55 GW of CSP generating capacity, predominately in Arizona and

[117] Additionally, there are about 10,600 exploratory mining claims located near the Grand Canyon on BLM land and within the Kaibab National Forest (Pitzer 2009).

[118] Wet cooling plants can use 0.85 gallons/kWh, and are highly efficient even in hot climates; dry cooling requires much less water, often just 0.03 gallons/kWh, but is not efficient in some of the high temperature zones found in the lower Colorado River Basin (Kyl, 2010; WRA, 2010; Averyt, 2010; Wang, 2009; Kaplan, 2008; SEIA, 2010). The Department of Energy calculated that the amount of water needed per MWh of electricity produced at a CSP plant with wet cooling technology is twice that of fossil fuel plants and usually higher than a nuclear plant (Kyl, 2010). One strategy for mitigating the high water requirements of CSP has been the use of hybrid cooling systems. The Department of Energy studied hybrid facilities that used wet-cooling only on hot days. The DOE discovered that a hybrid system using only 50% of the water of a wet cooling system would maintain 99% of its performance, and a hybrid system using only 10% of a wet cooling system's water would maintain 97% of its performance (CRS, 2009). These hybrid systems may reduce demand for water, while still ensuring solar remains a viable electricity source.

California, could require 505,000 acre-feet/year of water (CRS, 2009; Kyl, 2010). The BLM is currently preparing a Programmatic Solar Environmental Impact Statement for large-scale solar development in twenty-four locations. The entire process should be completed near the end of 2010 (Uram and Cohen, 2009).

- *The Introduction of Large-Scale Bioenergy*. The term 'bioenergy' encompasses biofuels and biomass power systems, with biofuels referring to the production of liquid transportation fuels, while biomass systems generate electricity. Widespread pursuit of bioenergy in the Colorado River Basin could reshape cropping patterns and modify water demand. Unlike traditional bioenergy crops—such as corn, sugar, and soybeans—the Southwest is probably better suited to next generation bioenergy feedstocks such as algae, perennial grasses, and woody biomass (GAO, 2009; Berndes, 2008; Mulder, 2010).

- *Reliability of Hydropower*. Hydropower is a major benefit of Colorado River development; facilities on the river satisfy the power demands of roughly 3 million people. However, hydropower production is threatened by projected decreases in river flows, and by the challenge of maintaining adequate head (storage) in the major reservoirs. According to the U.S. Climate Change Science Program, for every 1% decrease in Colorado River flows, there will be a 3% decrease in hydropower production (Bull, 2007). Any loss in power generation is likely to be replaced by generating technologies that require more water.[119]

- *The Scale of Wind Generation*. Wind power production uses significantly less water than conventional power sources. Once a wind facility is in operation, water is used primarily for blade cleaning; removing dust and insect buildup ensures that performance is not degraded. Compared to electricity produced by existing technologies, wind energy holds the promise of, perhaps, 1/500 the water footprint (per kWh) (AWEA, 2010; Averyt, 2010).

- *Energy Demands of Water Management*. Ironically, one of the biggest sources of energy demand in the West is water management. A large amount of energy is needed to collect, transport, treat and re-treat water as it is delivered to water users throughout the Southwest (CEC, 2005). For example, in California, the amount of energy needed to pump Colorado River water to residents is 1,916 kWh/acre-foot (Wilkinson, 2000), and thirty percent of all non-power plant natural gas is used for water-related activities (including pumping, heating, and treating water and wastewater) (Pitzer, 2009). The energy costs of

[119] It is difficult to calculate the water consumption associated with hydropower production, as storage reservoirs associated with hydropower facilities were often built to serve multiple purposes (Torcellini, 2003). The major hydropower facilities at Glen Canyon and Hoover Dams, for example, were not built primarily for power production; power is an ancillary benefit. When system storage is high, evaporative losses from Colorado River reservoirs can approach (or even exceed) 2 MAF/year.

water management are also very high in other Colorado River Basin locales reliant on uphill water pumping, such as the Central Arizona Project service area and many of the new pipelines proposed (or in development) in regions such as Colorado's Front Range. For example, the Northern Integrated Supply Project (NISP), would require roughly 1,450 kWh/AF to pump water from the Poudre River to reservoirs in Northeastern Colorado (WRA, 2010). Other emerging water management strategies, such as desalination, also have significant energy implications (Craig, 2010; Stokes, 2009; Busch, 2004). To the extent that future water supply approaches are more energy intensive than past approaches, the stress on water resources is compounded.[120]

III. Concerns Over Water Supplies

Understanding and predicting the hydrology of the Colorado River is a difficult challenge (Snow, 2005). The Colorado, like other rivers and streams around the world, varies in annual flow depending on a variety of climatic and hydrologic conditions. Being a snow-dominated system, winter and spring snowfall in the Rocky Mountains is particularly salient. Natural ocean temperature fluctuations, such as the El-Niño-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), can have significant impacts on the amount of precipitation in the Colorado River Basin, which in turn affects the amount of flow.[121] Runoff and streamflow are also influenced by land-use conditions (including human activities), weather patterns, and other phenomenon, sometimes in highly complex and surprising ways.[122]

In recent years, severe drought on the river, combined with advancements in global climate change research, has prompted intense interest in better understanding the past, present and future of the Colorado's flow regime. Particularly influential was the impact on reservoir storage coinciding with drought conditions since the early 2000s. As shown in Figure B-3, from 1998 to 2010, combined storage in the two reservoirs dropped 22.15 MAF. This reduction in

[120] Additionally, growing energy consumption in the water sector is likely to increase the greenhouse gas emissions that are attributed to the detrimental climate changes affecting water systems throughout the region.

[121] A 2010 study published in the Journal of American Water Resources Association found that a possible convergence of these ocean conditions (ENSO, PDO, and ADO) could create substantial drought conditions in the Colorado River Basin. http://www.physorg.com/news205156605.html

[122] For example, one recent study found that human activities that disturb soils have increased dust deposition on snowpack in the Upper Colorado Basin, decreasing the snow's albedo, increasing the warming of the snowpack, accelerating the timing of spring runoff, and ultimately, decreasing the annual flow of the river by roughly 5% (Painter et al. 2010).

reservoir storage has not only concerned water managers, but has been featured prominently in reports by the mainstream public media.[123]

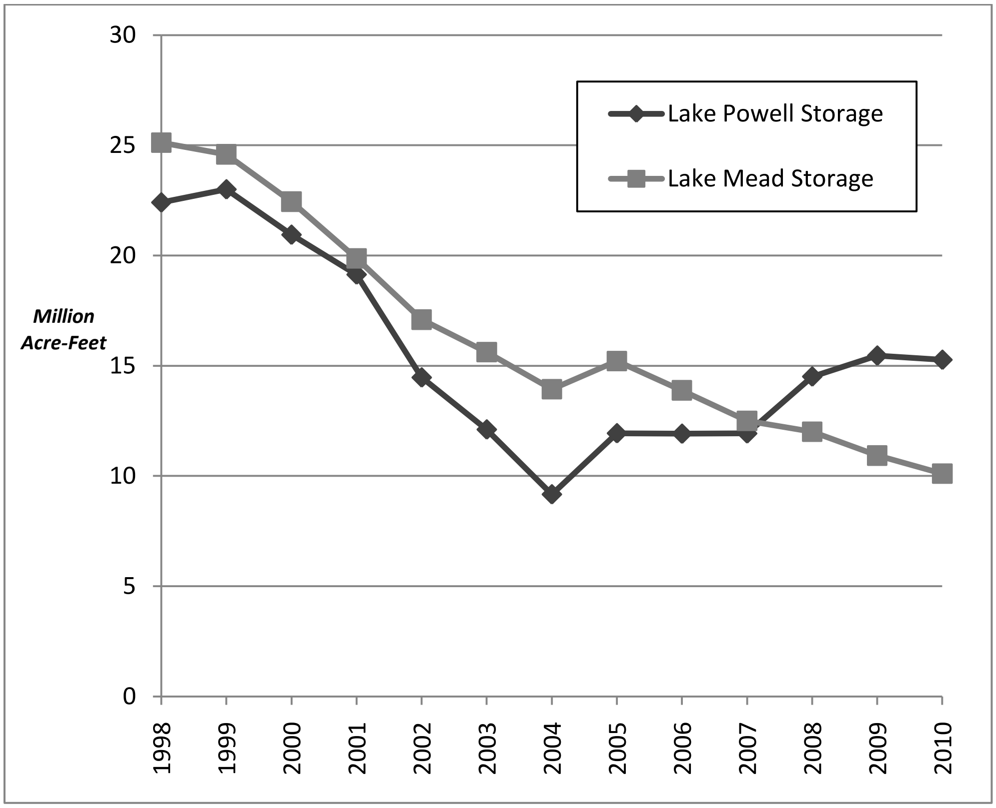

Figure B-3. Storage on Lakes Powell and Mead, 1998 to 2010 (September 30th values).

[123] Several news articles highlight the dramatic reduction in Lake Mead storage levels and potential future consequences, against the backdrop of celebrations marking the 75th anniversary of Hoover Dam construction. "Lake Mead at 54-year low, stirring rationing fear." Arizona Republic. By Shaun McKinnon. August 12, 2010. http://www.azcentral.com/arizonarepublic/news/articles/2010/08/12/20100812lake-mead-low-water-level.html. "Lake Mead's Water Level Plunges as 11-year Drought Lingers." NY Times. By Paul Quinlan. August 13, 2010. http://www.nytimes.com/gwire/2010/08/12/12greenwire-lake-meads-water-level-plunges-as-11-year-drou-29594.html?pagewanted=1. "Water Use in Southwest Heads for a Day of Reckoning." NY Times. By Felicity Barringer. September 27, 2010. http://www.nytimes.com/2010/09/28/us/28mead.html?hpw. "Water Crisis Hits Western Cities and States." CNBC. By Molly Mazilu. September 28, 2010. http://www.cnbc.com/id/39397641. "ENERGY: Hoover Dam could stop generating electricity as soon as 2013, officials fear." North County Times. By Eric Wolff. September 11, 2010. http://www.nctimes.com/business/article_b7e44e9e-087d-53b2-9c49-7ea32262c9a9.html "Lake Mead sinks to a new historic low." The Arizona Republic. Shaun McKinnon. October 19, 2010. http://www.azcentral.com/arizonarepublic/news/articles/2010/10/19/20101019lake-mead-water-level-new-historic-low.html

These conditions have raised several important questions regarding river flows and water supplies on the Colorado, pertaining to drought frequency (and system vulnerability), and the potential implications of long-term climate change. An overview of these issues and research is presented below.

Hydrologic Variability and Water Supply Vulnerability

Understanding hydrologic variability on the Colorado requires viewing the river over a long time period. The longest view is provided by paleo reconstructions—i.e., estimates of past flows based primarily on tree ring studies. A diverse suite of paleo reconstructions now exist across the basin, looking as far back as 762 A.D. (Meko et al., 2007). When comparing these studies to the roughly one century of gauging data, two observations stand out. First, the 20th Century was slightly wetter than average. Measured Lees Ferry flows of approximately 15.2 MAF (USBR, 2008) are above the reconstructed long-term estimates, which generally range from 13.0 to 14.7 MAF (Stockton and Jacoby, 1976; Michealsen et al., 1990; Hidalgo et al., 2000; Woodhouse et al., 2006; Meko et al., 2007; National Academy of Sciences, 2007). And second, the 20th Century was unusually tame in terms of its hydrologic variability (National Research Council 2007; Woodhouse et al., 2006). This is shown below in Figure B-4, which shows only 5 years in the past century falling in the lowest 10th percentile of Lees Ferry flow, compared to 14 in the 19th Century, 10 in 18th Century, 8 in 17th Century, and 9 in the partial reconstruction of the 16th Century (see the small red dots above the trace).[124] Going back further, Meko et al. (2007) found a mid 1100s event featuring a 25 year period where flows averaged less than 85% of the historical average and with an absence of high flows for roughly six decades.

[124] Although not shown, completing the 20th Century time series by adding data from 1998 and 1999 does not change the results of drought frequency, as both years were slightly above the long-term average.

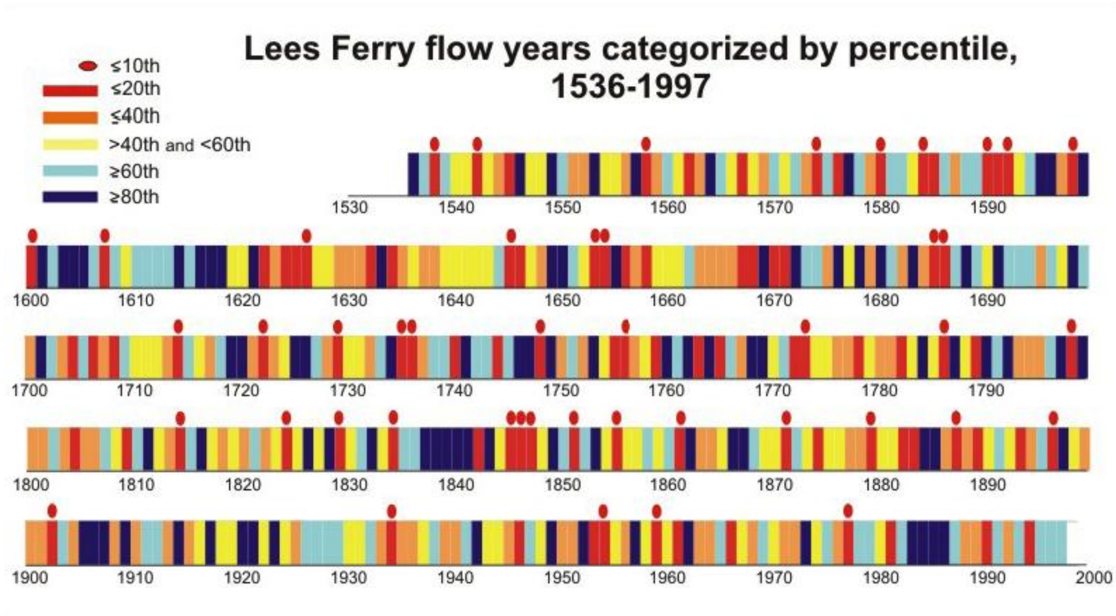

Figure B-4. Lees Ferry flow years categorized by percentile, 1536-1997 (from Woodhouse et al. 2006).

As noted in Appendix U of the 2007 EIS, "Although the climate of the past is unlikely to be replicated in the future, there is no reason to believe that the range of variability and sequences that have occurred in the past could not recur in the future" (USBR – Appendix U, 2007: U75). In other words, we may need to cope with droughts more frequently than in our recent past; our current drought may be a sign of things to come. If that is the case, then it is important to note that the impacts of the current event caught many water managers and researchers off guard. Specifically, the speed at which reservoirs declined was beyond what most expected, and was certainly beyond what was modeled in the "Severe Sustained Drought" (SSD) research project conducted in the early 1990s, which utilized a severe drought pulled from the paleo record to test the water supply reliability of the modern system. As Kenney et al. (2010) show in their comparison of the SSD study and the present situation, a major lesson of the current drought is that Lower Basin water supplies have become significantly more vulnerable to droughts (of all sizes) in the past two decades, and the source of this vulnerability is largely due to the growth in demands. As illustration, they cite the case of Lake Mead elevations. As shown in Figure B-5, storage amounts in Lake Mead were stable in the early 1990s, but have declined steadily in the 2000s, despite the fact that releases from Lake Powell in 1990-1994 were almost identical to those in 2001-2010. The cause of storage declines, even though Lake Mead inflows have not changed, can most likely be attributed to increased Lower

Basin demands, specifically the completion and operation of the Central Arizona Project (Kenney et al., 2010).[125]

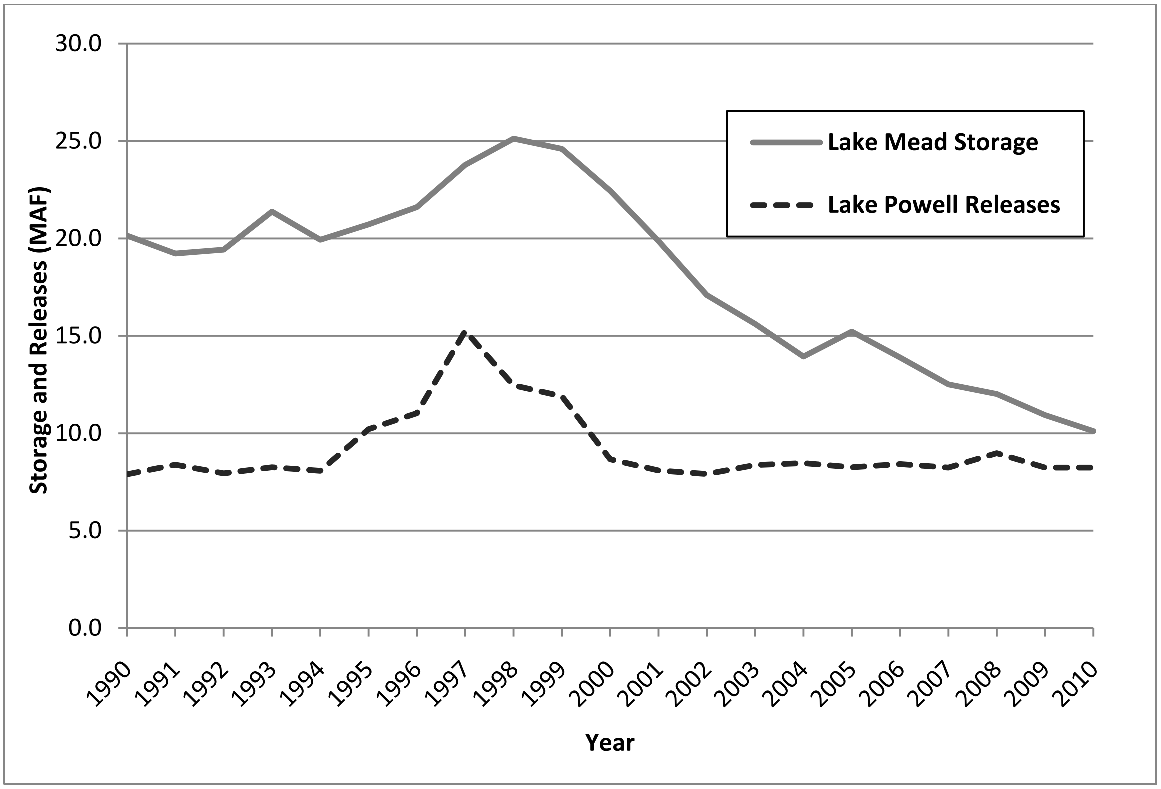

Figure B-5. Relationship of Lake Mead Storage to Lake Powell Releases.

The continued decline in Lake Mead storage threatens to erase the modest recovery in Lake Powell storage observed since 2004, thereby further increasing water supply vulnerability. As explained in a recent New York Times article[126] reporting on the Bureau's "Draft Annual Operating Plan for Colorado River Reservoirs 2011," declines in Lake Mead will be largely mitigated over the next couple years by enhanced "equalization"—i.e., releases from Lake Powell in excess of the minimum objective release (of 8.23 MAF). The Annual Operating Plan (AOP) projects Lake Powell releases in water year 2011 of 11.3 MAF, which may be sufficient to

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[125] The new "rule of thumb" for Lake Mead is that storage drops 1 MAF/year as long as the Lower Basin uses their full apportionment (and no more) and the Upper Basin makes the minimum objective release (8.23 MAF/year). Thus, it is the absence of high (surplus) releases, more so than the existence of low flows, that is the mechanism for translating droughts into Lower Basin shortages.

[126] "Water Use in the Southwest Heads for a Day of Reckoning." New York Times. By Felicity Barringer, September 27, 2010. http://www.nytimes.com/2010/09/28/us/28mead.html?emc=eta1

keep Lake Mead above elevation 1075 (feet)—the mark at which curtailments begin for Lower Basin users (especially CAP customers), as outlined in the 2007 Interim Rules (USBR, 2010). While this provides short-term relief to Lower Basin water users, this operating regime makes it very difficult to recover system-wide storage (and rebuild the drought buffer), and provides no incentive for Upper Basin states to slow depletions, as much of the water saved is likely to be lost to the Lower Basin through equalization. Drought vulnerability, therefore, is likely to be a perpetual and growing problem, and is a function of institutional rules as much as a function of natural climatic variability.

Average Flows and the Significance of Climate Change

Estimating average annual flows on the Colorado River remains a complex and controversial topic. Early gauges were inaccurate (and not always in ideal locations), not all major tributaries are monitored, and estimating “natural” flows at Lees Ferry requires subtracting (or “backing out”) upstream depletions—still a difficult challenge. As noted earlier, tree ring studies have suggested an average of 13.0 to 14.7 MAF—with the higher number supported by the most recent investigations (Meko et al., 2007). Including the recent drought into the gauged record suggests an average of 15.05 MAF from 1906-2006 (USBR, 2008). Of course, as understood by every student of the Colorado River, these figures are all well below the estimates used by Compact negotiators, who used the wet conditions of the early 20th Century to assume that average flows were much higher. Records used by Compact negotiators suggested an annual Lees Ferry flow of at least 16.8 MAF, although the Reclamation Service (Bureau of Reclamation) suggested a more conservative estimate of 16.4 MAF. However, once the Compact was signed and the process of state-by-state ratification began, it became evident that several negotiators believed the 16.4 MAF/year was overly conservative, and many negotiators internally operated on assumptions of larger flows. For example, in Utah, R.E. Caldwell told the state legislature that the annual yield was in excess of 20 MAF; in Colorado, an estimate of 20.5 MAF was offered by Delph Carpenter; while in Wyoming, Frank Emerson argued that the river’s yield was 22 MAF (Hundley Jr., 1975). In retrospect, all these estimates were widely optimistic. The significance of this error hovers over all current Colorado River disputes, and provides the backdrop to modern climate change studies that are nearly unanimous in predicting further reductions in average flows.

Although many people view climate change as a relatively new phenomenon and area of study in the Colorado River Basin, scientists have hypothesized for several decades that anthropogenic emissions of greenhouse gasses and subsequent increases in temperature will decrease the flow of the Colorado River (Revelle and Waggoner, 1983). For example, a 1983 report of the National Academy of Sciences (by Revelle and Waggoner) found that a 2°C increase in temperature combined with a 10% decrease in precipitation would reduce virgin flow at Lees Ferry by approximately 40% $\pm$ 7.4%.

According to the latest report from the Intergovernmental Panel on Climate Change (IPCC), average global temperatures have increased by approximately 0.74°C since 1906 (IPCC, 2007). This warming has been especially pronounced in the American Southwest, which, already being a semi-arid region, is highly susceptible to hydrologic changes deriving from increased temperatures (Overpeck and Udall, 2010). Some of the more pronounced changes include a reduction in late-season snowpack levels and a trend towards earlier spring runoff (Barnett et al., 2004; Barnett et al., 2008; Gleick and Chalecki, 1999; Karl et al., 2009; Miller and Piechota, 2008). As a snowmelt driven system—i.e., approximately 85% of the river's flow originates as snowpack in the Upper Basin—these impacts resonate throughout the Basin.

As noted earlier, the general consensus of the scientific literature is that the average flow of the Colorado will decline over the rest of this century.[127] The expected direction of change is not an area of significant debate; predicting the magnitude of change, however, is an area of vastly different opinions. While estimates range from 6-45%, a review by Milly et al. (2005) found that greater than 90% of the GCM models project runoff decreases of 10-30% for the time period 2041-2060.[128] Other researchers cite similar numbers (*e.g., see*: Seager et al., 2007; Barnett and Pierce, 2009). Additionally, these reductions in average flows are expected to be accompanied by an increase in the frequency and duration of droughts (Overpeck and Udall, 2010; Hoerling and Eischeid, 2007; McCabe and Wolock, 2007). The combined impact of reduced flows and increased droughts is particularly disconcerting, and is a major thread of current research on the Colorado River.

Numerous studies have found that even small reductions in Colorado River flow can have significant and immediate impacts on storage levels, as the entire flow of the river is already devoted to consumptive uses (USBR - Appendix U, 2007; Christensen et al., 2004; Christensen and Lettenmaier, 2006; Harding et al., 1995; Nash and Gleick, 1993). For example, Nash and Gleick (1993) theorized that every percentage drop in runoff could result in as much as a three-fold reduction in storage levels.[129] Along those lines, modeling by Christensen et al. (2004) for

[127] For a comprehensive review, see Appendix U of the 2007 EIS. Other relevant studies include: Barnett et al., 2004; Bates et al., 2008; Christensen and Lettenmaier, 2006; Christensen et al., 2004; Hoerling and Eisheid, 2007; McCabe and Wolock, 2007; Miller and Piechota, 2008; Milly et al., 2005; Nash and Gleick, 1991; Revelle and Waggoner, 1983; Seager et al., 2007; and Stockton and Boggess, 1979; among many others.
[128] It is worth noting that one of the most modern of the studies (by Christensen and Lettenmaier, 2006), using the latest IPCC models associated with the 2007 IPCC Fourth Assessment (AR4), was on the low end of the projected flow declines (6-7% by 2040-2069).
[129] The Nash and Gleick (1993) study was also among the first to consider reductions in hydropower generation as a function of climate change induced flow reductions.

the time periods 2010-39, 2040-69, and 2070-98 suggested runoff declines of 14%, 18%, and 17%, respectively, with corresponding declines in reservoir storage of 36%, 32% and 40%.[130]

Going one step further, Tim Barnett and David Pierce in two studies (2008, 2009) sought to relate pressures on reservoir storage to the ability to satisfy water demands. In their first, and highly controversial, paper entitled "When will Lake Mead go dry?," they projected that Lake Mead would no longer be able to deliver water by 2021 due to the combined interaction of climate change, natural variability, and current overuse (Barnett and Pierce, 2008). Updated research a year later took a slightly different approach. In that work, the authors looked at the ability of the system to supply current scheduled deliveries under three runoff scenarios: no climate change, a 10% decrease in runoff, and a 20% decrease in runoff (Barnett and Pierce 2009).[131] This study confirms previous findings that even relatively small decreases in runoff can drastically affect the reservoir storage system. With further analysis, the authors determined that "long-term sustainable deliveries" from the Colorado River system (including deliveries to Mexico) to be in the 11-13.5 MAF/year range.

The Barnett and Pierce papers moved the discussion of climate change on the Colorado one step further—from climatology, to hydrology, to reservoir storage, to deliveries. Rajagopalan et al. (2009) has begun the next logical step: assessing the ability to mitigate potential shortages through management reforms. Much like the second Barnett and Pierce analysis, Rajagopalan et al. utilize three different flow scenarios (no climate change, 10% reduction, and 20% reduction) to estimate future risk of depleting active system reservoir storage and thus losing the ability to make deliveries. But within each of these flow scenarios, five alternatives (A-E) of demand growth and management alternatives were examined to determine how risk of drying differs depending a variety of variables.[132] Figure B-6 shows the results for each of the three scenarios:

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[130] Projected flow declines by mid-century are largely shaped by greenhouse gas emissions that have already occurred, thereby resulting in relatively consistent output among models and researchers. For longer term projections, the GCM output is highly dependent on assumptions of future emissions. Widely different emission assumptions lead to widely different projections in flow.

[131] Actually, each of these three variables was calculated against two datasets, the gauged record and the paleo record, resulting in six scenarios. In each case, the paleo-based scenarios produced earlier and more significance shortages.

[132] All alternatives suggest consumptive uses of 7.5 MAF in the Lower Basin and 1.5 MAF in Mexico; Upper Basin depletions follow the Depletion Schedule (found in the 2007 EIS) in Alternatives A and B, but call for a slower pace of new depletions in Alternatives C, D and E. Each Alternative is also defined by a shortage policy that varies based on the amount of the curtailment (ranging from 2.5% to 8% from Alternative A to E) and the trigger at which curtailments occur (ranging from 36% of reservoir storage in Alternative A to 50% in Alternative E).

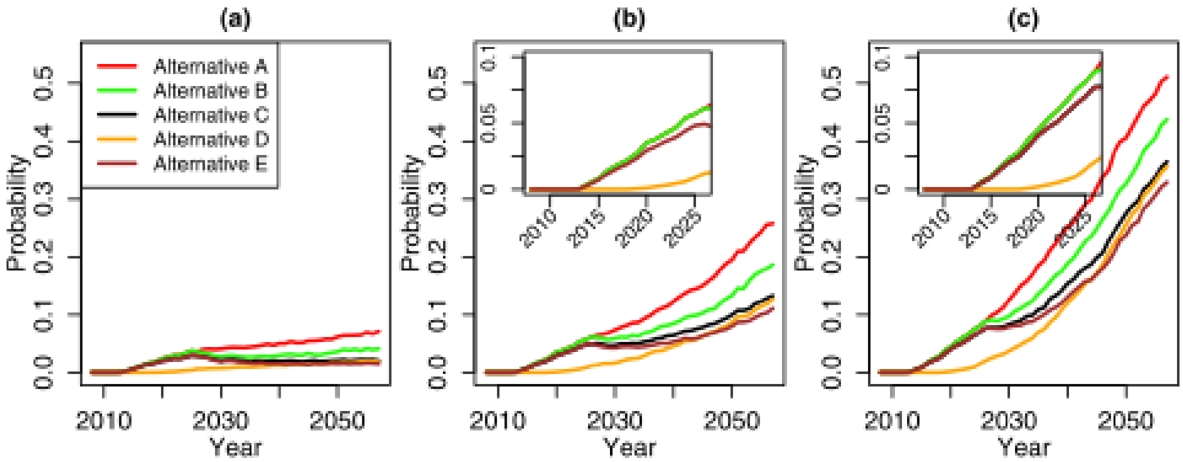

Figure B-6. (a) Risk of drying (depleting active system-wide reservoir storage in a given year) for five management alternatives under assumptions of no climate change-induced average flow reduction with an initial demand of 13.5 MAF. (b) Same as Figure "a" but for natural climate variability and a superimposed 10% reduction in the annual average inflow over the 50-year period. Inset shows the risk in the near term for the period 2008-2026. (c) Same as Figure "b" but for 20% reduction in annual average inflow (Rajagopalan et al., 2009).

As each graphic shows, the risk of "drying" before 2026 is under 10% for every climate, demand, and management alternative. After the Interim Rules expire in 2026, however, the authors did find that the probability of drying does start to increase nonlinearly, especially under the 20% climate change reduced flow scenario. Under the 10% and 20% reduced flow scenarios, the risk of drying after 2026 increases to about 26% and 51%, respectively, if there are no changes in the current management of the system (Alternative A). However, the study found with aggressive institutional changes regarding shortage allocations and demand growth limitations, the risk of drying under the 10% reduced flow scenario could be decreased (from 26%) to 11% after 2026. It was not the scope of this paper to discuss exactly what these management or demand growth policies could or should be, but the study did illustrate the point that institutional reforms can reduce shortage risks for the system, even with flows decreasing in the coming century.

IV. Conclusion

All of the research and trends discussed in this report show it will become increasingly unlikely, given current practices, that streamflows in future years will be sufficient to meet current demands. Satisfying current users while simultaneously meeting projected new demands and environmental flow goals is particularly unrealistic. Change, of some type, is not only needed, but is inevitable; the disparity between supplies and demands will be corrected in some way, either planned or unplanned. Under the current management regime, the mechanism is the steady depletion of storage, followed by curtailments. This approach has several negative consequences, not the least of which is the enhanced drought vulnerability that is associated with low reservoirs. Fortunately, a variety of options can be pursued to address the imbalance between supplies and demands, but this will only occur once the shortcomings of the existing pathway are more fully appreciated.

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Appendix C: Colorado River Issues and Options: Survey of CRWUA Members

In order to better inform and guide research conducted through the Colorado River Governance Initiative (CRGI) (at the University of Colorado), the following survey was administered in 2010 to the members of the Colorado River Water Users Association (CRWUA). Working from the 2008 membership directory, researchers identified 903 unique, individual email addresses. Each of these individuals received an invitation to complete the survey online. A first announcement was sent in May (on either the 13th, 14th or 16th); a follow-up reminder was sent in June (on either the 24th, 28th or 29th). The survey was closed on July 6th. Questions 1-4 pertain to issues of water supplies, demands and water availability; question 5 focuses on the perceived need for institutional reform; and questions 6-7 focus on potential solution strategies.

Compiling the data yielded 185 unique responses (i.e., responses from different individuals), although not all respondents answered all questions. The survey was completely anonymous; however, almost all respondents voluntarily indicated their location (by state) and occupation/affiliation. As shown in the following tables, these variables have been used to organize the results. Following the presentation of the quantitative results, the unedited write-in comments are shown.

Contents

Distribution of CRGI Survey Respondents						
	Occupation/Affiliation					
	Water Manager / Government	Water Professional	Water User	Citizen / Other or Unknown	Non-governmental Organization	**TOTAL**
Region						
Arizona	**52.6%** (30/57)	**36.8%** (21/57)	**3.5%** (2/57)	**5.3%** (3/57)	**1.8%** (1/57)	**30.8%** (57/185)
California	**47.2%** (17/36)	**33.3%** (12/36)	**11.1%** (4/36)	**8.3%** (3/36)	**0%** (0/36)	**19.5%** (36/185)
Nevada	**56%** (14/25)	**24%** (6/25)	**12%** (3/25)	**4%** (1/25)	**4%** (1/25)	**13.5%** (25/185)
Colorado	**57.1%** (16/28)	**21.4%** (6/28)	**7.1%** (2/28)	**7.1%** (2/28)	**7.1%** (2/28)	**15.1%** (28/185)
New Mexico	**50%** (3/6)	**16.7%** (1/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)	**3.2%** (6/185)
Utah	**38.9%** (7/18)	**44.4%** (8/18)	**5.6%** (1/18)	**5.6%** (1/18)	**5.6%** (1/18)	**9.7%** (18/185)
Wyoming	**50%** (4/8)	**25%** (2/8)	**12.5%** (1/8)	**12.5%** (1/8)	**0%** (0/8)	**4.3%** (8/185)
Other / Unknown	**42.9%** (3/7)	**14.3%** (1/7)	**0%** (0/7)	**28.6%** (2/7)	**14.3%** (1/7)	**3.8%** (7/185)
TOTAL	**50.8%** (94/185)	**30.8%** (57/185)	**7.6%** (14/185)	**7.6%** (14/185)	**3.2%** (6/185)	

<u>Supplies, Demands and Water Availability (Questions 1-4)</u>

<u>Question 1</u>. Between now and 2026, what do you think the chances are that Lake Mead storage will drop to a level that requires curtailments to CAP (as called for in the shortage sharing rules)?						
	Very Likely (≥ 90%)	Probable (≥ 70%)	Possible (~ 50%)	Unlikely (≤ 30%)	Very Unlikely (≤ 10%)	Don't Know
Region						
Arizona	**14%** (8/57)	**40.4%** (23/57)	**31.6%** (18/57)	**7%** (4/57)	**3.5%** (2/57)	**3.5%** (2/57)
California	**19.4%** (7/36)	**30.6%** (11/36)	**38.9%** (14/36)	**8.3%** (3/36)	**0%** (0/36)	**2.8%** (1/36)
Nevada	**40%** (10/25)	**32%** (8/25)	**8%** (2/25)	**16%** (4/25)	**4%** (1/25)	**0%** (0/25)
Colorado	**3.6%** (1/28)	**25%** (7/28)	**32.1%** (9/28)	**17.9%** (5/28)	**14.3%** (4/28)	**7.1%** (2/28)
New Mexico	**16.7%** (1/6)	**16.7%** (1/6)	**66.7%** (4/6)	**0%** (0/6)	**0%** (0/6)	**0%** (0/6)
Utah	**27.8%** (5/18)	**16.7%** (3/18)	**22.2%** (4/18)	**22.2%** (4/18)	**11.1%** (2/18)	**0%** (0/18)
Wyoming	**12.5%** (1/8)	**25%** (2/8)	**37.5%** (3/8)	**25%** (2/8)	**0%** (0/8)	**0%** (0/8)
Other / Unknown	**14.3%** (1/7)	**57.1%** (4/7)	**28.6%** (2/7)	**0%** (0/7)	**0%** (0/7)	**0%** (0/7)
Occupation / Affiliation						
Water Manager / Government	**17%** (16/94)	**31.9%** (30/94)	**29.8%** (28/94)	**13.8%** (13/94)	**5.3%** (5/94)	**2.1%** (2/94)
Water Professional	**15.8%** (9/57)	**31.6%** (18/57)	**29.8%** (17/57)	**10.5%** (6/57)	**7%** (4/57)	**5.3%** (3/57)
Water User	**35.7%** (5/14)	**28.6%** (4/14)	**28.6%** (4/14)	**7.1%** (1/14)	**0%** (0/14)	**0%** (0/14)
Citizen / Other or Unknown	**14.3%** (2/14)	**42.9%** (6/14)	**35.7%** (5/14)	**7.1%** (1/14)	**0%** (0/14)	**0%** (0/14)
Nongovernmental Organization	**33.3%** (2/6)	**16.7%** (1/6)	**33.3%** (2/6)	**16.7%** (1/6)	**0%** (0/6)	**0%** (0/6)
TOTAL						
Count [185]	34/185	59/185	56/185	22/185	9/185	5/185
Percentages	**18.4%**	**31.9%**	**30.3%**	**11.9%**	**4.9%**	**2.7%**

<u>Question 2a</u>. What do you think the chances are that a "compact call" will arise between the Upper and Lower Basins by 2026?						
	Very Likely (≥ 90%)	Probable (≥ 70%)	Possible (~ 50%)	Unlikely (≤ 30%)	Very Unlikely (≤ 10%)	Don't Know
Region						
Arizona	**1.8%** (1/56)	**28.6%** (16/56)	**26.8%** (15/56)	**21.4%** (12/56)	**14.3%** (8/56)	**7.1%** (4/56)
California	**8.3%** (3/36)	**38.9%** (14/36)	**22.2%** (8/36)	**16.7%** (6/36)	**8.3%** (3/36)	**5.6%** (2/36)
Nevada	**17.4%** (4/23)	**30.4%** (7/23)	**26.1%** (6/23)	**8.7%** (2/23)	**13%** (3/23)	**4.3%** (1/23)
Colorado	**3.7%** (1/27)	**22.2%** (6/27)	**14.8%** (4/27)	**33.3%** (9/27)	**22.2%** (6/27)	**3.7%** (1/27)
New Mexico	**0%** (0/6)	**50%** (3/6)	**50%** (3/6)	**0%** (0/6)	**0%** (0/6)	**0%** (0/6)
Utah	**5.9%** (1/17)	**29.4%** (5/17)	**17.6%** (3/17)	**23.5%** (4/17)	**23.5%** (4/17)	**0%** (0/17)
Wyoming	**0%** (0/8)	**37.5%** (3/8)	**25%** (2/8)	**25%** (2/8)	**12.5%** (1/8)	**0%** (0/8)
Other / Unknown	**0%** (0/7)	**33.3%** (2/7)	**16.6%** (1/7)	**0%** (1/7)	**50%** (3/7)	**0%** (0/7)
Occupation / Affiliation						
Water Manager / Government	**6.5%** (6/92)	**29.3%** (27/92)	**22.8%** (21/92)	**18.5%** (17/92)	**19.6%** (18/92)	**3.3%** (3/92)
Water Professional	**3.6%** (2/55)	**23.6%** (13/55)	**23.6%** (13/55)	**25.5%** (14/55)	**14.5%** (8/55)	**9.1%** (5/55)
Water User	**7.7%** (1/13)	**69.2%** (9/13)	**15.4%** (2/13)	**7.7%** (1/13)	**0%** (0/13)	**0%** (0/13)
Citizen / Other or Unknown	**0%** (0/14)	**50%** (7/14)	**35.7%** (5/14)	**14.3%** (2/14)	**0%** (0/14)	**0%** (0/14)
Nongovernmental Organization	**16.7%** (1/6)	**0%** (0/6)	**16.7%** (1/6)	**33.3%** (2/6)	**33.3%** (2/6)	**0%** (0/6)
TOTAL						
Count [180]	10/180	56/180	42/180	36/180	28/180	8/180
Percentages	**5.6%**	**31.1%**	**23.3%**	**20%**	**15.6%**	**4.4%**

<u>Question 2b</u>. What do you think the chances are that a "compact call" will arise between the Upper and Lower Basins by 2050?						
	Very Likely (≥ 90%)	Probable (≥ 70%)	Possible (~ 50%)	Unlikely (≤ 30%)	Very Unlikely (≤ 10%)	Don't Know
Region						
Arizona	**21.3%** (10/47)	**25.5%** (12/47)	**23.4%** (11/47)	**12.8%** (6/47)	**6.4%** (3/47)	**10.6%** (5/47)
California	**30%** (9/30)	**33.3%** (10/30)	**13.3%** (4/30)	**6.7%** (2/30)	**10%** (3/30)	**6.7%** (2/30)
Nevada	**28%** (7/25)	**40%** (10/25)	**8%** (2/25)	**12%** (3/25)	**4%** (1/25)	**8%** (2/25)
Colorado	**25.9%** (7/27)	**7.4%** (2/27)	**33.3%** (9/27)	**14.8%** (4/27)	**11.1%** (3/27)	**7.4%** (2/27)
New Mexico	**40%** (2/5)	**40%** (2/5)	**20%** (1/5)	**0%** (0/5)	**0%** (0/5)	**0%** (0/5)
Utah	**14.3%** (2/14)	**14.3%** (2/14)	**14.3%** (2/14)	**42.9%** (6/14)	**7.1%** (1/14)	**7.1%** (1/14)
Wyoming	**37.5%** (3/8)	**12.5%** (1/8)	**37.5%** (3/8)	**12.5%** (1/8)	**0%** (0/8)	**0%** (0/8)
Other / Unknown	**20%** (1/6)	**20%** (1/6)	**20%** (2/6)	**0%** (0/6)	**40%** (2/6)	**0%** (0/6)
Occupation / Affiliation						
Water Manager / Government	**23.9%** (21/88)	**22.7%** (20/88)	**23.9%** (21/88)	**17%** (15/88)	**6.8%** (6/88)	**5.7%** (5/88)
Water Professional	**20.8%** (10/48)	**25%** (12/48)	**14.6%** (7/48)	**14.6%** (7/48)	**12.5%** (6/48)	**12.5%** (6/48)
Water User	**44.4%** (4/9)	**33.3%** (3/9)	**22.2%** (2/9)	**0%** (0/9)	**0%** (0/9)	**0%** (0/9)
Citizen / Other or Unknown	**50%** (6/12)	**33.3%** (4/12)	**8.3%** (1/12)	**0%** (0/12)	**0%** (0/12)	**8.3%** (1/12)
Nongovernmental Organization	**0%** (0/5)	**20%** (1/5)	**60%** (3/5)	**0%** (0/5)	**20%** (1/5)	**0%** (0/5)
TOTAL						
Count [162]	41/162	40/162	34/162	22/162	13/162	12/162
Percentages	**25.3%**	**24.7%**	**21%**	**13.6%**	**8%**	**7.4%**

<u>Question 3</u>. Between now and 2050, do you expect average natural flows on the river (at Lee's Ferry) to be:				
	Roughly the same as the past century (about 15 MAF/year)	Higher than the previous century	Lower than the previous century	Don't know
Region				
Arizona	**31.6%** (18/57)	**1.8%** (1/57)	**56.1%** (32/57)	**10.5%** (6/57)
California	**22.9%** (8/35)	**0%** (0/35)	**65.7%** (23/35)	**11.4%** (4/35)
Nevada	**32%** (8/25)	**0%** (0/25)	**64%** (16/25)	**4%** (1/25)
Colorado	**35.7%** (10/28)	**0%** (0/28)	**46.4%** (13/28)	**17.9%** (5/28)
New Mexico	**0%** (0/6)	**0%** (0/6)	**83.3%** (5/6)	**16.7%** (1/6)
Utah	**38.9%** (7/18)	**0%** (0/18)	**38.9%** (7/18)	**22.2%** (4/18)
Wyoming	**25%** (2/8)	**0%** (0/8)	**62.5%** (5/8)	**12.5%** (1/8)
Other / Unknown	**42.9%** (3/7)	**0%** (0/7)	**57.1%** (4/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**27.7%** (26/94)	**1.1%** (1/94)	**60.6%** (57/94)	**10.6%** (10/94)
Water Professional	**35.1%** (20/57)	**0%** (0/57)	**50.9%** (29/57)	**14%** (8/57)
Water User	**15.4%** (2/13)	**0%** (0/13)	**53.8%** (7/13)	**30.8%** (4/13)
Citizen / Other or Unknown	**42.9%** (6/14)	**0%** (0/14)	**57.1%** (8/14)	**0%** (0/14)
Nongovernmental Organization	**33.3%** (2/6)	**0%** (0/6)	**66.7%** (4/6)	**0%** (0/6)
TOTAL				
Count [184]	56/184	1/184	105/184	22/184
Percentages	**30.4%**	**0.5%**	**57.1%**	**12%**

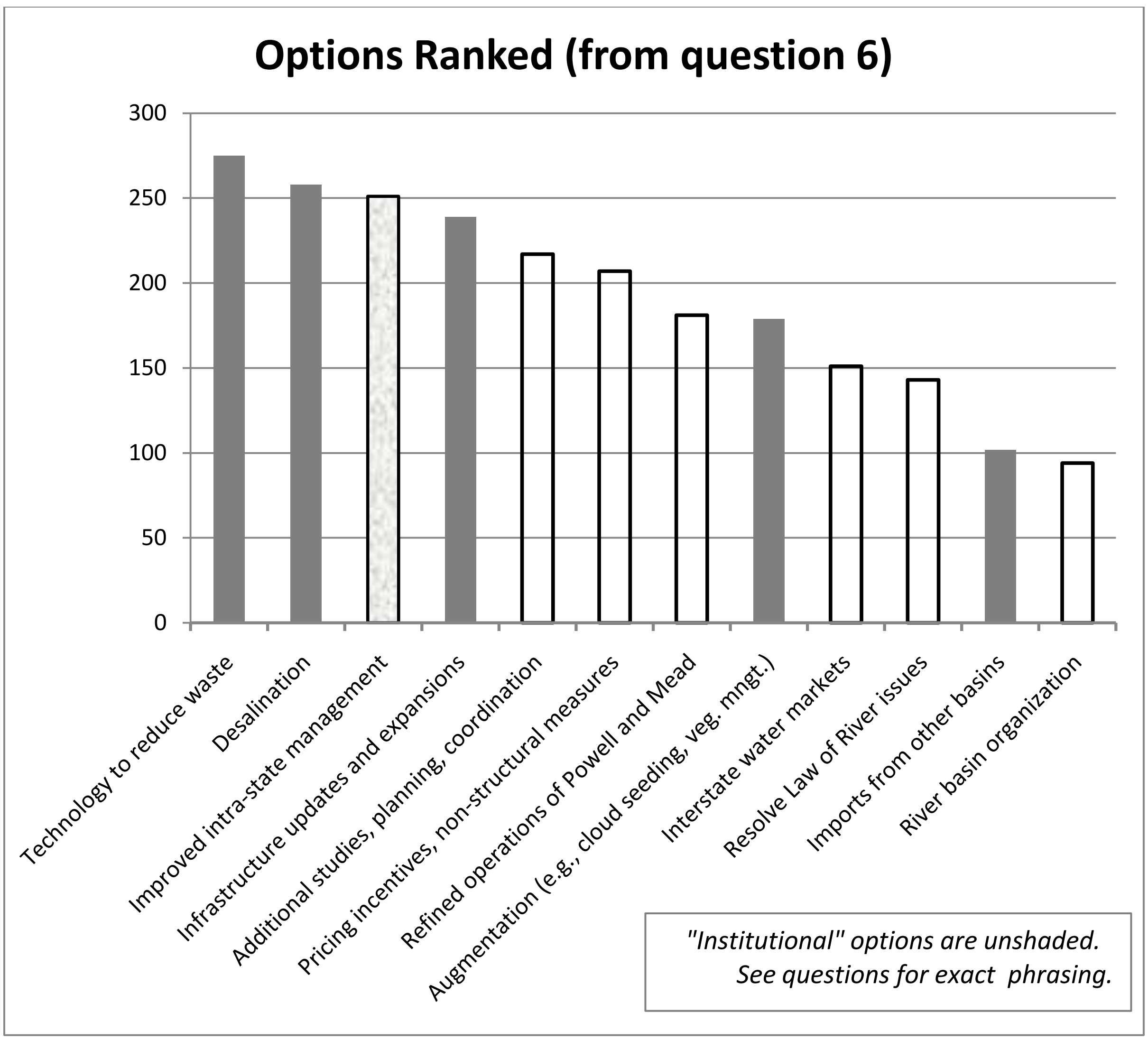
<u>Question 4</u>. Based on your understanding of water use trends and projections, at what point in time do you expect total average water demands on the Colorado River to meet (or exceed) total average supplies (based on 10-year running averages)?					
	It has already happened	By 2020	By 2050	Later than 2050	Don't Know
Region					
Arizona	**35.1%** (20/57)	**26.3%** (15/57)	**21.1%** (12/57)	**10.5%** (6/57)	**7%** (4/57)
California	**41.7%** (15/36)	**38.9%** (14/36)	**13.9%** (5/36)	**2.8%** (1/36)	**2.8%** (1/36)
Nevada	**60%** (15/25)	**20%** (5/25)	**16%** (4/25)	**4%** (1/25)	**0%** (0/25)
Colorado	**17.9%** (5/28)	**17.9%** (5/28)	**25%** (7/28)	**14.3%** (4/28)	**25%** (7/28)
New Mexico	**50%** (3/6)	**16.7%** (1/6)	**33.3%** (2/6)	**0%** (0/6)	**0%** (0/6)
Utah	**27.8%** (5/18)	**11.1%** (2/18)	**33.3%** (6/18)	**22.2%** (4/18)	**5.6%** (1/18)
Wyoming	**62.5%** (5/8)	**0%** (0/8)	**37.5%** (3/8)	**0%** (0/8)	**0%** (0/8)
Other / Unknown	**71.4%** (5/7)	**28.6%** (2/7)	**0%** (0/7)	**0%** (0/7)	**0%** (0/7)
Occupation / Affiliation					
Water Manager / Government	**36.2%** (34/94)	**26.6%** (25/94)	**23.4%** (22/94)	**6.4%** (6/94)	**7.4%** (7/94)
Water Professional	**36.8%** (21/57)	**22.8%** (13/57)	**19.3%** (11/57)	**14%** (8/57)	**7%** (4/57)
Water User	**42.9%** (6/14)	**28.6%** (4/14)	**14.3%** (2/14)	**0%** (0/14)	**14.3%** (2/14)
Citizen / Other or Unknown	**64.3%** (9/14)	**14.3%** (2/14)	**14.3%** (2/14)	**7.1%** (1/14)	**0%** (0/14)
Nongovernmental Organization	**50%** (3/6)	**0%** (0/6)	**33.3%** (2/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL					
Count [185]	73/185	44/185	39/185	16/185	13/185
Percentages	**39.5%**	**23.8%**	**21.1%**	**8.6%**	**7%**

PERCEIVED NEED FOR INSTITUTIONAL REFORM (QUESTION 5)

Question 5. In your opinion, will addressing current and future water availability concerns on the Colorado River require making changes to the Law of the River and related "institutional" arrangements?					
	No, the Law of the River is adequate as is	Minor updates or revisions may be needed	Significant changes to the Law of the River are necessary	The Law of the River is inadequate and requires a fundamental restructuring	Don't Know
Region					
Arizona	**17.5%** (10/57)	**52.6%** (30/57)	**12.3%** (7/57)	**8.8%** (5/57)	**8.8%** (5/57)
California	**27.8%** (10/36)	**36.1%** (13/36)	**16.7%** (6/36)	**13.9%** (5/36)	**5.6%** (2/36)
Nevada	**0%** (0/25)	**28%** (7/25)	**48%** (12/25)	**20%** (5/25)	**4%** (1/25)
Colorado	**32.1%** (9/28)	**39.3%** (11/28)	**21.4%** (6/28)	**0%** (0/28)	**7.1%** (2/28)
New Mexico	**16.7%** (1/6)	**16.7%** (1/6)	**66.7%** (4/6)	**0%** (0/6)	**0%** (0/6)
Utah	**22.2%** (4/18)	**50%** (9/18)	**11.1%** (2/18)	**11.1%** (2/18)	**5.6%** (1/18)
Wyoming	**50%** (4/8)	**50%** (4/8)	**0%** (0/8)	**0%** (0/8)	**0%** (0/8)
Other / Unknown	**50%** (3/6)	**33.3%** (2/6)	**0%** (0/6)	**16.6%** (1/6)	**0%** (0/6)
Occupation / Affiliation					
Water Manager / Government	**21.3%** (20/94)	**50%** (47/94)	**17%** (16/94)	**8.5%** (8/94)	**3.2%** (3/94)
Water Professional	**22.8%** (13/57)	**36.8%** (21/57)	**26.3%** (15/57)	**7%** (4/57)	**7%** (4/57)
Water User	**14.3%** (2/14)	**21.4%** (3/14)	**28.6%** (4/14)	**21.4%** (3/14)	**14.3%** (2/14)
Citizen / Other or Unknown	**15.4%** (2/13)	**46.2%** (6/13)	**7.7%** (1/13)	**15.4%** (2/13)	**15.4%** (2/13)
Nongovernmental Organization	**66.7%** (4/6)	**0%** (0/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL					
Count [184]	41/184	77/184	37/184	18/184	11/184
Percentages	**22.3%**	**41.8%**	**20.1%**	**9.8%**	**6%**

SOLUTION PREFERENCES (QUESTION 6)

In this question, respondents were presented with 12 different "solution strategies" and asked to rate each as "high Priority," "Medium Priority," or "Not a Priority." The order that each option was presented in the survey varied randomly from respondent to respondent. Tables on the following pages provide the full results for each category. In the figure below, they are compiled into a rough "ranking order" determined by assigning 2 points per every "high priority" response, 1 point for every "medium priority" response, and zero points for each "not a priority" response. These rankings are admittedly quite rough, as several respondents indicated their preferences would, in practice, be largely shaped by the details of any specific proposal. Proposals that are primarily "institutional" in nature—the focus of the Colorado River Governance Initiative—are shown as unshaded bars.



<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation? • **OPTION: Improved technology to reduce wastes and inefficiencies (e.g., canal lining, advanced irrigation systems)**				
	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**42.1%** (24/57)	**47.4%** (27/57)	**10.5%** (6/57)	**0%** (0/57)
California	**69.4%** (25/36)	**16.7%** (6/36)	**13.9%** (5/36)	**0%** (0/36)
Nevada	**64%** (16/25)	**32%** (8/25)	**4%** (1/25)	**0%** (0/25)
Colorado	**53.6%** (15/28)	**35.7%** (10/28)	**10.7%** (3/28)	**0%** (0/28)
New Mexico	**100%** (6/6)	**0%** (0/6)	**0%** (0/6)	**0%** (0/6)
Utah	**83.3%** (15/18)	**5.6%** (1/18)	**11.1%** (2/18)	**0%** (0/18)
Wyoming	**62.5%** (5/8)	**37.5%** (3/8)	**0%** (0/8)	**0%** (0/8)
Other / Unknown	**42.9%** (3/7)	**28.6%** (2/7)	**28.6%** (2/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**58.5%** (55/94)	**29.8%** (28/94)	**11.7%** (11/94)	**0%** (0/94)
Water Professional	**54.4%** (31/57)	**35.1%** (20/57)	**10.5%** (6/57)	**0%** (0/57)
Water User	**57.1%** (8/14)	**28.6%** (4/14)	**14.3%** (2/14)	**0%** (0/14)
Citizen / Other or Unknown	**85.7%** (12/14)	**14.3%** (2/14)	**0%** (0/14)	**0%** (0/14)
Nongovernmental Organization	**50%** (3/6)	**50%** (3/6)	**0%** (0/6)	**0%** (0/6)
TOTAL				
Count [185]	109/185	57/185	19/185	0/185
Percentages	**58.9%**	**30.8%**	**10.3%**	**0%**

Question 6: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation? • **OPTION: Utilize desalination as part of a regional water management framework**				
	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**66.1%** (37/56)	**26.8%** (15/56)	**7.1%** (4/56)	**0%** (0/56)
California	**65.7%** (23/35)	**22.9%** (8/35)	**11.4%** (4/35)	**0%** (0/35)
Nevada	**60%** (15/25)	**40%** (10/25)	**0%** (0/25)	**0%** (0/25)
Colorado	**28.6%** (8/28)	**46.4%** (13/28)	**17.9%** (5/28)	**7.1%** (2/28)
New Mexico	**16.7%** (1/6)	**66.7%** (4/6)	**16.7%** (1/6)	**0%** (0/6)
Utah	**44.4%** (8/18)	**27.8%** (5/18)	**22.2%** (4/18)	**5.6%** (1/18)
Wyoming	**50%** (4/8)	**25%** (2/8)	**25%** (2/8)	**0%** (0/8)
Other / Unknown	**28.6%** (2/7)	**71.4%** (5/7)	**0%** (0/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**51.6%** (48/93)	**37.6%** (35/93)	**9.7%** (9/93)	**1.1%** (1/93)
Water Professional	**64.3%** (36/56)	**25%** (14/56)	**8.9%** (5/56)	**1.8%** (1/56)
Water User	**57.1%** (8/14)	**28.6%** (4/14)	**14.3%** (2/14)	**0%** (0/14)
Citizen / Other or Unknown	**21.4%** (3/14)	**50%** (7/14)	**21.4%** (3/14)	**7.1%** (1/14)
Nongovernmental Organization	**50%** (3/6)	**33.3%** (2/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL				
Count [183]	98/183	62/183	20/183	3/183
Percentages	**53.6%**	**33.9%**	**10.9%**	**1.6%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Encourage improved water management within states as the primary strategy for reducing interstate tensions and promoting improved basin-wide conditions**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**50%** (27/54)	**27.8%** (15/54)	**20.4%** (11/54)	**1.9%** (1/54)
California	**47.2%** (17/36)	**38.9%** (14/36)	**13.9%** (5/36)	**0%** (0/36)
Nevada	**60%** (15/25)	**32%** (8/25)	**8%** (2/25)	**0%** (0/25)
Colorado	**53.6%** (15/28)	**39.3%** (11/28)	**7.1%** (2/28)	**0%** (0/28)
New Mexico	**100%** (6/6)	**0%** (0/6)	**0%** (0/6)	**0%** (0/6)
Utah	**38.9%** (7/18)	**50%** (9/18)	**11.1%** (2/18)	**0%** (0/18)
Wyoming	**50%** (4/8)	**37.5%** (3/8)	**12.5%** (1/8)	**0%** (0/8)
Other / Unknown	**57.1%** (4/7)	**14.3%** (1/7)	**28.6%** (2/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**53.2%** (50/94)	**36.2%** (34/94)	**10.6%** (10/94)	**0%** (0/94)
Water Professional	**47.3%** (26/55)	**34.5%** (19/55)	**18.2%** (10/55)	**0%** (0/55)
Water User	**57.1%** (8/14)	**28.6%** (4/14)	**14.3%** (2/14)	**0%** (0/14)
Citizen / Other or Unknown	**53.9%** (7/13)	**23.1%** (3/13)	**15.4%** (2/13)	**7.7%** (1/13)
Nongovernmental Organization	**66.7%** (4/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL				
Count [182]	95/182	61/182	25/182	1/182
Percentages	**52.2%**	**33.5%**	**13.7%**	**0.5%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Infrastructure updates and expansions designed to more fully capture high flows and/or reduce spills (e.g. tributary storage)**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**42.9 %** (24/56)	**37.5%** (21/56)	**17.9%** (10/56)	**1.8%** (1/56)
California	**50%** (18/36)	**41.7%** (15/36)	**5.6%** (2/36)	**2.8%** (1/36)
Nevada	**40%** (10/25)	**52%** (13/25)	**8%** (2/25)	**0%** (0/25)
Colorado	**50%** (14/28)	**35.7%** (10/28)	**10.7%** (3/28)	**3.6%** (1/28)
New Mexico	**66.7%** (4/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)
Utah	**50%** (9/18)	**27.8%** (5/18)	**16.7%** (3/18)	**5.6%** (1/18)
Wyoming	**37.5%** (3/8)	**37.5%** (3/8)	**25%** (2/8)	**0%** (0/8)
Other / Unknown	**42.9%** (3/7)	**14.3%** (1/7)	**42.9%** (3/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**42.6%** (40/94)	**40.4%** (38/94)	**14.9%** (14/94)	**2.1%** (2/94)
Water Professional	**53.6%** (30/56)	**30.4%** (17/56)	**12.5%** (7/56)	**3.6%** (2/56)
Water User	**28.6%** (4/14)	**57.1%** (8/14)	**14.3%** (2/14)	**0%** (0/14)
Citizen / Other or Unknown	**50%** (7/14)	**35.7%** (5/14)	**14.3%** (2/14)	**0%** (0/14)
Nongovernmental Organization	**66.7%** (4/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL				
Count [184]	85/184	69/184	26/184	4/184
Percentages	**46.2%**	**37.5%**	**14.1%**	**2.2%**

Question 6: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Pursue additional regional studies/planning efforts to better coordinate among jurisdictions and sectors including water, energy, land-use, and environment**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**37.5%** (21/56)	**42.9%** (24/56)	**16.1%** (9/56)	**3.6%** (2/56)
California	**38.9%** (14/36)	**41.7%** (15/36)	**19.4%** (7/36)	**0%** (0/36)
Nevada	**40%** (10/25)	**40%** (10/25)	**20%** (5/25)	**0%** (0/25)
Colorado	**25.9%** (7/27)	**55.6%** (15/27)	**18.5%** (5/27)	**0%** (0/27)
New Mexico	**66.7%** (4/6)	**33.3%** (2/6)	**0%** (0/6)	**0%** (0/6)
Utah	**44.4%** (8/18)	**44.4%** (8/18)	**11.1%** (2/18)	**0%** (0/18)
Wyoming	**25%** (2/8)	**37.5%** (3/8)	**37.5%** (3/8)	**0%** (0/8)
Other / Unknown	**42.9%** (3/7)	**28.6%** (2/7)	**14.3%** (1/7)	**14.3%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**37.6%** (35/93)	**44.1%** (41/93)	**16.1%** (15/93)	**2.2%** (2/93)
Water Professional	**33.3%** (19/57)	**50.9%** (29/57)	**14%** (8/57)	**1.8%** (1/57)
Water User	**35.7%** (5/14)	**28.6%** (4/14)	**35.7%** (5/14)	**0%** (0/14)
Citizen / Other or Unknown	**45.5%** (6/13)	**27.3%** (4/13)	**27.3%** (3/13)	**0%** (0/13)
Nongovernmental Organization	**66.7%** (4/6)	**16.7%** (1/6)	**16.7%** (1/6)	**0%** (0/6)
TOTAL				
Count [183]	69/183	79/183	32/183	3/183
Percentages	**37.7%**	**43.2%**	**17.5%**	**1.6%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Use pricing incentives and/or regulatory (non-structural) measures to more explicitly promote conservation and discourage waste**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**28.6%** (16/56)	**33.9%** (19/56)	**32.1%** (18/56)	**5.4%** (3/56)
California	**47.2%** (17/36)	**33.3%** (12/36)	**13.9%** (5/36)	**5.6%** (2/36)
Nevada	**28%** (7/25)	**48%** (12/25)	**24%** (6/25)	**0%** (0/25)
Colorado	**53.6%** (15/28)	**28.6%** (8/28)	**17.9%** (5/28)	**0%** (0/28)
New Mexico	**83.3%** (5/6)	**16.7%** (1/6)	**0%** (0/6)	**0%** (0/6)
Utah	**22.2%** (4/18)	**61.1%** (11/18)	**16.7%** (3/18)	**0%** (0/18)
Wyoming	**25%** (2/8)	**50%** (4/8)	**25%** (2/8)	**0%** (0/8)
Other / Unknown	**42.9%** (3/7)	**28.6%** (2/7)	**14.3%** (1/7)	**14.3%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**38.3%** (36/94)	**37.2%** (35/94)	**21.3%** (20/94)	**3.2%** (3/94)
Water Professional	**33.3%** (19/57)	**36.8%** (21/57)	**28.1%** (16/57)	**1.8%** (1/57)
Water User	**42.9%** (6/14)	**28.6%** (4/14)	**21.4%** (3/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**46.2%** (6/13)	**38.5%** (5/13)	**7.7%** (1/13)	**7.7%** (1/13)
Nongovernmental Organization	**33.3%** (2/6)	**66.7%** (4/6)	**0%** (0/6)	**0%** (0/6)
TOTAL				
Count [184]	69/184	69/184	40/184	6/184
Percentages	**37.5%**	**37.5%**	**21.7%**	**3.3%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation? • **OPTION: Further enhance/refine rules for coordinated operation of Lakes Powell and Mead**				
	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**29.8%** (17/57)	**45.6%** (26/57)	**19.3%** (11/57)	**5.3%** (3/57)
California	**11.1%** (4/36)	**41.7%** (15/36)	**36.1%** (13/36)	**11.1%** (4/36)
Nevada	**44%** (11/25)	**48%** (12/25)	**8%** (2/25)	**0%** (0/25)
Colorado	**21.4%** (6/28)	**42.9%** (12/28)	**17.9%** (5/28)	**17.9%** (5/28)
New Mexico	**50%** (3/6)	**33.3%** (2/6)	**16.7%** (1/6)	**0%** (0/6)
Utah	**27.8%** (5/18)	**44.4%** (8/18)	**22.2%** (4/18)	**5.6%** (1/18)
Wyoming	**12.5%** (1/8)	**50%** (4/8)	**37.5%** (3/8)	**0%** (0/8)
Other / Unknown	**42.9%** (3/7)	**28.6%** (2/7)	**14.3%** (1/7)	**14.3%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**27.7%** (26/94)	**40.4%** (38/94)	**23.4%** (22/94)	**8.5%** (8/94)
Water Professional	**24.6%** (14/57)	**49.1%** (28/57)	**19.3%** (11/57)	**7%** (4/57)
Water User	**21.4%** (3/14)	**42.9%** (6/14)	**28.6%** (4/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**42.9%** (6/14)	**50%** (7/14)	**7.1%** (1/14)	**0%** (0/14)
Nongovernmental Organization	**16.7%** (1/6)	**33.3%** (2/6)	**33.3%** (2/6)	**16.7%** (1/6)
TOTAL				
Count [185]	50/185	81/185	40/185	14/185
Percentages	**27%**	**43.8%**	**21.6%**	**7.6%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: River augmentation from weather modification (cloud seeding) and/or vegetation management (e.g., tamarisk control, logging)**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**32.1 %** (18/56)	**41.1%** (23/56)	**25%** (14/56)	**1.8%** (1/56)
California	**30.6%** (11/36)	**47.2%** (17/36)	**19.4%** (7/36)	**2.8%** (1/36)
Nevada	**24%** (6/25)	**40%** (10/25)	**36%** (9/25)	**0%** (0/25)
Colorado	**17.9%** (5/28)	**28.6%** (8/28)	**50%** (14/28)	**3.6%** (1/28)
New Mexico	**16.7%** (1/6)	**66.7%** (4/6)	**16.7%** (1/6)	**0%** (0/6)
Utah	**38.9%** (7/18)	**44.4%** (8/18)	**16.7%** (3/18)	**0%** (0/18)
Wyoming	**37.5%** (3/8)	**37.5%** (3/8)	**12.5%** (1/8)	**12.5%** (1/8)
Other / Unknown	**14.3%** (1/7)	**28.6%** (2/7)	**42.9%** (3/7)	**0%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**31.9%** (30/94)	**41.5%** (39/94)	**23.4%** (22/94)	**3.2%** (3/94)
Water Professional	**26.3%** (15/57)	**42.1%** (24/57)	**29.8%** (17/57)	**1.8%** (1/57)
Water User	**28.6%** (4/14)	**35.7%** (5/14)	**28.6%** (4/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**7.7%** (1/13)	**46.2%** (6/13)	**46.2%** (6/13)	**0%** (0/13)
Nongovernmental Organization	**33.3%** (2/6)	**16.7%** (1/6)	**50%** (3/6)	**0%** (0/6)
TOTAL				
Count [184]	52/184	75/184	52/184	5/184
Percentages	**28.3%**	**40.8%**	**28.3%**	**2.7%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Promote voluntary water reallocation across state lines (including between Upper and Lower Basin states)**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**16.1%** (9/56)	**33.9%** (19/56)	**46.4%** (26/56)	**3.6%** (2/56)
California	**37.1%** (13/35)	**42.9%** (15/35)	**20%** (7/35)	**0%** (0/35)
Nevada	**52%** (13/25)	**32%** (8/25)	**16%** (4/25)	**0%** (0/25)
Colorado	**10.7%** (3/28)	**39.3%** (11/28)	**50%** (14/28)	**0%** (0/28)
New Mexico	**33.3%** (2/6)	**33.3%** (2/6)	**33.3%** (2/6)	**0%** (0/6)
Utah	**5.6%** (1/18)	**22.2%** (4/18)	**66.7%** (12/18)	**5.6%** (1/18)
Wyoming	**0%** (0/8)	**37.5%** (3/8)	**62.5%** (5/8)	**0%** (0/8)
Other / Unknown	**28.6%** (2/7)	**42.9%** (3/7)	**14.3%** (1/7)	**14.3%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**18.3%** (17/93)	**33.3%** (31/93)	**47.3%** (44/93)	**1.1%** (1/93)
Water Professional	**28.1%** (16/57)	**40.4%** (23/57)	**28.1%** (16/57)	**3.5%** (2/57)
Water User	**35.7%** (5/14)	**35.7%** (5/14)	**21.4%** (3/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**30.1%** (4/13)	**38.5%** (5/13)	**30.1%** (4/13)	**0%** (0/13)
Nongovernmental Organization	**16.7%** (1/6)	**16.7%** (1/6)	**66.7%** (4/6)	**0%** (0/6)
TOTAL				
Count [183]	43/183	65/183	71/183	4/183
Percentages	**23.5%**	**35.5%**	**38.8%**	**2.2%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Revisit key Law of the River terms to identify and resolve points of ambiguity and dispute**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**16.1%** (9/56)	**35.7%** (20/56)	**44.6%** (25/56)	**3.6%** (2/56)
California	**16.7%** (6/36)	**36.1%** (13/36)	**36.1%** (13/36)	**11.1%** (4/36)
Nevada	**45.8%** (11/24)	**29.2%** (7/24)	**16.7%** (4/24)	**8.3%** (2/24)
Colorado	**21.4%** (6/28)	**35.7%** (10/28)	**35.7%** (10/28)	**7.1%** (2/28)
New Mexico	**50%** (3/6)	**16.7%** (1/6)	**33.3%** (2/6)	**0%** (0/6)
Utah	**22.2%** (4/18)	**38.9%** (7/18)	**38.9%** (7/18)	**0%** (0/18)
Wyoming	**25%** (2/8)	**12.5%** (1/8)	**50%** (4/8)	**12.5%** (1/8)
Other / Unknown	**0%** (0/7)	**28.6%** (2/7)	**57.1%** (4/7)	**14.3%** (1/7)
Occupation / Affiliation				
Water Manager / Government	**21.5%** (20/93)	**34.4%** (32/93)	**36.6%** (34/93)	**7.5%** (7/93)
Water Professional	**19.3%** (11/57)	**31.6%** (18/57)	**43.9%** (25/57)	**5.3%** (3/57)
Water User	**35.7%** (5/14)	**35.7%** (5/14)	**21.4%** (3/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**23.1%** (3/13)	**38.5%** (5/13)	**30.8%** (4/13)	**7.7%** (1/13)
Nongovernmental Organization	**33.3%** (2/6)	**16.7%** (1/6)	**50%** (3/6)	**0%** (0/6)
TOTAL				
Count [183]	41/183	61/183	69/183	12/183
Percentages	**22.4%**	**33.3%**	**37.7%**	**6.6%**

Question 6: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation?

- **OPTION: Importation of water from other basins (e.g., Great Lakes, Columbia, Mississippi)**

	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**5.4%** (3/56)	**21.4%** (12/56)	**67.9%** (38/56)	**5.4 %** (3/56)
California	**19.4%** (7/36)	**27.8%** (10/36)	**47.2%** (17/36)	**5.6%** (2/36)
Nevada	**24%** (6/25)	**52%** (13/25)	**20%** (5/25)	**4%** (1/25)
Colorado	**7.1%** (2/28)	**17.9%** (5/28)	**75%** (21/28)	**0%** (0/28)
New Mexico	**16.7%** (1/6)	**33.3%** (2/6)	**50%** (3/6)	**0%** (0/6)
Utah	**22.2%** (4/18)	**27.8%** (5/18)	**44.4%** (8/18)	**5.6%** (1/18)
Wyoming	**12.5%** (1/8)	**50%** (4/8)	**37.5%** (3/8)	**0%** (0/8)
Other / Unknown	**0%** (0/7)	**42.9%** (3/7)	**57.1%** (4/7)	**0%** (0/7)
Occupation / Affiliation				
Water Manager / Government	**14.9%** (14/94)	**30.9%** (29/94)	**51.1%** (48/94)	**3.2%** (3/94)
Water Professional	**5.3%** (3/57)	**33.3%** (19/57)	**56.1%** (32/57)	**5.3%** (3/57)
Water User	**42.9%** (6/14)	**0%** (0/14)	**57.1%** (8/14)	**0%** (0/14)
Citizen / Other or Unknown	**0%** (0/13)	**38.5%** (5/13)	**53.9%** (7/13)	**7.7%** (1/13)
Nongovernmental Organization	**16.7%** (1/6)	**16.7%** (1/6)	**66.7%** (4/6)	**0%** (0/6)
TOTAL				
Count [184]	24/184	54/184	99/184	7/184
Percentages	**13%**	**29.3%**	**53.8%**	**3.8%**

<u>Question 6</u>: As policy-makers search for solutions, what general categories of strategies should be the primary focus of research and experimentation? • **OPTION: Establish a Colorado River basin organization to aid in regional decision-making**				
	High Priority	Medium Priority	Not a Priority	No Opinion
Region				
Arizona	**7.1%** (4/56)	**21.4%** (12/56)	**64.3%** (36/56)	**7.1%** (4/56)
California	**19.4%** (7/36)	**30.6%** (11/36)	**47.2%** (17/36)	**2.8%** (1/36)
Nevada	**24%** (6/25)	**32%** (8/25)	**36%** (9/25)	**8%** (2/25)
Colorado	**10.7%** (3/28)	**25%** (7/28)	**60.7%** (17/28)	**3.6%** (1/28)
New Mexico	**33.3%** (2/6)	**50%** (3/6)	**16.7%** (1/6)	**0%** (0/6)
Utah	**11.1%** (2/18)	**16.7%** (3/18)	**72.2%** (13/18)	**0%** (0/18)
Wyoming	**0%** (0/8)	**0%** (0/8)	**100%** (8/8)	**0%** (0/8)
Other / Unknown	**16.6%** (1/6)	**0%** (0/6)	**50%** (3/6)	**33.3%** (2/6)
Occupation / Affiliation				
Water Manager / Government	**7.4%** (7/94)	**27.7%** (26/94)	**62.8%** (59/94)	**2.1%** (2/94)
Water Professional	**22.8%** (13/57)	**14%** (8/57)	**56.1%** (32.57)	**7%** (4/57)
Water User	**14.3%** (2/14)	**50%** (7/14)	**28.6%** (4/14)	**7.1%** (1/14)
Citizen / Other or Unknown	**16.7%** (2/12)	**16.7%** (2/12)	**41.7%** (5/12)	**25%** (3/12)
Nongovernmental Organization	**16.7%** (1/6)	**16.7%** (1/6)	**66.7%** (4/6)	**0%** (0/6)
TOTAL				
Count [183]	25/183	44/183	104/183	10/183
Percentages	**13.7%**	**24%**	**56.8%**	**5.5%**

SOLUTION PREFERENCES, CONTINUED (QUESTION 7: WRITE-IN COMMENTS)

Question 7. The preceding question featured a list of frequently mentioned strategies, however, many additional options are possible. In the box below, please describe any additional ideas or approaches that you think deserve more research or consideration.

Below are the unedited write-in comments (from 71 respondents) generated by this question. The number preceding each response is the unique ID number randomly assigned by the survey software to each respondent. It is impossible to correlate ID numbers with particular individuals or with the state or affiliation associated with the respondent.

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1104: Assessment of underground storage of surpluses to reduce/eliminate evaporational losses of surface reservorir storage.

1108: Need to develop a real-time water market based on the model implemented in the Murray-Darling system in Australia. Unfortunately, the Law of the River and the personalities involved are resistant to change. It is likely to take a major water crisis to enable the major re-structuring that is clearly necessary.

1109: Continue and expand upon climate variability research and down-scaling the regional models to the Colorado River Basin. Snowpack and streamflow runoff pattens/timing/relationships with regards to the climate variability. Create an on-line "library" and inventory of all past studies, research and related information that would be accessable to the public. Don't ignor basic data collection efforts - precip, weather, snowpack, streamflows, diversions, storage, etc.

1111: improved data collection and monitoring recharge and diversion of High flows in adjoining basins to avoid loss of valuable resources refinement of global climate models to be more regioanl in scope and accuracy

1115: The sky is not falling, development of the river is just occurring as anticipated when the compact was created. That means moving forward everyone will have to adjust to living within their allocation and accept that there will be more scrutiny and need to refine measurement and management to maximize use of the resource.

1117: Create a watershed framework wher conservation and water development strategies can be approached between states and regions of the upper and lower basins. Our governance model has worked to allow for flexibility in managing these reservoirs. Use the existing governance model and "law of the river" to increase this flexiblity Provide a more comprehensive process for tribal and environmental issues to be heard without jumping first to a litigation straegy - the states have already done this.

1118: Less emphasis on bugs and bunnies and more emphasis on human beings!

1120: There needs to be a far better effort to 1) reduce demand, 2) price water sensibly and 3) allocate water for the environment. Existing pricing is a subsidy for agriculture and provides no incentive for conservation. The era of big dams and augmentation is over. Existing management strategies are stuck in the mid-20th century.

1121: Exchanges between basins and between states Recharge possibilities in lower basin states for future use More research in the reuse of waste water More research in lower water use crops More research in use of saline water

1123: Reduce or stabilize demand - reduce population size

1125: The issue of return flow credits at the lower end of the system needs to be explored further from an operational not from a legal perspective. While the process works from a 'law of the river' and accounting view it would be more productive to recycle a portion of this water and reduce the releases from Lake Mead. - The purpose of the Yuma Desalting Plant needs to be aligned to current needs and not the late 1960's. It makes little sense to clean groundwater to the level of bottled water make it dirty again and throw it into the Colorado River. Meanwhile at every corner in Yuma, El Centro, Calexico and San Louis you pay $0.25 for a gallon of salt free water. This groundwater can be desalted to the levels of Colorado River water and applied to farms. This would also allow the so called negative term 'brine stream' to become a source of water for creating habitat.

1126: Open discussions with Republic of Mexico on the 1944 Treaty to lower Mexico's annual allotment.Promote the increased funding for Colorado River Salinity Control Board. Allow lower Basin States more access to storage behind Hoover Dam. Revisit allocations given to Indian Tribes.

1127: Expand programs like Drop 2, that will capture unused alloactions of water before they are lost.

1128: Reduction of salinity introduced into the river from communities.

1129: Strengthen property rights in water and allow greater transferability. Tamarisk removal but not weather augmentation.

1131: Encourage continued voluntary agreements amongst water users and states that address needs.

1132: Potential research concepts: Improved basin-level models regarding precip changes that might be expected with broader climate change. (Computer models seem to be effective for temperature predictions but are apparently inadequate for precip changes.) Evaluate the potential costs/benefits of outreach efforts that would inform the public about Colo Riv shortages and the importance of actions by water providers dependent on Colorado River flows. Perform a more refined evaluation of Upper Basin States' long-term demands to better inform decisions being made now by the Lower Basin States. Perform indpendent evaluation of conservation potential in Mexico presupposing the existence of US-MX arrangements that could institutionalize binational water transfers, leases and storage of Colo Riv waters.

1135: Adjust future allocations on a real-time basis according to the data that is being added (and will be added) to the the historical record and not just the historical data available at the time the compact was developed.

1137: Tweaking the law of the River to allow non-conserved water to be sold rather than simply flowing to the next priority would save water and costs. There is a disincentive to conserve water unless conservation can be shown to allow a transfer. One wastes water to reach their allotment to force the need for conservation and to force the sale/transfer. At least some type of partnership (where you have willing partners) to avoid the need for conservation to avoid the waste and cost should be allowed - this would be a happy medium. The net result in conservation would be the same or greater as the money generated would go toward improving the system from a capital, operation and conservation standpoint as there would then be a desire to sell more water. This would be a more market driven model. The value of the water would further drive more sales resulting in additional revenue and the desire to implement more conservation due to the value of the water. To avoid selling water that has a current economic use this could be restricted to average unused entitlement plus some additional amount. The money derived from unused entitlement would result in further conservation which would result in more unused entitlement. Allowing a certain amount above the unused entitlement (assuming some history of use is desired) would allow additional sales to occur until sufficient additional history is developed to show a reduction in use and thus additional unused entitlement available for sale. The water discharging into the Salton Sea could be used as a substantial resource mitigating many of the current and near term water resource problems. This could be done while addressing the diverse concerned parties (water agencies, irrigation districts, cities, states, environmental groups, etc.) but a huge coordinated effort would be required from a great leader to show this group a vision and to build consensus. The sea cannot be saved feasibly as is but it could be addressed and used as a water resource (upwards of 500,000 acre-feet per year - even after full QSA implementation) while maintaining a variety of lakes (fresh, saline and brine - albeit probably 1/4 the surface area of the current lake. The cost of this endeavor would be much lower than other options as the salinity of the water reaching (on average) is between 2500 and 3000 ppm.

1138: A Colorado River Basin Organization is in place - its called the Seven Basin States. Where in the west have canals not been lined? What are the consequences of lining those few remaining miles - loss of groundwater recharge? Loss of critical habitat? There are many other "advanced irrigation systems" besides drip, which is not suitable for all soils, crops and WQ issues. Power is a critical part of the Colorado River question. Conservation/reallocation/etc can and will affect power production. Power must not be left out f the discussions. Endangered fish species below lake Powell have recovered. It is not necessary to flatten the river below Powell for their benefit. Lake Powell should be operated to benefit water and power users as well as for species and recreational protection. Look for solutions that benefit all users (water, power, recreation, environment), not just one or two.

1142: The list of potential strategies listed above covers the major/feasible options.

1143: The Mississippi River flow is 440MAF/year vs the Colorado's 14-15MAF Get Transportatin and flood agencies to agree to export excesses and a resonable base suppply from MR to the Colorado River Basin.. 1% of the MR is the magic number of 4.4MAF that California now uses.... why note 2% and solve many needs at once... States between Colorando and the Mississippi should cooperate for their own best interest..... water the desert vs flooding New Orleans..

1144: More can be done with the Republic of Mexico to define and craft mechanisms where both enhanced conservation and shortage sharing sit side by side with stability in supplies and quality of supplies. These strategies might align with approaches taken in the Basin States but are complicated by international arrangements and relationships.

1146: Since demands on the Colorado River are linked to available supplies locally (The less available locally, the greater the demand on the river), the conservation and efficient use of local supplies not directly linked to the river need to be addressed. The benefit/cost of the continued use of Colorado River water for low-margin agricultural crops needs to be addressed including third party impacts. Example: Colorado River water is used to grow alfalfa while urban agencies spend $1500/AF to desalt water. Makes no sense, but this is linked to the "Law of the River" and, in California's case, the seven-party agreement.

1147: No-growth incentives

1150: Place emphasais on flexibility as to flows and storage so that maximum use can be accomplished for all parties in perpetuity. Keep working to refine the accomplishments to date. Build trust amongst the interested parties.

1151: Although I disfavor revisiting the Law of the River, I'm pretty certain that the issue of Lower Basin tributary flows and how they affect the Mexican Treaty obligation will be litigated. But to engage in contention will not advance the sharing of scarce water resources, and will lose valuable time and money in pursuing real-world solutions to drought.

1152: Resolving unquantified Tribal water rights.

1154: Terminate all proposals for water withdrawal projects immediately. Surplus water does not exist. Initiate a basin-wide Programmatic EIS with priority to recover the endangered fish, which will solve issues related to water quantity and quality. Transfer surface storage to depleted confined aquifers, with 15% reserved for severe and persistent drought emergencies. Transfer compact point from Lee's Ferry to Hoover Dam. Study the decommissioning of Glen Canyon Dam to reverse impairment in Grand Canyon National Park, and increase the range of critical habitat and restore its connectivity to the tributaries. Move buildings out of the floodplain. Answer the sediment problem in reservoirs and create a funding mechanism to mitigate. Reform agriculture and WAPA. Mitigate the dust problem. Basin-wide ban of oil and gas, in-situ oil shale development, and all mining of uranium, tar sands and oil shale.

1155: Quantify over-use in the Lower Basin and focus on finding ways to stop that over-use.

1162: On a long term basis, 300-1,000 years, we do not really know what is the average annual flow of of the Colorado River. An objective re-calculation of this figure is critical to any future decision-making.

1164: Future power plant development should be located near one of the large lakes (Flaming Gorge, Powel, Mead) to avoid water lost to evaporative cooling. Cooling water could be returned to the lake or below the dam with a slight increase of temperature.

1166: Water augmentation on a large scale by whatever means will be very expensive. Conservation has a limit, but I do not think we are even close to that at this point. Managed population growth is a key to the West's water issues.

1169: For the State of Nevada. I think that serious consideration should be given to the idea of the State of Nevada agreeing to accept the Yucca Mountain Nuclear Waste Disposal site in exchange for the Federal Government agreeing to significantly increase the amount of Colorado River water available to the State of Nevada. This would be accomplished by building and operating desalination plants either in Mexico, or California to satisfy a portion if not all of their

Colorado River allocation rights utilizing desalted ocean water. A portion of those water rights would then be transferred to the State of Nevada. Consideration should be given to using Nuclear power from newly constructed nuclear plants to provide the energy necessary to operate the desalination plants. Perhaps this idea could be put before the voters in the State of Nevada for their approval. An expansion of this idea could be used to solve much of the two basin's water problems. The water presently allocated to Mexico and the State of California could go a long way towards solving the problems of the rest of the States in the Compact.

1170: The Colorado River is tapped out at current population and demand. There is a need to develop other in state water resources in addition to Colorado River water resources to support future population growth. Swapping state allocations and developing coastal desalination may be worth investigating.

1172: Study water supply and demand in the Basin without the traditonal political interference to protect the myhical 7.5 million acre-feet of "available" water supply in the Upper Basin. That includes studying the impacts of climate change not only to look at projected changes in the natural flow of the River but to include how diminished snow pack will actually impact demand in the Upper Basin based upon the current infrastructure in the Upper Basin. Refine research into the Law of the River regarding the actual current legal obligations for equalization, not inludging the current 2007 Managment Guidelines.

1179: Control population growth and build cities over aquafers. Limit growth to how much acre feet of water there is.

1185: We can't forget about infrastructure, conservation alone is not the answer to all our water supply needs/problems. Please make this point if nothing else. Most of the other ideas make sense, but no matter how we manage them we still, at the end of the day, have to have somewhere to put the water for our use. Those who think that by tinkering - or tampering with- the Law of the River will solve our water problems are kidding themselves. It has provided a workable framework for almost a century...modifications OK, major overhaul - NO

1186: 1. Reduce water consumption in the Lower Basin through making ongoing outside landscape water conservation activities the "baseline" for water use in Lower Basin areas. 2. Current desalination breakthroughs need to be factored into the discussion and dialogue about desalination as a source of water. For example, a) Saltworks Technologies is positioned to commercialize a breakthrough desalination technology during a time of increasing freshwater scarcity, rising energy prices, and mounting concerns over carbon impacts. Saltworks' patent pending technology employs an innovative Thermo-Ionic™ energy conversion system that uses up to 80 per cent less electrical/mechanical energy relative to leading desalination technologies. The energy reduction is achieved by harnessing low temperature heat and atmospheric dryness to overcome the desalination energy barrier. Saltwater is evaporated to produce a concentrated solution. This solution, which has concentration gradient energy, is fed into Saltworks' proprietary desalting device to desalinate either seawater or brackish water. Some electrical energy is used to circulate fluids at a low pressure, yet the bulk of the energy input is obtained through the evaporation of saltwater. Applications for Saltworks' technology include producing drinking water for communities and municipalities, irrigation water for agriculture, and process water for industry. It is especially well-suited for situations with low temperature thermal energy (30-40 degrees Celsius) such as simple solar thermal or waste heat. Performance of this novel process improves in arid regions, which happen to be the very regions that require freshwater. The technology also requires less pre-treatment and chemicals than traditional processes. The technology has been proof-tested by the National Research Council of Canada and BC Hydro's Powertech Labs. An outfitted 1,000 litre a-day seawater pilot plant complete with chemical free pre-treatment will soon be fully operational at a harbour location in Vancouver, British Columbia. b) High costs, in money and energy, limit the usefulness of desalination as a way to provide drinkable water in disaster areas. However, a new method could lead to portable desalination devices simple enough to run off solar power or a battery, but powerful enough to supply a family, or even a small village, with clean water. Additionally, the new desalination device also cleanses water of biological contaminants. Developed by scientists at MIT, the desalination device is about the size of a postage stamp, and can be fit together into larger daisy chains. An eight-inch-wide array of the desalination chips can produce four gallons of clean water every hour, while only using as much electricity as a light bulb. Plus, when tested with water mixed with plastic bits, human blood, and miscellaneous proteins in addition to salt, the unit pumped out 99-percent-pure water. The desalination chips separate water from contaminants by repelling the foreign particles electrically. Since this method does not use filter, the system can operate without high pressures. Simply pour the contaminated or sea water in the top, and wait for the pure water to come out of the bottom. According to the developers, it will take about two years to develop a commercial product containing 10,000 desalination chips. Whether this technique can expand beyond portable low-energy systems, and into the sort of large-scale desalination that provides many Middle Eastern countries with potable water, remains to be seen. 3. Ocean Thermal Energy Conversion (OTEC) should be investigated as a means of providing additional water supplies. The key to Craven's cool world is converting the ocean's thermal energy. The first step: Sink a pipe at least 3,000 feet deep and start pumping up seawater. The end result: an environmentally sustainable, virtually inexhaustible supply of electricity, freshwater for drinking and irrigation, even air-conditioning. Here's how it works: Refrigeration: Cold seawater circulates through a closed loop of pipes that replace the coolant and compressor found in conventional air-conditioning units. Irrigation: Pipes carrying cold water run beneath fields of crops, sweating freshwater to irrigate plants and chilling their roots, promoting faster crop cycles. Desalination: Cold seawater passes through Craven's "skytowers," which contain closely packed radiator-like networks of pipes. The frigid pipes sweat in the tropical heat, producing freshwater condensate. Power Generation: Pipes draw warm water from the ocean surface and cold water from the seabed. The warm water enters a vacuum chamber and is evaporated into steam that drives an electricity-producing turbine. The cold water condenses the steam back into water for drinking and irrigation.

1197: It may be intended by the desalinization item above, but the best option for augmenting supply after weather modification would be subsiding desalting in coastal areas (including Mexico) to enable exchange of some current exports. Another option with potential promise is genetic engineering for widely grown field crops to see what can be done to reduce plant water use without loss in yield or quality. Since the Colorado water system is mostly a closed basin, almost all so called "waste and return flow" is being reused now. Many so called conservation and efficiency measures heap on added costs to the users for little or no actual systemwide savings and are therefore not justified.

1199: This won't be popular in the environmental arena, but I think establishing more of a direct tie between water and energy development in the Colorado River Basin could accomplish two objectives - allow development of the substantial energy reserves in the basin and simultaneously provide the basin with innovative water development/management ideas and efforts. If we require the large energy development firms to help solve the basin water problem before they're allowed access to the coal/gas/tar sands/oil shale fields, etc., the money and political will to make the difference necessary would be intrinsic and we'd be more likely to be successful in the long-term on both the water and energy fronts.

1200: Implement interstate and interbasin water storage and short-term water exchange programs. Implement an interstate/interbasin water bank that allows voluntary water sellers and buyer to meet critical water supply needs. Implement cooperative programs with Mexico. Focus on administrative actions for management of the River and reservoir system that avoids either a restructuring of the "Law of the River" or an intrepretation of it.

1201: Place a high priority and funding on genetic research that breeds varieties of existing crops that can thrive and increase production using less of and a higher saline water.

1202: I believe that is what the Basin Study will do.

1204: Instead of two basins, upper and lower, create three basins, upper (everything above confluence of San Juan), middle (San Juan R. Lake Powell, Grand Canyon, Lake Mead, CR south to Parker Dam),and lower (lower CR river below Parker Dam serving agriculture in Arizona and California) Create a fixed water right in the upper and lower, and leave the hydrologic risk in the middle. This puts the urban users (Phoenix, Tucson, Alberquerque, Las Vegas, Los Angeles, San

Diego) in a common risk pool with the resources (reservoirs) with which to manage risk. A risk analysis needs to be performed with this approach so that fixed water rights in upper and lower can be established and middle can contemplate what risk it could assume given risk projections. Put this in place with a federal statute sponsored by seven states. Get rid of the CR Compact as obsolete. Permit deals between basins and within basins. Tax all users based on volume of use as a basis to maintain environmental conditions.

1208: We should stop talking of future demands without attaching a price to the discussion. A classic blunder is the current Colorado effort to etablish future demands. If a commodity is free the demand is close to infinity.

1213: It is important to know what the problems are and what the various options presented above would do to resolve them, at least partially. For example, I have no idea what is meant by Colorado River Basin Organization and what it would do. The seven states already have a structure for addressing issues and have done so successfully with the shortage sharing guidelines. Better understanding of the issues and challenges is needed in order to really prioritize options and trade-offs. I would expect that people answering this survey have different levels of knowledge, let along perspective!

1217: *Absolutely NO changes to the Colorado or Upper Colorado River Compacts!!! Colorado will never be able to negotiate as good a deal as what we have now. *8.23 MAF release by the BoR to Lower Basin is wrong. No shortage determination was ever made! Lower Basin owes this water to Mexico not the Upper Basin. *Administration MUST be real time! No 10 year moving average. Under the Constitution of the State, we operate under the priority system and All basins must be treated equally. Curtailment on a 10 year moving average (particularly since we don't know futue flows) would take water from those legally entitled to use it. *I believe you have pre-determined the outcome of this survey and will not act in the best interests of the State of Colorado. Stay out of these issues!

1218: Changing the law of the river is thrown around by professors and others. That law need not be changed. It is fine the way it is, and attempting to change it would bring great disruption. Also, urban areas need to find water in ways other that going to agriculture. We need to keep our agricultural areas alive within the United States. Finally, if the southwest is going to contine to grow, new supplies must be found -- like ocean desalination. However, desalination may not be enough when you go out 50 years. So importation from other sources may be needed. We should not shrink back from such alternatives. It can be done. But stopping growth does not seem like a realistic possiblity, no matter what the professors say.

1219: Continue to explore binational opportunities for augmentation.

1220: The states are well organized and equipped to address upcoming problems and have worked with federal agencies well. Those that want institutional changes are most often from groups that don't now have a vote and don't represent elected officials.

1221: Law of the River that currently exists is sufficient for river managment between the Upper Basin and the Lower Basin. Lower Basin drought agreements need to be more seriously administrated!!

1229: Determine a new, probably lower, Colorado River yield based on the reliable historic record to date and then adjust each state's allocation on a pro rata basis. This may require revisting the trigger levels for CAP curtailment and Compact calls. I would consider these minor changes as the priciples of the Law of the River would not change, just the allocation values and trigger levels. I'd also suggest revisting the allocations at regular intervals as the longer historic record reveals actual flow changes brought about by climate change rather than modeled changes. This would attenuate Compact changes and hedge against errors in the modeling assumptions.

1234: Regional desal was mentioned as an option, but not sure what this meant. I think we should seriously look at desal in combination with Colorado River Water transfers as a possible solution - i.e., AZ or NV could pay for desal plants to be built in CA and in exchange for CA having access to this new water supply, they would let AZ and/or NV remove a like amount of CA allocation from the CR.

1237: Rework the Endangered Species Act. This has become a tool that is being misused by those with other agendas. Pull back the Clean Water Act.

1238: Augmentation is of the highest priority especially for the Lower Basin, and it will allow the Upper Basin to develop its water as allowed by the Compact without interference from the Lower Basin.

1239: Having coastal areas pursue utilizing the brackish and saltwater resources to augment and/or meet their freshwater needs rather than relying on large diversions from inland water resources.

1241: The users of CRW need to address the fact that the river is overallocated. Once upper basin agricutlure fully develops, the 16.5 MAF allocation (including Mexico) will run into the 13 to 14 MAF average historical flows based on 1000 years of data from tree rings. If CRW users in the US do not do this to themselves, the federal government will be forced to step in and do it for them. This has already happened in Australia. The public will demand a reallocation. It will not be pretty.

1245: Provide more incentives for states that don't utilize their allottment.

1248: Greater utilization of reclaimed water for potable use, greater use of poor quality groundwater (including water from federal and state superfund sites) for potable use, requiring groundwater management legislation for states that do not currently have such statutues and development of longer-term land fallowing agreements should all be encouraged.

1249: The Seven Basin States and the Federal Government need to continue to work together to solve the future problems on the river. An orginization already exist call the governors representative on Colorado River Issues to resolve problem on the Colorado River. This group continues to met on the issues facing the basin. Over the past ten years several programs have been developed by this group, to reduce the issues between the Upper and Lower Basin States. This group is now meeting with Mexico to determine what additional solutions to problems can be negotated within the Law of the River to solve water supply problems. Many in the academic world see the documents making up the Law of the River to be inflexiable and therefore solutions to problems are limited. The Law of the River is a flexiable living group of documents that can be used to solve future problems. If the Academic world would realize this they could possibly be helpful in solving future problems. If the academic world takes the position they are the only ones that can solve the problems on the river, they will likely be left standing on the side wondering why the basin states do not want to use their expertise.

1258: At what point do we take a realistic approach to future growth in the Colorado River Basin, particularly in light of the numerous unknowns surrounding future river water availability?

1261: Limit development in those areas suffering (or will suffer) water shortages.

1263: The demand on the Lower River exceeds supply. The DOI should revise the Lake Mead shortage criteria to be consistent with DOI's 1968 testimony before the Congress which was the basis for the authorization of CAP -- i.e., shortage to CAP of one MAF in any year when Lake Mead was below elevation 1124. Take Reclamation out of River Management decisions and vest in a seven State compact Commission.

1267: Manage Population Growth and Developement based on water supply.

1276: cooperation with Mexico for the establishment of a nuclear power facility near or south of Mexicali to power a large desalization plant to enhance supplies for Mexicali, the Salton Sea and for Southern California, to enable exchanges for River Water and enhance supplies.

1277: Reducing California's allocation.

1280: Storage of summer flood flows within urban areas or off mainstem Increased use of groundwater storage

1284: 1. Education of citizens on the scarcity of clean water and weather changes that affect the availability of water for domestic, industrial and farming uses. There is too much waste. 2. Settle water rights issues with Tribal Nations and promote collaboration, not fighting for who has the upper hand but rather, what is good for all citizens. With the Navajo Nation, the Indian Irrigation Project funding should be provided for all the structural improvements promised years before. 3. United States Government putting money with laws and policies to address water scarcity due to climate changes, improvement of farming irrigation techniques for all farmers--small and corporate, and support sustainable economy in all states. The dependence for numerous products from other countries could hurt our nation. 4. Give tax breaks for households and businesses implementing water conservation practices

1286: Increase desalinization of ocean waters, reduce/eliminate lawn watering, eliminate potable water use for landscape irrigation, increase underground storage options vs. surface storage to reduce evaporative losses, reduce high water consuming electrical generating facilities in favor of photovoltaics, and, no joke, consider taking steps to increase the number of beavers in upper watersheds to slow water movement and provide (relatively) free water storage in lieu of large storage reservoirs.

1288: Interstate transfers, voluntary agricultural fallowing and rotational cropping programs such as the Palo Verde program, transfers between Mexico and US entities, close consideration and possibly restriction or recycling of product water used in energy development projects.