Exploring Climate Change Driven Shifts to Water Rights and Policy Along the Colorado River

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Defense: April 6, 2015

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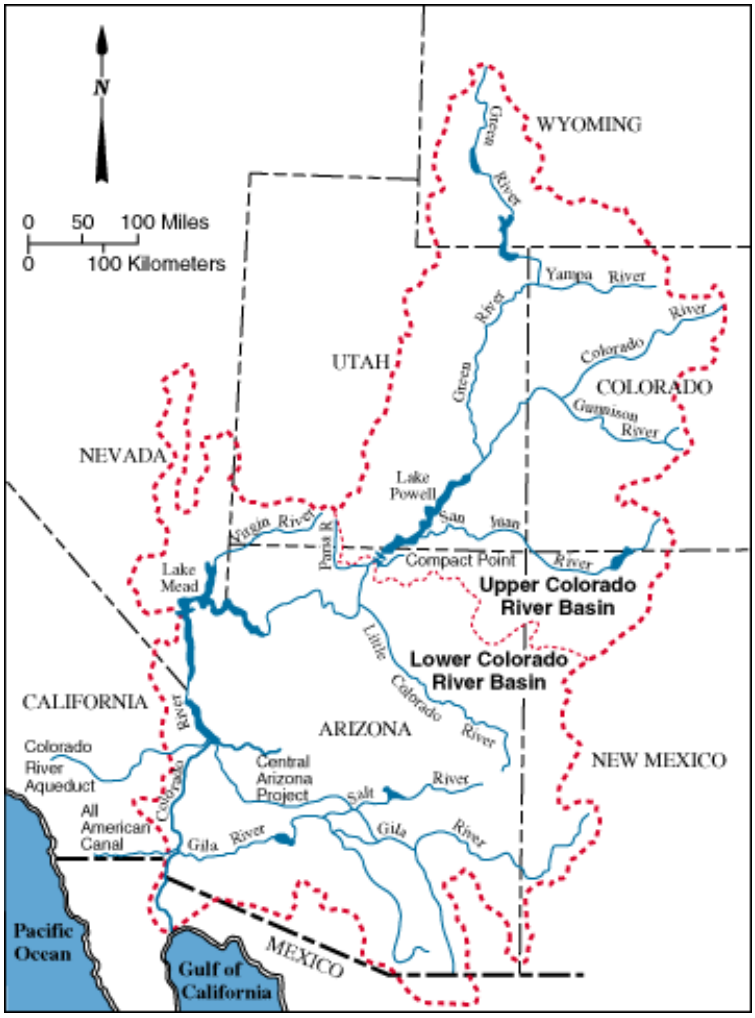
Abstract

The goal of this study is to evaluate the current discussion on how climate driven shifts in hydrology will affect water rights and policy on the upper Colorado River. Global and local temperatures have been increasing steadily. In certain areas of Colorado snowmelt has shifted earlier and is likely to continue to do so. Precipitation as snow is decreasing at certain elevations in the Rocky Mountains. Focusing on water users in the western slope of Colorado, these environmental changes suggest a number of shifts in river hydrology. There will likely be less overall storage as snowpack and possibly earlier more pronounced peak flows. It is expected that earlier flow timing could reduce the ability of senior agriculture users to apply water to crop irrigation. This in turn could increase the value of temporary transfer or fallowing strategies proposed to meet anticipated municipal and industrial water needs. Reduction of agricultural production in certain crops, or shifts to crops that use less water or can be irrigated earlier in the season could also be expected. Junior holders will be affected in potentially different ways. Initially as peak flows shift earlier junior rights holders such as fishing or kayaking industries may see a potential benefit in more water available earlier in the season. However, late season shortages as a result of flow shifts have the potential to exacerbate the value of senior rights. My approach is to combine a review of scientific literature, policy literature, and discussions with professionals and experts on these issues to produce an overview that identifies the most prominent issues and consequences concerning these shifts.

Introduction

Water rights and regulation in Colorado are already in a phase of evaluation and scrutiny. A functional system for preserving, regulating, and accessing water is necessary for public welfare and economic development. Populations are increasing, and along with them the direct demand for water and for goods and services that require the use of water. Prior appropriation doctrine is firmly entrenched as the standard for agricultural access, industrial and municipal use, and as system for resolving disputes over withdrawal and infringement of water rights. Recent increases in economic development, production, and demand throughout Colorado have led to considerations on how to move forward within the state's framework for regulating water. The state government has been working toward the drafting of a new water plan that is considering changes in the current legal and regulatory structure. The state's current draft primarily focuses on reducing the hurdles within the permitting process for multi-use and storage projects with some small mention made to increasing legal incentives for conservation. As future strategies within Colorado's prior appropriation system are being debated in the wake of potential issues with the existing system, climate change and increased warming stands to pose even greater problems to regulations, as they exist now. The Colorado River Basin is particularly relevant for study, as it is susceptible to the contemporary challenges and potential shifts in local hydrology.



-Map of the Colorado River Basin area, taken from the Bureau of Reclamation (2005).

http://www.usbr.gov/lc/region/g4000/contracts/watersource.html

In their draft plan the state of Colorado anticipates significant future supply gaps purely from population growth and increased demand, let alone climate change driven alterations. A major source of water not just for localities and agriculture on the Western Slope, the Colorado River is also a current and contentious source of water for major municipalities along the Front Range. The water in the Colorado also goes to Arizona, California, Utah, New Mexico, Nevada, and Wyoming under the 1922 Colorado River Compact. The Compact also allocates surplus water for use to Mexico, with water to meet

deficiencies drawn equally from the upper and lower basins; later allocations were specifically established under the 1944 Water Treaty with Mexico (Colorado River Governance Initiative 2011). Potential for a curtailment of water use on the western slope as a result of rights to Mexico under this compact further complicates the situation on the Colorado River. This study attempts to look at the issues surrounding water rights and prior appropriation on the Colorado River, and how a changing climate will likely exacerbate or alter those problems.

Global temperatures have risen over the past century and will continue to do so. The Earth's average temperature has likely increased by 0.85 degrees Celsius since 1880 (IPCC 2014). Effects of global warming vary locally and with different topography but researchers estimate that in Colorado local temperatures have increased by on average 2 degrees Fahrenheit since the 1970s; predicting that by the year 2025 Colorado will be 2.5 degrees Fahrenheit warmer than the current temperatures (Klein et. Al. 2014). Increasingly hotter temperatures are not the only shifts produced by climate change. Throughout Colorado's Rocky Mountains increased variability and magnitude of climate driven temporal and volume shifts in snowmelt, snowpack, and precipitation have already been observed and are expected to continue.

Research based on SNOTEL data, snow telemetry sensors run by the National Resources Conservation Service, suggests that snowmelt timing has shifted in the Rocky Mountain region by a median of 4.8 days per decade since the 1970s. Some SNOTEL sites have recorded snowmelt shifts as large as over a week per decade. Throughout all the regions since 1978 snowmelt at the observed sites was occurring 14.4 days earlier (Clow 2010). Models analyzing future shifts predict this pattern to continue. As much as one to

two weeks earlier snowmelt for each degree Celsius increase in temperature is possible (Rauscher et. Al. 2008). Early models have suggested as much as 15-25 days sooner snowmelt onset by the year 2050 in Colorado (Stewart et. Al. 2004).

Along with earlier snowmelt changes in precipitation are anticipated as well. Declines in net precipitation have already been observed in mountain regions over the last few decades (Miller et. Al. 2011). Additionally, a greater portion of the potentially decreasing precipitation is falling as rain instead of snow. These shifts are likely most prominent at the mid-elevation levels already at the precipice of melting where gradual temperature increase means exceeding the melting point for existing snowpack (Knowles et. Al. 2006). All of this translates into earlier peak flows from snowmelt and changes in traditional seasonal flow characteristics. While these models are not exact, nor are they guaranteed to come true, the overall message is that these shifts are occurring, and will continue with a significant though ultimately uncertain magnitude (Oyler et. Al. 2015; Lukas et. Al. 2014). Any shifts along these lines are cause for concern, and we should consider possibilities with values above and below the scale of published models when addressing what the future may hold and how we can best prepare for those changes (Lukas et. Al 2014).

While clearly there is an understanding that potentially detrimental interactions between existing policy and changes produced by climate warming are incipient, an overview of the general discussion and plans on the Colorado River will be useful to better understand regulation's interaction with the rapidly changing physical system, as it exists now. In considering a review of scientific and regulatory literature as well as discussions with professionals and policy experts, this research intends to look at the current planning

and thinking among stakeholders, outside experts, and academics around the most immediate concerns and the areas most affected. The majority of scientific and policy sources come from researchers and analyst within Colorado.

Discussion

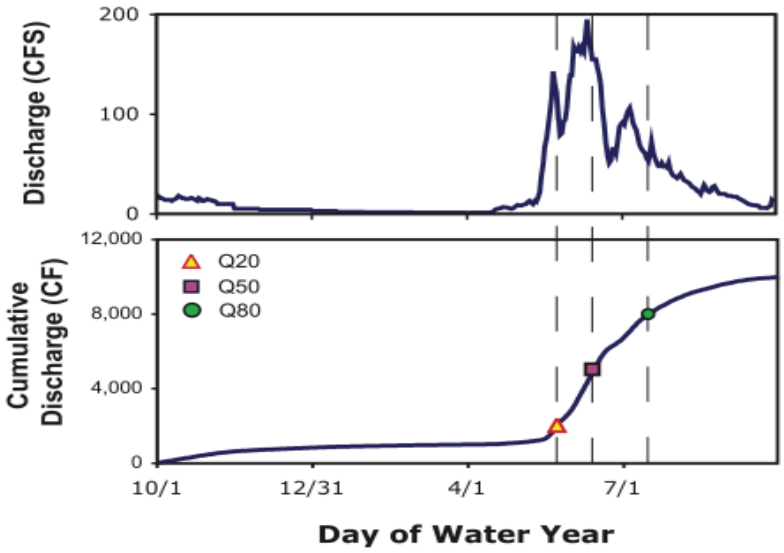


FIG. 2. Example of annual snowmelt-dominated hydrograph and associated cumulative discharge plot. Q20, Q50, and Q80 are 20th, 50th, and 80th percentiles of cumulative annual flow during the water year.

(Clowe 2010)

Among the most prominent of issues looking forward is the decrease of water storage in the form of snowpack. This change disrupts the typical flow pattern of the river hydrograph around which traditional withdrawal habits and irrigation are based. Melting as a gradual release of water from snowpack storage smooths the flow characteristics of the river and helps make more water available over a longer period. The cycle of snow accumulation then melt and timing of peak flows is crucial to the seasonality of agricultural

irrigation, which makes up the majority of water rights users along the Colorado River Basin (Bureau of Reclamation 2012). With earlier peak flows agricultural users may not be able to withdraw enough water during their traditional irrigation season. On the other hand, a shift from traditional flow patterns may disproportionately affect junior users as withdrawals from senior rights holders monopolize the diminishing seasonal supply of water. Additionally, while the earlier timing may be a problem, instream rights holders should benefit from the higher peak flows produced by climate change driven earlier more rapid snowmelt. Timing shifts in flow volume will likely have an impact on recreation industries for kayaking and fishing that can be dependent on having minimum flows in order to maintain their operations. It is possible that certain senior water rights will become much more valuable if they remain usable within the increasing scarcity and uncertainty from the changing system, however many junior holders especially those recreational and conservation instream diversions held by the CWCB, could find their rights much more valuable. If the irrigation season shifts early enough that agriculture cannot adapt to the change, more water may be available for recreation and other junior holders downstream.

As less water overall is readily available during the traditional irrigation season there may be the potential for farmers to be motivated to transfer away from agricultural uses. While there could be some incentive to switch to crops that use less water overall or are more compatible with the shifts in flow timing, other users may see good reason for transfers or fallowing arrangements, du to the increasing price being paid by cities. These arrangements typically involve short-term water transfers by leasing through water banks or super ditch companies. Particular organizations typically act as a clearinghouse or

storage and transfer program for water that is leased at auction or by contract. While water banks have been used extensively in other states they have not really taken hold in Colorado. One experiment is the Arkansas Valley Water Bank program, which failed because of a combination of limiting factors including unusually high prices and little participation (Scanga 2013). A few programs resembling water banks have been successful in other parts of the state. The Northern Colorado Water Conservancy District is a conglomerate of reservoirs, tunnels, and canals created by the Colorado-Big Thompson project in which groups subscribe to shares equal to set units of water (Northern Water 2013). State run water banks like the Idaho Water Supply Bank seem to effectively facilitate transfers by ensuring beneficial use and regulating the price at which water rights are bought and sold (Wilkins-Wells 2006). When water becomes potentially less usable, especially in certain drier years, some of the alternative rotational fallowing strategies that compensate farmers in exchange for temporary transfer to municipal uses may become more financially attractive to some rights holders. Additionally, projects that offer funding for increased efficiency improvements on irrigation infrastructure for crop production in exchange for municipal access to saved water may have an increased value proposition for agricultural users. These arrangements generally involve partial or full funding for irrigation ditch infrastructure used to divert water that is significantly more efficient than the existing systems. The Agriculture Water Enhancement Program from the National Resource Conservation Service is one example. This now defunded federal program provided funding for irrigation efficiency improvements to qualifying agricultural rights holders (Natural Resources Conservation Service). Municipalities or companies can provide similar programs. In exchange for the improvements some of the excess water no

longer needed for crop production is given to the municipalities or entities that funded the project. While increased agricultural efficiency can only be good considering the share of Colorado's water used in agricultural production, effects from these improvements will probably not be isolated. The majority of the sizable inefficiencies in the irrigation canals are through water lost in leaks and seepage to groundwater (Howell 2001). Some portion of this groundwater recharge inevitably winds up back in the river downstream. While the legal instruments exist to "shepherd" water downstream to man-made storage for institutional withdrawal this could have a detrimental affect on downstream water users both senior and junior, as well as further altering the timing for instream diversions (D. Wolfe, personal communication, October 28, 2014). Reducing the presence of groundwater recharge from users upstream could have a ripple effect on further decreasing the amount of water available to rights holders downstream. If these types of projects cannot secure water for the financiers, organizations have little motivation to offer funding for agricultural efficiency improvements. If these improvements do end up reducing groundwater recharge and subsequently decreasing the water available to downstream rights holder this could open these and other similar agreements up to injury claims by potentially infringed rights holders (Scanga 2007). It is generally accepted that agricultural users face many challenges in adopting efficiency improvements, for example conveyance limits in prior appropriation. Termed "Use it or Lose" the current regulations require an evaluation of historic beneficial consumptive use to establish the amount of withdrawal held during the permanent transfer of a water right. This means that the more water a rights holder puts to beneficial use, the greater the value of their water right when they go

to sell it (Doherty et. Al. 2012). This creates an unfortunate financial motivation for needless waste of water, especially among the most senior rights holders.

On the forefront of legal hurdles is the possibility of curtailment calls under the 1922 Colorado River Compact. The Colorado Compact allows for states in the lower basin to require a curtailment from the upper basin if the rights holders in the lower basin are not receiving adequate water under their allotments. While the compact allotted 15 million-acre-feet in total, 7.5 million to each basin, tree-ring data suggests that the average flow of the Colorado River is much lower than what was originally appropriated (Colorado River Governance Initiative 2011). For example, USGS records indicate that the average flow for the Colorado River at Lee's Ferry, accounting for upstream consumptive use, was just 9.4 million-acre-feet for the period from 2000 to 2002 (USGS 2004). Considering that the compact was likely allocated during an unusually high flow year, even a small drought under modern growth and increased use scenarios could pose a problem. Whether or not the Upper Basin states would be required to deliver the allocated 7.5 million-acre-feet at the loss of the their own water use is another unanswered question. If there is such a requirement under the compact the available water for upper basin states can only be expected to decrease considering the current drought and increased water use in many of the lower basin states. Researchers have suggested that there is no other way to allocate the water that would allow both basins to keep their historic water availability indefinitely given present conditions let alone under proposed climate change and growth scenarios (Colorado River Governance Initiative 2013). The cost and ambiguity in potential litigation from a compact call motivated by inadequate deliveries to the lower basin under extreme

low flow conditions is yet another hurdle to reforms under the compact as it exists or refining current regulations to improve resilience in the shifting climate.

Also, contributing to the uncertainty is the lack of recorded "Present Perfected Rights" (PPR) in the upper basin of the Colorado River (Colorado River Governance Initiative 2011). These rights, which had been established as beneficial at the time of the Colorado River Compact ratification are most senior to all other rights and are not subject to curtailment under the compact. While the PPR's in the lower basin states were identified in a decree following the Supreme Court case Arizona v. California the upper basin remains comparatively unestablished. The Bureau of Reclamation Colorado River Basin Water Supply and Demand Study estimated the total tribal rights allocation on the Colorado River to be about 2.9 million-acre-feet yearly, with much of that likely considered PPR's. While the majority of PPR's are assumed to lie in the lower basin and thus are formally quantified, with specific tribal rights unquantified on the on the Upper Basin, claims of PPRs could pose a significant challenge to future changes, including potential restrictions or reforms of water usage by agricultural rights holders along the upper basin.

Those regions where a significant amount of withdrawal already comes from man-made storage facilities can expect much less of an effect, at least in the near future, on their patterns of water use. Increases in reliance on man-made storage will likely be necessary with current use patterns. With relatively low regulatory and social hurdles when compared to increased efficiency for infrastructure or statutory changes; anxiety about water uncertainty will very likely motivate governing bodies to increase the rate they approve and fund storage projects, regardless of their effectiveness as a long-term solution. The recent drafts of the Colorado state water plan mention furthering water conservation

and reuse goals; but make a special focus on increasing existing projects like mountain reservoirs and storage, which would help replace some of the storage lost from shifts in snowmelt. The plan draft hopes that increasing current multi-use storage can help smooth some of the shift and uncertainty resulting from anticipated gaps in supply and demand along the basin, but regulators do not explicitly consider climate driven effects. The plans focus on demand management through conservation and reuse is admirable, but still fails to really consider more systematic efficiency problems or provide thoughts beyond existing local efforts. While much of this water could be held in man-made storage projects, there is still the potential for increased storage loss from evaporation with the increasing temperatures due to climate change. Researchers have shown that evaporation is a major driver of water loss from storage in lakes and reservoirs that can only be expected to increase given climate warming trends (Finch et. Al. 2008). While there are many technological solutions, one that is particularly promising is managed aquifer recharge. Managed aquifer recharge involves refilling depleted aquifers with organized conveyances to be recovered for later withdrawals (EPA). In Arizona, under the Tonopah Desert Recharge Project attempts at using aquifer recharge as storage have proved successful (Buss 2011). Especially in Colorado geographic placement and extent of aquifers limits the extent to which recharge practices can work as a successful solution. The effective use of managed aquifer recharge is highly location dependent and requires a better evaluation of the technical and legal limitations to be considered a wide scale solution, but may very well prove to be a significant asset in new storage projects.

Increasing man-made storage options, even in high mountain areas still fails to address how the current regulatory system will respond to hydrological shifts. While

proposals to increase reservoir storage could be generally expected to face less opposition than alternatives depending on time and place, there could still be potential legal action and consequences if rights holders are afraid that the project is impacting their ability to withdraw water. Recreation and conservation groups may have a problem with increased storage that affects certain flow timing. Situations such as this and other concerns pose additional challenges in understanding how and when water will be released from the likely increasing storage projects. This uncertainty illustrates how little has been done in addressing how the legal system will accommodate challenges to what may be necessary measures to address water availability in the future.

With the greater loss of available water to agricultural users and the increased demand of municipal water requirements, instream diversions and conservation easements will become even more important and less attainable. Much of the minimum flows supported by research for ecological health may no longer be feasible in the changing system. Instream diversions held by the Colorado Water Conservation Board protect flow levels for habitat of threatened and endangered species along with recreational interests and use. On the Colorado River native fish species such as the Cutthroat Trout rely on traditional flow characteristics for reproduction and habitat formation (Center for biological Diversity 1999). Already habitat fragmentation from heavily reduced flow areas created by diversions has caused the Colorado River Cutthroat to occupy a fraction of its historic range (Wyoming Game and Fish Department 2010). On top of that, an increasing reliance on manmade storage will very likely further disrupt and fragment cutthroat habitat along the Colorado River and its tributaries. Some alternative strategies exist besides instream diversions owned by the CWCB to address ecological health of species in

river and stream ecosystems. Off-stream diversions can provide habitat and spawning areas for fish, especially in areas where existing fragmentation is a dominant problem. Off-channel diversions involve appropriating water in existing agricultural diversion infrastructure for ecological and recreational beneficial uses. The water right is non-consumptive and the majority of the flow returns to the river downstream (Browning 2004). Older ranch properties can be converted to ecological and recreational areas that improve fish habitat quality by increasing spawning and survival of juvenile fish (Zeeley et. Al. 1996).

Current flow characteristics make it difficult to meet established flow requirements; especially in the fall after most of the snowmelt driven flow is exhausted (Yampa-White-Green Basin Implementation Plan 2014). The expected pattern of climate driven hydrological shifts can only exacerbate existing shortfalls. The effects of curtailment on in-stream diversions could be highly location specific. If users upstream of the diversions are required to restrict use for rights holders lower down the river the minimum flow requirements may be more easily met as a side effect. However, as more water is transferred to municipal uses, and a greater amount of withdrawal comes from manmade storage projects in-stream conservation and recreational diversion may be at a greater risk.

From interviews with experts, to evaluate the state of the contemporary discussion on water regulation it seems that there is little attention paid to the effects of climate change on current and future water policy. The existing path appears to be towards increasing storage projects without addressing potential issues such as evaporation or release timing. Many discussions that look at alternative strategies for temporary transfer such as fallowing and efficiency improvements also ignore possible roadblocks from

climate driven hydrological shifts. Finally, the increasing difficulty of meeting instream diversion flow targets, and potential problems with threatened and endangered species in stream ecosystems only focus on warming based change in passing.

Explaining this sense of avoidance is difficult, but it doesn't appear intentional or organized. Instead it may likely be in part because climate change can be a polarizing political topic in the already incredibly tense water policy discussions. Further, while it is a looming reality, warming can appear somewhat ancillary to more exigent concerns of government and other organizations becoming set aside for later.

Much of the literature concerning climate shifts in hydrology on water rights looks at one particular aspect. Some publications, such as the Colorado River Basin Demand Study or some of the publications by the Colorado River Governance Initiative look at a broader range of issues and scenarios. For the most part however, publications are primarily concerned with issues from increased use, for example the state's draft water plan, and not necessarily hydrological shifts. The paper "Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation" produced by the Western Water Assessment provides a significantly more in depth review of the existing scientific data and models concerning climate change on water than the overview in the introduction of this paper. They address a number of scales and scenarios in the context of warming and identify many potential supply gaps possible for the future with existing infrastructure. Western Water Assessment's publication offers an extensive and detailed look at how warming can be expected to increase uncertainty in nearly all aspects of the hydrological system, including established storage and supply frameworks.

Interviews

In interviewing water related academics and professionals to identify the major themes in contemporary policy discussion, the primary strategy did not involve a standardized survey or set of questions for each individual. Rather, the process was more conversational based on the interests and expertize of those interviewed. People were identified for questions by their professional and academic experience in the areas of water policy and by recommendation from other participants in the water policy realm. After initially contacting them through email if the potential interviewee had time a brief phone or in-person conversation would be scheduled. While there was no set script for the conversations a number of the same questions were posed to multiple experts, such as how the value of senior rights might be affected by climate shifts, which received a wide variety of different responses. Other questions like those concerning the primary written sources of information looking at the effects of these shifts on instream flow programs yielded similar information, or sometimes absence of, from experts interviewed. Many of the themes and conclusions drawn in this paper are from the notes in which those conversations resulted.

The change in value of more traditionally senior water rights compared to junior rights along the lines of recreational and instream diversions was a common topic that came up throughout the conversations. In particular several people felt that the junior rights holders might find their water rights more valuable following climate change driven shifts because agricultural users would have a harder time making traditional withdrawals when peak flows are shifted earlier. Climate Researcher Brad Udall felt that climate change driven shifts had the potential to flip some of the relative value of junior and senior rights

without significant adaptation (B. Udall, personal communication. October 31, 2014). State Engineer Dick Wolfe felt similarly, that it was possible instream rights could benefit if traditional withdrawals couldn't be maintained with the shifting hydrology (D. Wolfe, personal communication, October 28, 2014). On the other hand some people like water attorney Ramsey Kropf suggested that water rights of senior holders would become that much more valuable following difficulties introduced by earlier snowmelt flows (R. Kropf, personal communication. November 7, 2014).

Everybody I spoke with mentioned the possibility and problems of dealing with a compact call to Colorado. This appears to be one of the more prominent concerns, motivated as much by expectations of increased use as well as climate change driven effects. In suggesting that senior rights may be more important following climate shifts, Ramsey Kropf indicated that the threat of compact call would be large part of why (R. Kropf, personal communication. November 7, 2014). Considering the lack of previous experience dealing with a major compact call to the upper basin, the exact reaction rights holders and administration was a common area of uncertainty. Almost everyone seemed concerned more with avoiding a compact call than addressing how best to react to one however.

As one might expect, most people I spoke with, like EDF attorney Aaron Citron, felt that increases in man-made storage were inevitable (A. Citron, personal communication. October 1, 2014). There was a generally awareness that increases in infrastructure would likely have to be incremental as larger scale projects would be unfeasible in many cases. Water attorney Ramsey Kropf seemed to feel that while more storage would be likely that large-scale projects would be much less feasible (R. Kropf, personal communication,

November 7, 2014). Solutions such as increasing existing dam heights in some places or extending reservoir storage were possible solutions State Engineer Dick Wolfe suggested administrations and the public might consider (D. Wolfe, personal communication, October 28, 2014).

One particular subject that seemed to be relatively unevaluated was the growing role of evaporation in loss from the storage. While several people interviewed emphasized the role of seepage in diversion inefficiency, with recognition to the importance of seepage derived return flows for downstream withdrawals, even those that considered it a factor did not think that evaporation was playing a major role in transfer or storage water loss.

Water banks were another major topic that most interviewed seemed on the same page. Many, such as Aaron Citron with the EDF believed that forbearance agreements and water banks would become increasingly useful tools moving forward (A. Citron, personal communication. October 1, 2014). People were aware of previous attempt and current activity in the water banking realm as a promising, if not necessary, movement forward. Some, such as Colorado Law Professor Mark Squillace have been exploring different aspects and strategies of both permanent and temporary transfers through possible policy that could succeed in Colorado (M. Squillace, personal communication. September 12, 2014).

Several other unique points came up throughout the interviews. Engineer Dick Wolfe mentioned that changes in returns flows from shifting hydrology, not just snowmelt, could become an increasingly problematic factor as well. He was also aware that there may have to be greater changes in consumption at most levels to accommodate climate effects (D. Wolfe, personal communication, October 28, 2014). Aaron Citron also indicated there

may be an increased involvement of NGO's and others outside the public sector in better facilitating the necessary shifts in the face of warming (A. Citron, personal communication. October 1, 2014). Finally, Climate Researcher Brad Udall thought that very few experts had considered in depth the implications of climate change on prior appropriation and water policy in the western United States (B. Udall, personal communication. October 31, 2014).

Conclusion

My initial curiosity in looking at this topic came from the lack of information I had seen about the specifics of water allocation in general, and a curiosity as to how institutions and organizations were reacting to some of the science I had studied in my various hydrology and climate courses. After investigating a number of water basins focused in the state of Colorado, the importance of the Colorado River became increasingly obvious as an ideal area of study. Additionally, the lack of a consensus on climate driven effects to policy as well as an appropriate reaction was another reason to approach the Colorado River from this angle.

Much of the literature and discussion on climate driven effects focused on the potential of shortages to incite a compact call. How Colorado would be required to respond to such an event was well consider despite the lack of a conclusive answer among experts. The Compact looms in the forefront of any discussion on the future of water policy, with little to address the immediate uncertainty. Few had addressed exactly how agriculture and municipalities might adjust consumption in the face hydrological shifts, if they considered an adjustment to consumption at all.

The most prominent issues in moving forward the discussion on water policy appear to be taking a better look at how storage will be managed in the future, giving greater consideration to the role evaporation will play in storage efficiency with increased warming, and considering the problems with conservation and ecological sustainability that require water rights.

While many people are proponents of implementing different water bank strategies, how the increased storage will be managed to accommodate the withdrawal habits of existing users is an area that could benefit from greater evaluation. Physical storage to replace storage lost as snowmelt is another institutionally controlled aspect of the withdrawal system that could be a target for and give rise to new disputes. When there are more direct ways to release water via man-made storage, injury disputes may seem more attractive to some individuals given the more tangible volume of water potentially available. Investigation into how possible federal intervention for PPR's or Endangered Species Act issues may change man-made storage management is also an area worth considering. The role of groundwater recharge from diversion seepage, and the importance of return flows in providing adequate water for withdrawal downstream adds an additional layer of complication to allocating water from controllable storage in a way that allows the most efficient use and reduces conflict. Water banks and temporary transfer strategies will likely go hand-in-hand with increases in man made storage, making the management of these structures even more important in allowing flexible water use strategies in the future. Policy concerning water banks and storage management should keep in mind the necessary interdependence of the two; hopefully towards a regulatory structure that is mutually beneficial to both programs.

Much of the uncertainty in developing policy and legal systems around the release of man-made storage and the development of temporary and permanent water bank transfers is the fear of, and cost that injury disputes can put on transfers. Even seemingly uncontroversial transfers can face significant opposition depending on time and region they are proposed. It appears obvious that reducing the uncertainty of where and how much of a specific water right is held, along with what reasonable permanent and short-term transfer options could be available, will need to be addressed to prevent a gridlock in the management of future release and transfer practices. There are many strategies for approaching this, as the literature and experts have suggested, what is most imperative is allowing some type changes to be implemented to move forward. This will be important in the viability of short-term measures such as rotational fallowing agreements, or transfers in exchange for efficiency improvements. Instituting even temporary policy changes to allow programs like this to move forward could provide a helpful and immediate advances in increasing the efficiency of major sections of agricultural water use.

Despite its major role in the hydrological cycle and the scientific evidence suggesting evaporation is only likely to increase, policy discussions have generally ignored addressing the role of evaporation in current and future storage. Additional forms of storage, and strategies to mitigate water loss from evaporation in existing reservoirs would seem a highly relevant area of inquiry. There are many technologies that exist in addition to programs like managed aquifer recharge. Identifying the most financially and political feasible would make it that much easier and more affordable when more widespread adoption may become necessary. Its seems hard to imagine creating more storage, or allowing additional diversion infrastructure, without placing attainable requirements, and

providing affordable means to manage impending inefficiencies in an era of already scarce water. Encouraging current storage project proposals to consider the future need for greater evaporation management could save a lot of expense and trouble for the long-term efficiency of new man-made storage projects and existing infrastructure increases.

Conservation focused instream diversions, as well as other private means, such as off stream habitat, towards the maintenance of recreational areas and wildlife habitat should be looked at in greater detail. It may become increasingly hard to secure water that meets instream requirements and alternative strategies may be necessary to augment existing policy to provide for adequate conservation of habitat quality and recreational opportunities. The immense variety and quality of recreation and environment based outdoor opportunities available to residents and tourist alike is one of the exceptional and unique strengths of Colorado. Policy and future legal frameworks must consider the value of these qualities beyond their immediate economic contributions, and look at what often-irreplaceable ecosystems and locales will continue to contribute to Colorado. Conservation can often be a thorny subject, and may be thrown aside when stakeholders are fearful of a shortage of water for municipal or agricultural use. That makes forward planning all the more important for conservation and ecological sustainability; there are many areas that already cannot afford any less water to maintain ecosystem health. Considering what this may mean for wildlife populations in the future, and looking for novel strategies to address shortages in ecosystems, will be an important and necessary aspect of conservation efforts in the face of increased warming.

It is especially important that all facets of water rights users consider how they might alter their consumption patterns to accommodate changes produced by warming. It

seems as if there is an assumption that technological means will be immediately present to prevent disruption caused by changes in hydrology. While it should hopefully be the goal that improvements to infrastructure and changes to policy will help minimize the impacts of warming, the habits of users themselves cannot be ignored. Agriculture, municipalities, and industry will need to consider what about their use could change; whether it is seasonality, services they prioritize, how water is accessed, and of course how much is necessary. Anticipating some form of response to impending shifts will allow better understanding both of what infrastructure and policy improvements will most address future needs, as well as how we will all interact with and use water within the changing systems.

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