AN ANALYSIS OF ALTERNATIVES FOR WATER DISTRIBUTION BETWEEN MUNICIPAL AND AGRICULTURAL USERS OF COLORADO RIVER WATER

A THESIS

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Abstract:

The Colorado River is often referred to as the "lifeblood" of the American Southwest, as it sustains rapidly growing cities, feeds millions of agricultural acres, and forms some of the world's most incredible natural features. The Colorado River is also one of the most highly dammed, diverted, and otherwise regulated rivers in the world. In the last few decades, the demands on the flows of this river have begun to exceed its supply, which is threatened not merely by over-allocation but also by drought and climatic uncertainties. The river's dwindling supplies are no longer enough to support the Southwest's rapid population growth in municipal areas while simultaneously answering to the demands of the more senior water rights holders, the agriculturalists. This thesis is an exploration of the current contentions between agricultural and municipal users of Colorado River water, with a focus on the alternatives available to address these ongoing issues. Of many options, including increased infrastructure and various conservation measures, water banking has been identified as the strategy most socially, economically, and environmentally qualified to address these pervasive imbalances in water supply and demand of the Colorado River.

Chapter 1: Introduction

The Colorado River is one of the most highly dammed, diverted, and otherwise regulated rivers in the world. Located in the southwest United States, it has long been a critical force sustaining life in the most arid region of the country. The Homestead and Mining acts of the late 1800s set a precedent for "beneficial" water use in the West being defined as diversion and storage, bringing multitudes of settlers into what was previously considered a remote, inhospitable region. Population has boomed and development has raced ahead at lightning speed since these first pioneers established Westernized living in the West, so much so that the Colorado River is today over-allocated.

The "face" of the river has been drastically altered, for better and for worse, from its historical variability and wildness to its present condition which some refer to as a giant plumbing system for use by our societies. Compounded by recent drought, this means that demand is dangerously close to overtaking supply on the river. Early 2011 brought a brief respite, with the most snow and subsequent highest flows of the river since the drought began in 2001, buying a little more time before shortages become severe.

Yet as population and municipal demands for water continue to increase rapidly, future supplies of the river are under serious threat, even without the projected impacts of climate change. Competing users and interests are stretching supplies thin from many directions, while simultaneously looking for new and innovative ways to get more water. Now we face the question, is consumptive use of the Colorado River a zero sum game, where one user impedes and cancels out another? Or can efforts from all sides be made to reduce total consumption, improve efficiency of use and secure a sustainable future for both humans and the environment in the Colorado River Basin?

Research centered on these issues plaguing the Colorado River Basin facilitates analysis about the allocation of water between the Colorado River's two biggest users, agriculture and municipalities. The crisis of water distribution on the Colorado River is one of, if not the most, pressing issue on the river today. The hypothesis to be explored and supported is that the method of water-sharing in the Colorado River Basin involving "buy and dry," in which agricultural lands and subsequent water rights are purchased for use by municipalities (and these lands are no longer used for growing crops), involves less desirable outcomes to society than other potential alternatives.

This issue of water re-distribution is of critical importance because it affects the future of *everyone* using Colorado River water. Historical animosity and contentions aside, we are at a time in the west in which the finite limits of available water are finally being recognized and even accepted. If we want all existing uses to survive, it is imperative that *all* stakeholders work cooperatively towards finding the most economically, environmentally, and socially sound solution to the river's growing supply and demand imbalance.

This thesis intends to address this issue by providing a thorough background on water use by both agricultural and municipal water users, and ending with an analysis of available alternatives. Chapter two addresses water's role in the development of the west in the past, as well as the current situation (including the supply and demand imbalance) in and around the basin today. Chapter three deals specifically with storage and diversion of the Colorado River, with a review of the river's major infrastructure and its varying functions. Chapter four focuses on agricultural water use, including the structure and distribution of agricultural water rights, infrastructure in the basin that is specific to agriculture, and the economic and social aspects of agriculture irrigated by the Colorado River. Chapter five carries out the same focus for municipalities, including an additional discussion on the growing populations in and outside of the basin that are increasing the demand for municipal water. Finally, chapter six analyzes potential solutions for water re-distribution, including conservation, reuse, and the creation of robust water markets in the Colorado River basin, the latter of which are identified as the most economically, environmentally, and socially agreeable alternative.

Chapter 2: Hydrology for Human Use: Past, Present, and Future

History of the West: Water's Role in Development

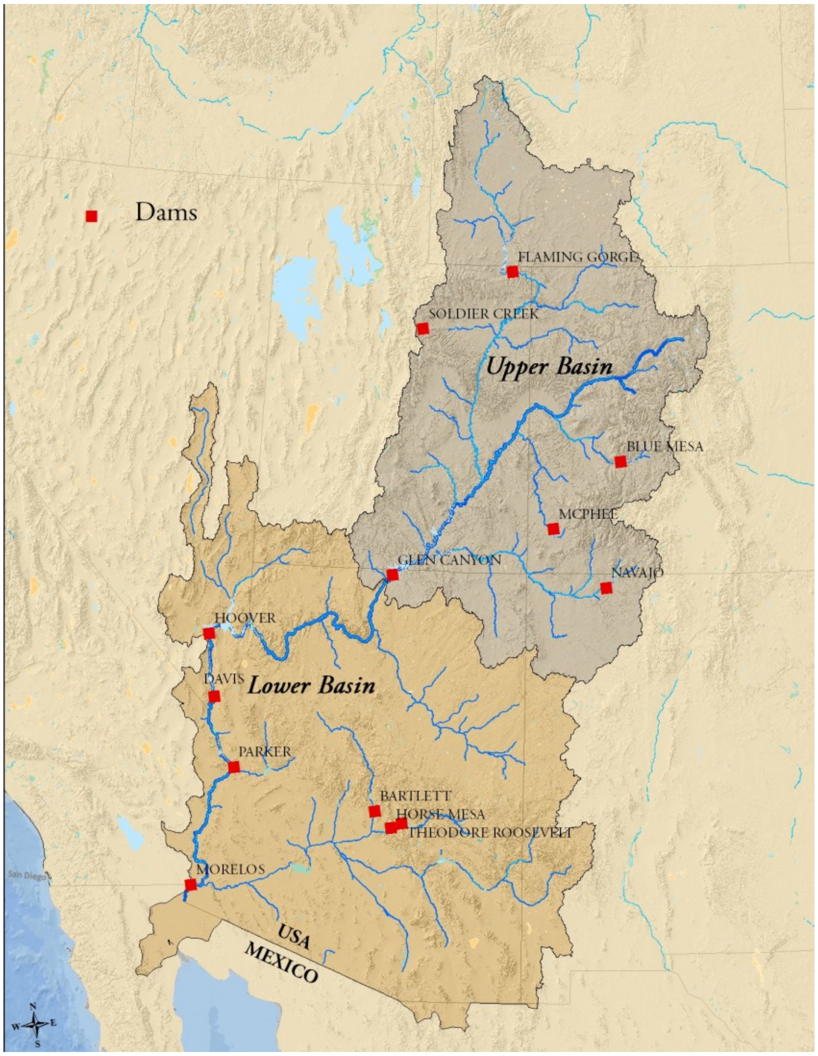

Figure 1, Map of the Colorado River Basin. Source: State of the Rockies Project 2012

When John Wesley Powell first explored the Colorado River in 1869, the water ran fast, high and muddy through pristine canyons such as the Grand. Today, many of these same stretches of river are clear and cold due to the construction of dams, and host lower flows because of upstream diversions. The river has changed immensely since Powell first charted its waters, in physical characteristics, environmental impacts and its role in human society.

Once the Homestead Act was signed by Abraham Lincoln in 1862, the West was opened up for further settlement by westward-migrating populations as legally, land and water became more readily available. Following this was the General Mining Act of 1872, which allowed miners to stake a claim and, if valuable minerals were found, to purchase land for either $2.50 or $5.00 an acre. Because these two pieces of legislation also required water for their success, the system of prior appropriation and Western water law spread. Once all the best alluvial lands were claimed, the government passed the Enlarged Homestead Act in 1909 that was more conducive to dryland farming and gave homesteaders double the acreage because of lower land quality.[1] All of these acts only encouraged plentiful water use, as irrigation and small diversions became increasingly commonplace to support agriculture, and a precedent for western water consumption was set.

With the influx of people to the western US, population centers in and adjacent to the Colorado River Basin began to grow and transportation became increasingly key to a successful western economic system. Towns that became stops along the railroad often prospered disproportionately, Las Vegas being a perfect example. Established around 1905, the springs in Las Vegas allowed it to be a sort of oasis in the desert, one that settlers in small but growing numbers believed would become an agricultural paradise. The prior abundance of water in this now bone-dry city, which today survives entirely on water imported from the Colorado River, is what originally allowed it to grow into a booming metropolis.[2]

Figure 1 displays a comprehensive outline of the Colorado River Basin. The river and its tributaries are present, and the darker center and lighter outside shading surrounding the river line indicate periods of low and high flow, respectively. The major dams along the river are indicated by a red square, the major pipelines are indicated by red lines, and major diversions as well as amount of water diverted are indicated by turquoise lines of varying thickness. Locations receiving diversions of water out of the basin, called transbasin diversions, are evidenced by red cross-hatching. This map provides a beginning idea of the layout of the river, as well as how and where Colorado River water is transported for use.

The Bureau of Reclamation was established in 1902, in part to begin what is today a legacy of damming, diverting, and otherwise managing the Colorado River. It dove right in to project creation in the basin, allowing for increased homesteading and western economic development.[3] Once it became clear that settlements in the west were not only permanent but growing and demanding increasing water, the need for legal water allocations was recognized. In 1922, the Colorado River Compact was created, dividing the Basin into Upper and Lower regions and creating water delivery requirements for each.

With delivery requirements now in place, it became necessary to create means by which to store and control water past minimal irrigation diversions. The Hoover Dam was constructed between 1931 and 1936 during the Great Depression, and was at the time the largest manmade structure after the Great Wall of China.[4] Its construction controlled floods, provided irrigation water, allowed for hydroelectric power production, and created Lake Mead, which increased water security by providing a more reliable source of multi-year water. Following the construction of Hoover Dam came many more large-scale projects to store and move water, especially the construction of Glen Canyon Dam and its corresponding reservoir, Lake Powell, in 1966. Glen Canyon Dam allowed for increased development of the Upper Basin, as Hoover had allowed for the Lower Basin. These projects were accompanied by the growing concept of "water buffaloes," those water managers who were adamant about obtaining increasing amounts of water in order to maintain a high rate of economic and human development in the West.

The 1922 Compact divided water use by Upper and Lower Basins, apportioning a flow of 15.0 maf that was assumed to be the Colorado River's average flow. Unfortunately, 1922 fell in the wettest ten-year period in the century of recorded Colorado River flow history (1914-1923), and as such may have greatly overestimated the actual average flows of the river over decades.[5] This over-estimation, coupled with the attitude of assumed abundance of western water based on historical rates of consumption, presents a difficulty today as regional populations grow and expected flows decrease. The Boulder Canyon Act of 1928 divided up the Lower Basin's apportionment by state, while the Upper Colorado River Basin Compact of 1948 designated apportionments for Upper Basin states. Figure 2 shows the amounts of water apportioned to each basin state.

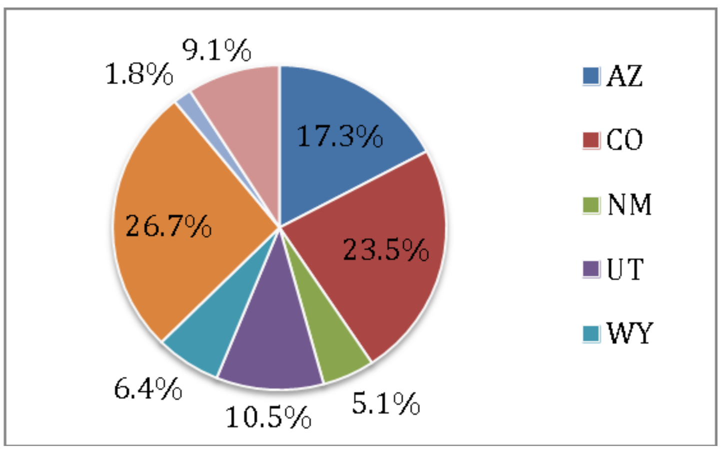

Figure 2, Water Apportionment by State. Source: Dale Pontius and SWCA, Inc. Environmental Consultants, "Colorado River Basin Study: Final Report," Report to the Western Water Policy Review Advisory Commission, 1997.

In 2000, the Colorado River basin entered a period of severe drought in which the region experienced reduced precipitation and reduced river flows. Droughts are generally multi-year cycles, and this drought has continued through the present day.[6] This cycle mandated the creation of the Interim Shortage Guidelines in 2007 in order to guide re-apportionment in a time of severe decreased flows. All Lower Basin states apart from California will accept reduced deliveries pending severity of flow reduction if the guidelines are enforced, and California is being strictly held to its 4.4 maf apportionment (which has not always been the case in the past).[7] This roughly translates into cutbacks mostly in municipal water use, with a less severe decline (if any) in water available for irrigated agriculture based on seniority of water rights.

As this drought continues, water storage levels have been hard hit as users continue to withdraw water for various uses at rates faster than replenishment. In October 2010, Lake Mead reached a historic low of 1,083 feet above sea level; operations of the first intake station fail at a water elevation of 1,050 and below.[8] So far, 2011 has been the wettest year since the drought began in 2000, and Lake Mead has risen to 1,107 feet. One wet year does not end a drought, however, and the bottom line is that historic flows are changing. In retrospect it is proving harmful to existing and promised future human uses as well as environments dependent upon in-stream flows that annual water in the Basin was overestimated when the Compact was created in 1922. The only consistent characteristic in flows of the Colorado River is variability, a phenomenon that Colorado River water users have historically tried to accommodate with multi-year storage, but to which humans and nature may soon be forced to adapt.

Water Supply and Demand: Trying to Make the Ends Meet

In order to understand the water supply of the Basin, it is necessary to compare Colorado River supplies to those of other life-sustaining waters around the world. The Mississippi River is the fifth-largest river in the world by volume, with an average annual flow rate between 200,000 and 700,000 cubic feet per second (cfs). This is still only a fraction (usually around 9%) of the Amazon River, which experiences average annual flows around seven *million* cfs.[9] By contrast, the Colorado River had an average annual peak flow of 85,000 cfs before the construction of

Hoover and Glen Canyon Dams, with tree ring analysis indicating a high of 250,000 cfs reached on a few occasions in the last 4,000 years. With the dams on the Colorado River in place today, average annual flows above Glen Canyon Dam are closer to 50,000 cfs, and sometimes as low as 30,000 cfs.[10]

The ways in which we use these limited flows in the southwest U.S. have varied throughout time, but always involve a strong agricultural emphasis. This is due in part to historical trends, as well as a climate in the Lower Basin that is highly conducive to winter crop growth. Agricultural use of Colorado River water today hovers around 80% of the river's total supply, whereas cities (municipal and industrial use) use is closer to 15% of the total. While today trends are such that irrigated acreage in the basin is declining while municipal demands are increasing, water allotment has not yet shifted to reflect this. Note in Figure 3,[11] which displays a breakdown of different water uses globally, that the percentage of water dedicated to agriculture in the arid southwest is higher than the global average.

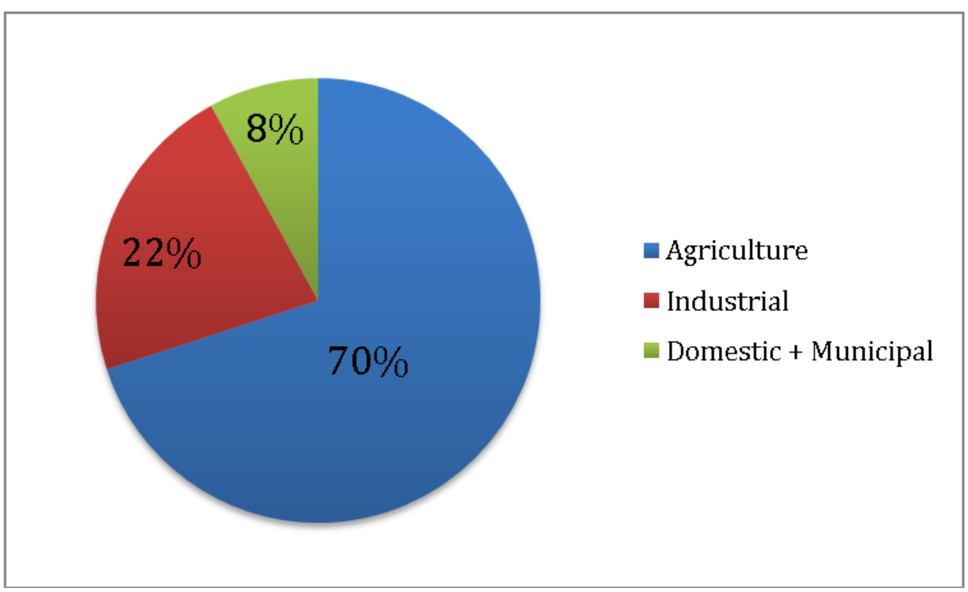

Figure 3, Water Use Breakdown Global Average. Source: Glen Canyon Dam Visitor's Center 2011.

The major stress in the system today is coming from these expanding municipal demands, created by rapid population growth. The numbers are startlingly simple; the basin and its outside service population, now nearing 30 million, are massive compared to the past, and flows are either plateauing or decreasing. With efforts made to conserve water or reduce demand still not enough to have a significant impact, this situation will lead to serious overapportionment and shortages. Figure 4, from a recent report by the Colorado River Governance Initiative (CRGI) takes the standard U.S. Bureau of Reclamation supply and demand graph and extends the imbalance projection to the year 2058 with a no-significant-behavior-change scenario.[12] This projection is impossible in actuality for a finite resource such as the Colorado, and will require adaptation.

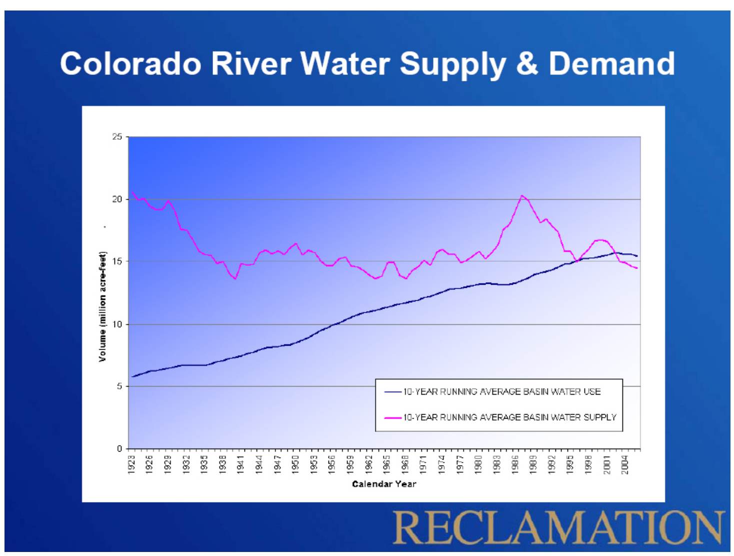

Figure 4, Supply and Demand Graph. Source: US Bureau of Reclamation, 2011.

Timing is also an issue in the overapportionment of the Colorado River, as increasing numbers of previously marginalized water rights are being recognized. While legally sound, this presents an issue for the already fully-apportioned Colorado River. The 1908 Supreme Court case *Winters vs. US* asserted that reservations have federally reserved implicit water rights (enough to fulfill the "purpose" of the reservation, often agriculture), whose priority dates back to the time of that reservation's establishment.[13] This was a step forward for Native American water rights, but today the issue is that the actual amount allotted to many reservations remains to be quantified, which can only occur through either settlement or negotiation processes. The river is already over-allotted, and adding "new" water users to this imbalanced demand equation will only further stress the limited supplies of the Colorado River.[14]

The failure of the U.S. to assert and protect Native American tribes' water rights, as well as the delay in recognizing instream flows for National Parks and other public lands as a priority, has caused tension as previously senior water rights holders are trumped by these groups. Junior water rights holders experience a further squeeze when these water rights are litigated and claimed, as even with increasing numbers of competing demands there is still only a finite supply of Colorado River water annually and over multi-year periods.

Basin State	**1971-1975 average per year**	**1996-2000 average per year**	**2006-2010 average per year (Upper Basin only)**
Arizona	5.18 maf	4.83 maf	no data
California	5.19 maf	5.14 maf	no data
Colorado	1.73 maf	2.06 maf	2.14 maf

Nevada	0.15 maf	0.39 maf	no data
New Mexico	0.27 maf	0.41 maf	0.42 maf
Utah	0.80 maf	0.94 maf	0.84 maf
Wyoming	0.32 maf	0.43 maf	0.42 maf
Water to Mexico	1.63 maf	2.91 maf	no data
Total	17.3 maf	19.1 maf	no data

Figure 5, Consumptive Water Use by State, 1970-1975, 1996-2000. Source: US Bureau of Reclamation Consumptive Use Reports.

With the passage of the Interim Shortage Guidelines in 2007, the belt around water use is tightening. States, especially the historically larger water users in the Lower Basin, are being more closely held to their allotted water amount, which can be seen in Figure 5. One example of this is California, which prior to the shortage requirements was receiving closer to 5.6 maf annually as opposed to its allotted 4.4 maf. This was due in part to its location as one of the last downstream users, allowing them temporarily to take up the extras not consumed by the Upper Basin. It is also feasible because reclamation projects to help the upper basin states store and use their shares have been eclipsed by society's changing attitudes towards major dams as well as severe budget limitations. In spite of this, it has come to the point where Lower Basin demands can only be met if the Upper Basin begins to release amounts beyond the obligations of the Compact.[15] Furthermore, the CRGI reports that demands on the Colorado River system as a whole now likely exceed long-term supplies, even without drought conditions.[16]

Users of Colorado River water (be they water utilities, project managers, farmers, and more) had a tendency previously to always seek out new supplies through infrastructure creation, as opposed to accepting finite limits and engaging in conservation. This was due in part to the

West's continued stereotype as a remote final frontier, a vision which does not consider the reality of booming metropolises and rapid population growth. One example of a project meant to satisfy growing municipal demand is in Las Vegas, where a $1.5 billion dollar pipeline has been proposed. The pipeline, which is very controversial amongst residents of the affected areas, would tap into the groundwaters of various basins north of the city.

Some projects are more ecologically and monetarily feasible than others. One "wild" water supplement suggestion has been to create a pipeline drawing water to the arid west all the way from the Mississippi River basin, something that most consider damaging and hugely costly. Limits to growth in the American West are unappealing in a region of the country that is considered a newer economy, still rising to its full potential. Growing cities desire a reliable water supply for secure support, the antithesis of setting limits. As a result those depending upon water in the Colorado River Basin display path-dependency, desiring to continue unconstrained growth with little to no limits on water. Reality confronts illusion in the current complex situation of existing demand outsripping supply; actions taken now to balance supply and demand will dictate the future withdrawal and in-stream water uses of the Colorado River.

In the past, the go-to solution has been further infrastructure development. This is evidenced by the overwhelming number of dams, diversions, and storage projects that currently contain and dictate the flows of the Colorado River. The next chapter describes the history and use of some of the major infrastructure inside and outside of the Basin.

Chapter 3: Storage and Diversions of the Colorado River

A History of Defying Nature to Optimize the River's Supply over Space and Time

For better or worse, water flowing through the Colorado River no longer reaches the sea at the Gulf of California. This is due to the massive amounts of infrastructure installed on the river, to control its flows for human "beneficial use" as dictated by the 1922 Compact. Beneficial use is defined by the U.S. Bureau of Reclamation (BOR) as "the consumption of water brought about by human endeavors," which includes water for "municipal, industrial, agricultural, power generation, export, recreation, fish and wildlife, etc., along with the associated losses incidental to these uses."[17] Beneficial uses were previously recognized only as those which were directly beneficial to humans, such as agriculture, municipal and industrial use, hydropower generation, and export. This also means that even evaporation from reservoirs is considered an acceptable use because it is associated with a beneficial human use of the same water, saving it as a reliable water source.

Little consideration historically has been given to the idea of leaving water in the river for environmental or recreational purposes. This is more a result of rapid development and previously plentiful supplies than it is an example of hostile neglect. Obvious shortages, changing climatic conditions, and increasing instances of threatened and endangered species have forced a review of what uses constitute "beneficial," if not purely human. While most users understand what qualitatively constitutes beneficial use, the BOR recognizes that "an inability to exactly *quantify* these uses has led to various differences of opinion."[18]

Furthermore, a beneficial use may be classified as consumptive or non-consumptive based on the nature of water use. If the water is "consumed" in the sense that it cannot be returned to the system in any worthwhile manner, the use is considered consumptive. Examples of this include much of irrigated agriculture (although there are some return flows if the water can be treated) or certain municipal uses such as lawn-watering and air conditioning. Other uses, such as many uses in buildings (sinks, showers, etc.), are considered non-consumptive because they allow water to be returned to a wastewater treatment plant. From there, it can be treated and returned to the river, where it can generally be re-used by downstream water rights holders.[19]

The Colorado River has long been diverted for use by individual farmers, miners, and other small scale uses. In 1902, Congress and President Theodore Roosevelt created the BOR by enacting the Reclamation Act, authorizing the study of irrigation needs as well as the construction of dams throughout the U.S. A canal system was already in place in parts of the Colorado River basin at this time, but it was old and dilapidated. In 1905, high floods broke through one head gate near the Imperial Valley, which flooded the region and recreated the Salton Sea.

Under the Reclamation Act, the 1928 Boulder Canyon Project Act ushered in the age of large-scale infrastructure construction on the Colorado River by authorizing the construction of the Hoover Dam and the All-American Canal. The construction of Parker Dam in 1938 created Lake Havasu and allowed water storage for southern California, and Glen Canyon Dam's completion in 1963 created increased storage for the Upper Basin.[20]

Each dam, reservoir, pipeline and canal, on the Colorado River has a different story behind the reasons for its construction, but the underlying theme is increased control of an otherwise hugely variable natural-flow resource. There are over 20 major dams on the Colorado. Considerably more are in the Upper Basin, but the ones located in the Lower Basin are much larger.[21] Many have associated reservoirs, as well, which at a most basic level not only protect against damaging floods but allow for water security by having a reliable water source even in times of drought.[22]

Dams and Reservoirs

The first major dam built on the Colorado River was the Hoover Dam, finished in 1936 and located in the Black Canyon between Arizona and Nevada. Apart from fulfilling the needs for flood control and electric power generation, Hoover's construction created Lake Mead, supplying irrigation water to the 1942 All-American Canal. Lake Mead has a total storage capacity nearing 28.5 maf when at its highest elevation, 1,229 feet above sea level. Between 1931 and 1963 (when the Glen Canyon Dam was constructed upstream), 91,000 af/year of sediment were deposited behind Hoover Dam in Lake Mead. Had this continued, the life of the reservoir would have been drastically shortened, but Glen Canyon Dam now captures sediment flows and causes the Colorado River to flow mostly cold and clear from Lee's Ferry down to Hoover Dam.[23]

Another concern associated with Lake Mead is a high rate of evaporation, approximately 800,000 af annually, due to its large area (247 square miles) and its location in a hot, dry, arid semi-desert. While originally constructed largely for irrigation purposes, Lake Mead today supplies 90% of Las Vegas' water supplies. According to BOR (the operating agency), 1.5 maf of Lake Mead's storage is reserved for flood control, 2.4 maf for sedimentation control, 15.8 maf for multiple uses (flood control, power, irrigation, municipal and industrial waters), and finally 10 maf for inactive storage.[24] However after ten years of drought, Lake Mead today sits at elevation 1,107 feet, full to only 46% capacity with 11.95 maf of active storage.[25] This is up from 2010's historical low of only 1,083 feet, a concern because hydropower generation fails at elevation 1,050 feet. A study by Scripps Institute of Oceanography in 2008 suggested that there is a 50% risk of Lake Mead running dry by 2021 if water use behaviors do not change, due to the combined impact of climate change, over-apportionment, and evaporation.[26]

While not the next major infrastructure project chronologically, Glen Canyon Dam is second only in size and capacity to Hoover. The dam was completed in 1966, and is located 15 miles upstream of Lee's Ferry in the Upper Basin. Glen Canyon Dam is one of the major parts of the 1956 Colorado River Storage Project, intended to allow increased development of the Upper Basin. The main reason for its construction was to fulfill 1922 Compact requirements that were going unmet because of significant variability in flows from year to year, meaning that the Upper Basin had no way by which to guarantee it was delivering the requisite 7.5 maf to the Lower Basin. With the creation of Lake Powell behind Glen Canyon Dam, the Upper Basin had a mechanism with which to control and store these flows. Glen Canyon Dam also offered a relatively inexpensive way, economically speaking, of generating hydroelectricity.[27] Unfortunately, its construction was highly controversial as it flooded the colorful Glen Canyon and has caused numerous ecological issues.

Lake Powell has a total storage capacity of 27 maf, and as of July 2011 was at 18.34 maf (75% capacity).[28] The lake reached its lowest recorded level in 2005 during the height of the drought, when it was only at 33% capacity. If the lake falls too low for power generation (elevation 3,490; as of July 2011, it was at 3,659 ft) however, water can still be passed through the dam in order to meet Compact requirements. At full capacity, the power plant at Glen Canyon Dam can produce 1,320 megawatts (5 billion kilowatt hours of hydroelectric power per year), which can be sold to support 1.7 million people in the Upper Basin (400,000 households).[29] Loss of this power generation has major implications for human uses of the Basin.

Glen Canyon Dam is considered to be one of the riskier projects built on the Colorado River, due to its role as first flood control station. In 1983, large precipitation and flooding events meant that the lake was above capacity and the dam nearly failed, but opening the spillways prevented catastrophe. Lake Powell is also threatened by sediment build up, as the Colorado is an unusually high-sediment river. It is estimated that about 100 million tons of sediment wind up behind the dam annually (equal to 30,000 dump truck loads daily),[30] and if no dredging actions are taken the lifespan of the reservoir is predicted to be no more than 400 years.[31] Evaporation from Lake Powell is also a serious concern, as it loses an average of 860,000 af annually; this is enough to supply the city of Los Angeles. In fact, Lake Powell loses more than 6% of the Colorado River's annual flow to evaporation, around three times Nevada's entire allotment.[32]

Situated on the Green River, the largest tributary to Colorado, Flaming Gorge Dam is located 32 miles downstream of the Utah-Wyoming border in Utah. The Flaming Gorge Reservoir, created by the dam, backs up some 91 miles into southern Wyoming. Flaming Gorge was also a part of the 1956 Colorado River Storage Project allowing for Upper Basin development, and its waters are used for additional storage in the Upper Basin. The reservoir holds 3.8 maf at full capacity, and is able to generate 151,950 kilowatts of hydroelectric power.[33] Due to the influx of 159% of average precipitation in the Green River basin in 2011, the reservoir is now only four feet below maximum levels and contains 3.59 maf of water.[34]

Moving eastward to Colorado, the Wayne N. Aspinall Unit in Colorado on the Gunnison River is also a large facet of the Colorado River Storage Project. The Aspinall Unit, named for the congressman that was a large advocate for western water resource development, consists of three dams and associated reservoirs. Altogether the unit has a 290,000 kilowatt capacity, or 17% of the Colorado River Storage Project system, and runs for a 40-mile stretch on the Gunnison. The structure the farthest upstream is Blue Mesa Dam, completed in 1966 with the capacity to generate 86,400 kilowatts (30% of Aspinall Unit capacity). The associated Blue Mesa Reservoir is the largest body of water in Colorado and has a storage capacity of 0.94 million acre-feet, with a present active capacity of 0.8 maf. The middle dam is Morrow Point, which is both the largest and most productive of the three with a 173,334 kilowatt generating capacity (60% of the unit's total). The associated reservoir has a smaller storage capacity, at 117,190 af, and is actively storing 113,200 af. The final and smallest dam is Crystal, the last part of the Colorado River Storage Project, which was completed in 1976 with a generating capacity of only 31,500 kilowatts.[35] The Aspinall Unit works as a system to provide power and a reliable water source, and while it has certainly changed the environmental character of the region, it has also allowed for fertile agriculture in a previously fallow region.[36]

In the Lower Basin, 155 miles downstream of Hoover Dam, are Parker Dam and Lake Havasu which straddle the Arizona-California border. The dam was constructed between 1934 and 1938 with the primary intention to create a storage reservoir, and secondarily to generate hydropower. Parker Dam is often referred to as "the deepest dam in the world" because much of its structure (about 85%) is located below the riverbed. Its nameplate generating capacity is 120 megawatts. Lake Havasu is the associated reservoir; with a storage capacity of 646,200 af (the current level is 584,300 af), it is the primary water source both for the Colorado River Aqueduct (bringing water to Los Angeles, San Bernadino, and San Diego counties) and the Central Arizona Project (CAP), making it an incredibly important water source in the desert.[37]

Morelos Dam is the final dam on the Colorado River, located right on the border between Yuma, Arizona and Los Algodones, Mexico. While its eastern part is located in AZ, Mexico is responsible for all of its operations and maintenance, and it is run by the International Boundary and Waters Commission (IBWC). It was completed in 1950, pursuant to the 1944 treaty with Mexico guaranteeing 1.5 maf of Colorado River waters annually. The dam is L-shaped, meaning that the natural flow of the river is stopped and completely diverted, largely (85%) for irrigation purposes in crop-abundant areas such as Mexicali. Morelos is purely for diversion and has no storage component, meaning that at present, there is no way for Mexico to store any water of the Colorado River. If there are excess flows or heavy rain events that cause farmers to cancel orders, this water just flows through the old riverbed,[38] although the Colorado River has not reached the sea (Gulf of Mexico) since 1998.

This brief overview gives a mental outline of where, how, and why the flows of the Colorado River are redirected, usually for human consumptive use. The next section discusses similar infrastructure in the Colorado River Basin intended primarily to provide water for agricultural uses, as well as where this water is used and what purpose it serves economically.

Chapter 4: Colorado River Water Use for Agriculture

Water Rights for Agriculture

Many of the stresses on the Colorado River today arise from competing users. Each stakeholder believes their personal use to be the most important, but prior appropriation dictates which rights are senior and junior. Agricultural users in the basin hold rights of the highest priority, and nearly 80% of the flows from the Colorado currently are used for agricultural purposes. However, farming is beginning to dwindle in the basin as increased urbanization overtakes this historically rural area. Municipal and industrial use of Colorado River water is 15% and growing quickly as populations explode. Most cities have junior water rights, however, due to their later establishment, and therefore agricultural users and municipal users occasionally clash over distributions. Other important beneficial uses of water are for recreation and hydropower production, two activities that are easily forgotten in the resource race between agriculture and municipalities.

Agriculture holds most of the senior rights to Colorado River water because it is the most long-established and continuing livelihood in the Basin. Before agriculture came mining, which was the system under which the current framework of individual water rights was developed. The West is ruled by prior appropriation, a basic water rights structure in which the first person to lay claim to a source of water (particularly useful in the days of mining) subsequently holds a water right that dates back to the time of that claim. Any users that come along later and want water from the same or similar spot along the river must file a claim for junior water rights. This means that in times of shortage, these junior water rights holders are the first to have their water use curtailed, and senior rights always hold priority.

Agriculture has today become a livelihood that is practiced by a small minority of people within and around the Colorado River Basin. Because of the happenings of history, however, agriculture is water and water rights-rich. Nearly all of the senior water rights in the Colorado River basin are held by agricultural users, even though these users represent only a small fraction of the population served by the Colorado River.

Infrastructure for Agriculture

Agricultural diversions of water have been around since the beginnings of most civilizations, as they are vital to the survival of crops and, subsequently, agriculture. Starting with basic ditches, humans have progressed to complex pipelines. These diversions have been the staple of many societies, especially in regions where water is scarce. Colorado River managers started out small with these sorts of diversions to support agriculture in the arid southwest, and today such projects lay claim to some of the largest agricultural infrastructure in the United States.[39] Today, however, nearly all new proposed infrastructure projects are designed to obtain more water for growing cities as western urban populations skyrocket.

One major project constructed specifically to secure irrigation waters is the All American Canal System, located in the southeastern corner of California. This series of projects was initially authorized by the Boulder Canyon Project Act of 1928, and consists of the All-American Canal (80 miles), the Coachella Canal (123 miles), and Imperial Dam and Desilting Works. The Imperial Dam impounds the Colorado River, where water then flows into the desilting basins in order to prevent the high sediment load of the river from clogging up irrigation canals. This water next flows either to the All-American Canal, which irrigates the Imperial Valley, or to the Gila Gravity Main Canal in Arizona. This complex system provides water to upwards of 600,000 acres of land in the Imperial and Coachella valleys, and is actually the Imperial Valley's sole source of water. The All-American Canal replaced the old Alamo Canal, which was located mostly in Mexico, and today runs parallel to the Mexican border. The All-American Canal is the largest irrigation canal in the world, with a larger volume of water flowing through it than New York's Hudson River, and at its furthest point upstream regularly carries flows of 15,000 cubic feet for second (cfs).[40]

The Imperial Dam is coordinated with releases from Parker Dam. If there is a rain event or other unexpected flows, Senator Wash (which is about 2 miles upstream of Imperial Dam) stores the excess water so that it does not inundate the dam. The reservoir originally created by Imperial Dam was supposed to hold 85,000 af, but because of how quickly it filled with sediment now stores only 1,000 af today; it is dredged occasionally in order to allow functioning of the Gila Main Canal. Unfortunately, because of its location right on the border with Mexico, the All-American Canal has been the site of many drownings of people trying to cross it in order to enter the United States.[41]

In the 1980s, it became clear that the All-American Canal was losing excessive amounts of water due to seepage through its earthen bottom. In 1988, the Secretary of the Interior was authorized to line the canal. While the project was not fully authorized until 2003 due to questions of funding, and was not completed until 2010, it is now saving 67,700 af annually. It required re-building 23 miles of lined canal parallel to the existing one, and the water conserved will be used both to settle Native American water rights and to help California eliminate its dependence on surplus Colorado River waters. However, the project was originally done with no consultation with Mexico, which was benefitting from the downstream releases prompted by the seepage, and the elimination of this “informal” source of water further strained US-Mexico river relations in the 1990s.[42]

In another effort to better manage the lower Colorado system and conserve water, the Drop 2 Reservoir (also known as the Brock Reservoir) was approved in 2007 and construction finished in October 2010. This reservoir is intended to store excess waters from the All-American Canal, such as cancelled orders or non-storable flows such as surprise rain events. Prior to the reservoir’s construction, releases for the All-American Canal system would be made up at Parker Dam three days in advance. If any unexpected weather or events occurred within the time that it took this water to travel downstream, there was no capacity to store it, and the water would not be put to any sort of beneficial use before it reached Mexico. The 8,000 af Drop 2 Reservoir allows for the storage of these waters, saving upwards of 70,000 af annually.[43] However, there is some contention with Mexico over the reservoir’s construction, as it negates excess flows that were previously put to beneficial use in Mexico.[44]

While agriculture is dwindling as a livelihood, as shown in Figure 6, and subsequently as a water-using sector in many parts of the United States, there are many regions supplied by the Colorado River that are still going strong. Examples include both the Imperial and Wellton-Mohawk Irrigation districts at the southern tip of the lower basin bordering Mexico, where around 600,000 acres of land are irrigated with Colorado River water. This continuously presents contention over which new infrastructure developments should be prioritized: those for cities or those for continuing agricultural production. This region of the lower basin is an example where agriculture takes priority, but many developing areas in the Upper basin present the opposite outcome.

Year	Percent of Total Labor Force Employed in Agriculture	Agricultural GDP as a share of Total GDP
1900	41.0%	no data
1930	21.5%	7.7%
1945	16.0%	6.8%
1970	4.0%	2.3%
2002	1.9%	0.7%

Figure 6: Farming's changing role in the Nation's economy. Compiled by Economic Research Service, USDA. Share of workforce employed in agriculture, for 1900-1970, Historical Statistics of the United States; for 2000, calculated using data from Census of Population; agricultural GDP as part of total GDP, calculated using data from the Bureau of Economic Analysis.

Agricultural Water Use

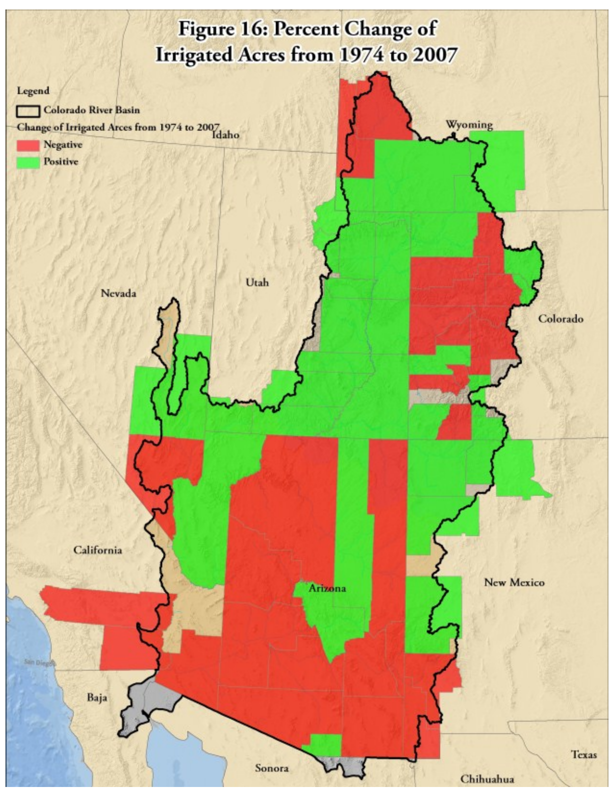

Figure 7, Change in cropland as percentage of land area in the Colorado River Basin, 1974-2007. Source: State of the Rockies Project 2012.

Despite its reputation as perhaps the driest region in the country, large portions of the southwest have a climate generally conducive to year-round farming, as long as water can be provided. According to the Colorado River Water Users Association (CRWUA), the agriculture fed by water from the Colorado River basin supplies 15% of the nation's crops, as well as 13% of the livestock.[45] Many counties in the basin are dependent on agriculture as their primary economic income, as well as a few massive counties outside of the basin (Imperial Valley being a prime example). It is agricultural giants such as Imperial and Coachella Valleys in California and the Wellton-Mohawk district in Arizona that are primarily responsible for this output, but there are also fairly fertile areas in the Upper Basin that host a fair share of irrigated land. Figure 7 shows the change in acres of cropland as a percentage of that county's total land area.

While the Upper Basin states experience harsh winter climates, Wyoming and Colorado are both boosted by a $1 billion input to their economies from their respective seasonal agriculture. Utah has 340,000 acres that are irrigated by the Colorado River, and New Mexico has 100,000 acres. New Mexico boasts an alfalfa crop that contributes between $35 and $60 million annually to their economy. Nevada is actually the only basin state that uses none of its Colorado River apportionment for agriculture.[46]

Much of U.S. agriculture is feasible because of significant subsidies from the government, which are detailed by the table on agricultural subsidies by county in Figure 8. These subsidies are due in part to a continuing belief in the importance of producing our own food as nation and not relying on imports from other countries. "It's a national resource that we should protect," says Vince Brooke, Assistant Water Manager of the Imperial Irrigation District.[47] For many agriculturalists of the Colorado River Basin, these subsidies come in the form of reduced water and energy prices.

County	State	Total USDA Subsidies 1995-2010
Maricopa	Arizona	$485,334,259
Pinal	Arizona	$462,288,174
Yuma	Arizona	$123,530,633
Cochise	Arizona	$99,105,005
La Paz	Arizona	$81,678,473
San Juan	Utah	$43,774,886
Moffat	Colorado	$43,108,035
Montezuma	Colorado	$34,824,040
San Juan	New Mexico	$34,493,923
Dolores	Colorado	$28,781,069
Montrose	Colorado	$22,157,852
Delta	Colorado	$21,775,592
Hidalgo	New Mexico	$21,455,046
Duchesne	Utah	$20,068,643
Uintah	Utah	$17,048,539
Emery	Utah	$13,376,653
Lincoln	Wyoming	$13,222,518
Imperial	California	$10,542,939
Rio Arriba	New Mexico	$9,400,186
Carbon	Wyoming	$9,213,433

Figure 8, Agricultural Subsidies by county. Source: Environmental Working Group, 2011 Farm Subsidy Database, http://www.farm.ewg.org

In the Imperial Irrigation District, for example, growers pay nothing for water, but merely pay for the price of its delivery; even then, it is only $20/af.[48] This does not reflect the true cost of water from the Colorado River in the dry Lower Basin, but makes it possible for farmers to grow productive crops without being overly concerned about spending huge amounts on irrigation. A similar situation is true in the Wellton-Mohawk Irrigation District, where each property has a water right of four af per year per acre at a low rate. Beyond this, there is a tiered rate system, and water rates have increased for the last four years, but only minimally. Farmers and the overall economy desire an abundant crop, and the irrigation districts are in place to supply water at a low rate to insure this.[49]

The region of Mexico supplied by Colorado River water is also a significant agricultural area. Unlike the U.S., however, the relationship between farmers and the government is less supportive, and Mexican farmers in the Sonoran Valley receive little to no subsidies for their food production. Due to their close proximity to the U.S. border where crops are highly subsidized, Mexican farmers are frequently fighting a difficult battle and losing significant amounts of money through their crops which cannot compete on a price basis with subsidized US production.[50]

All of this is possible in part because of the seniority of most agricultural rights. Miners, turned farmers after the boom and bust cycle of mining ended in the late nineteenth century, were often the first landowners to establish any water rights in the Colorado River Basin. Wellton-Mohawk Irrigation District, for example, holds the most senior water rights for the Colorado River, meaning when shortages are imposed they are the last water users to feel any change.

Imperial Valley and Wellton-Mohawk combined produce nearly 80% of the nation's winter vegetables, indicating their importance as a production center along the Colorado River. Imperial Valley has 475,000 acres of cropland, most irrigated by flood irrigation, and has an average use of 5 af per acre of crop, annually. The top crops in Imperial in 2009 were alfalfa (28.2%), wheat (21.9%), Bermuda grass (11.1%), Sudangrass (6.6%), and lettuce (6%). For this, Imperial Valley diverts a total of 3.1 maf annually, a significant portion of California's Colorado River allotment (the rest goes to Southern California municipalities through the CRA). Evaporation from canals causes a loss of approximately 10% of this water.[51]

Wellton-Mohawk district (the largest irrigation district in Arizona) is significantly smaller but relatively successful, with only 65,000 irrigated acres of farmland. For this, they divert 450,000 af of Colorado River water annually, but return 120,000 to 140,000 af downstream, flows which actually create the Cienega de Santa Clara wetlands in Mexico. This means that the annual consumptive use limit of water by the Wellton-Mohawk district is around 278,000 af. The most prevalent crops in Wellton-Mohawk are iceberg lettuce, cotton, wheat, Sudangrass, and some little seed crops. Corn, alfalfa, and wheat all require flood irrigation, which is generally less efficient than drip irrigation. Twelve-thousand af are reserved for municipal and industrial uses in the district annually, but because of having a rural population, rarely is the full 12,000 af ever fully used.[52]

Because of extreme uncertainty over prices in agriculture, most farmers in these regions of the Colorado River basin attempt to diversify their crop yield. One example of this is the fact that cotton is selling for some of the highest prices it has in decades. It also helps that farmers are able to grow two crops each year in some fields, due to the warm climate.[53]

The largest economic revenue, however, comes from the livestock in Imperial and Wellton-Mohawk Valleys. The latter has the largest cattle feeding yard west of the Mississippi River at 150,000 head, but the lot actually consumes more power than it does water.[54] Livestock is the biggest agricultural commodity revenue-wise in Imperial as well, where it generated an income of $343,201,000 in 2009.

Despite large subsidies, the revenue generated by agriculture in various regions of the basin is still fairly significant. As the largest agricultural region in the basin, Imperial's commodity total in 2009 was $1.45 billion, down from $1.68 billion in 2008. For comparison, the entire state of Arizona generated $1.8 billion in agricultural revenue in 2007, including the contributions of the Wellton-Mohawk district. Because farms in the Upper Basin are generally smaller or more specialized (an example being the Western Slope of Colorado), revenue is not quite on the same scale, although Colorado and Wyoming regularly bring in close to one billion dollars annually.[55]

Changes are occurring throughout the basin, however, as the population becomes increasingly urbanized. Demands for water transfers from agriculture to urban areas are growing steadily as pressures are put on water managers to supply increasing water to municipalities. This has caused some tension between agricultural communities and cities in the basin. "If they're short water, the first thing they do is run to the ag communities to get it," said Vince Brooke.[56] Imperial Valley has actually started a fallowing program, however, in which farmers are compensated for leaving their fields bare and transferring water over to municipal users.[57] This is true of many agricultural regions throughout the basin, where programs from basic fallowing all the way to the "buy and dry" technique are being implemented to better balance out water supply and demand. There has also been a decrease in irrigated acreage throughout the basin since the

1970s, which has also opened up the potential for a transfer of water from agricultural users who no longer need it to municipalities. The losses have been patchy and have therefore not had an overwhelming effect on the total amount of irrigated acreage in the basin, it is just an interesting trend of which to be aware.

In Imperial Valley, over $40.1 million has been put towards advancing a successful fallowing program since December 2003. Over 1,100 fields have been contracted out for fallowing purposes, and in total over 111,000 acres have been left fallow. This amounts to approximately 700,000 af of water ‘conserved,’ or delegated for other uses throughout the basin.[58]

These programs are especially pressing in regions of the Upper Basin where agricultural areas are not quite as large or well-established as those in the Lower Basin. This is also arguably where the pressing demands of urbanization are being felt most as the population is jumping from rural to urban at an unprecedented rate. Because of the historic nature of agriculture in the West, however, there is much opposition to these changes. Agriculture is an ingrained part of much of the cultural identity throughout the Colorado River Basin. Along with mining, it was one of the key livelihoods of nineteenth century settlers, and even as times change people are reluctant to relinquish this past livelihood which is still moderately successful.

Water use and distribution have always been politically charged topics, and in times of shortage, the tension only heightens. It is hard during shortages to recognize and weigh the importance of various water uses on the Colorado River. Population centers claim to be of primary importance, serving the needs of the people. Yet, as Kenny Baughman of the Wellton-Mohawk Irrigation District said, “The people…thought that milk and bread came from the grocery store. They have no idea it comes from farms."[59] While agriculture can often appear as hoarder of Colorado River waters, it is equally necessary to recognize its importance.

On the flip side of the Colorado River equation right now are the municipal users of water, who are growing rapidly in number. The next section addresses the infrastructure already in place to appropriately allocate water to thirsty cities in and outside of the Basin, and how this infrastructure is quickly becoming inadequate to serve growing demand. Increasingly, these municipalities are looking to agriculture to fulfill their water needs, which is why it is important to have a good background understanding in each.

Chapter 5: Municipal Water Use for Colorado River Water

The Growing Population of the Next Generation

At the advent of the Homestead Acts, population of the remote West began to grow, albeit slowly at first. Being the final frontier made the West a major attraction for farmers, miners, and later, developers. While this region has certainly experienced some serious boom and bust cycles with major transitions (from mining, to railroad, to services), the general trend of positive economic growth has resulted in consistently rapid expansions in population. In fact, perhaps in part due to its previously remote nature, the West has experienced the most intense population growth in recent years of any region in the country.

As shown in Figure 9, between 1950 and 2000, the percentage of the nation's population living in the West[60] increased from just 13.3% to 22.5%, nearly a quarter of the total. The 13 western states (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming) accounted for 50% of all US population growth from 1990 to 2000, with 91.5 million (one-third) of the 281 million-person total living in this region.[61] Five of the six fastest-growing states in the US between 2004 and 2005 were located in the West, including three Basin states: Arizona (3.5%), Nevada (3.5%), and Utah (2.0%).[62] Figure 9 displays the change in population, from 1990 to 2008, of today's twelve largest cities in the basin.

Water Agency/Provider	1990	2000	2008	Growth, 1990-2008
The Metropolitan Water District (LA)	14,393,420	16,145,476	17,987,917	25%
Southern Nevada Water Authority	750,621	1,364,248	1,922,069	156%
Tijuana & Rosarito, Mex.	829,233	1,323,214	1,632,508	97%
Phoenix, AZ	997,096	1,339,501	1,566,190	57%
Denver Water	891,000	1,000,000	1,154,000	30%
Tucson, AZ	662,251	835,504	952,670	44%
Mexicali, Mex.	363,149	568,983	890,032	145%
Albuquerque, NM	423,371	497,916	538,586	27%
Mesa, AZ	288,104	410,202	469,989	63%
Coachella Valley	235,722	332,485	462,386	96%
Colorado Springs, CO	303,522	382,693	424,416	40%
Salt Lake City, UT	333,000	372,192	391,515	18%

Figure 9, Water Agency and change in number of people to which water is provided. Source: Michael J. Cohen, "Municipal Deliveries of Colorado River Basin Water," Pacific Institute, June 2011.

Counter-intuitively for a region whose image is "rough and rural," the southwest U.S. is the most urbanized area of the country.[63] Recent influxes of population into southwestern cities, especially as the baby boomer generation begins to retire and settle in this warm area, has left rural areas in the Rockies region with lower-density populations than previous decades.[64]

Tens of millions of people from outside of the physical basin also acquire some or all of their water from the Colorado River; for example, more than half of the 30 million people receiving water from the basin live in Southern California. A recent report by the Pacific Institute found that 70% of the population receiving water from the basin does not actually reside within physical basin boundaries.[65] Trans-basin diversions such as the Colorado River Aqueduct from Lake Havasu to Los Angeles (which pumps 1.2 maf per year) move millions of acre-feet of water out of the basin to municipal users annually, and municipal demands are only increasing as populations grow.

Just as the population served by the Colorado River basin added 10 million people in only 18 years (1990-2008), so its growth is projected to continue into the future.[66] Nevada alone is expected to grow by one million people in the next 20 years, whereas the numbers for Colorado (an additional two million) and Arizona (an additional three million) are even greater.[67] That's six million additional people in twenty years between only three of the seven basin states, without even considering Mexico, which grew by 156% between 1990 and 2008. These significant additions to Colorado River water users only serve to stress further the already-dwindling river system.

Infrastructure for Municipalities

The largest and most expensive aqueduct system ever constructed in the United States is the Central Arizona Project (CAP). The project itself stemmed originally from the 1922 Compact, in which Arizona found their apportionment to be unfair in relation to California's (believing that they would not have as many opportunities for rapid development). Arizona was concerned as well about the distribution of water throughout the state, as prime agricultural areas in the counties of Pima, Pinal, and Maricopa were becoming increasingly reliant on non-renewable groundwater resources in order to keep the region fertile.[68] The Colorado River Basin

Act of 1968 was what finally authorized the construction of the CAP, originally as a project to bring water to approximately one million acres of farmland in these three counties. A stipulation of this major diversion, however, was that all CAP water rights would be junior to the older (senior) rights in California. With the 2007 Interim Shortage Guidelines in place, this has become a more pressing issue as CAP water must accept shortages that would otherwise be imposed on California.[69]

Construction of the CAP began in 1973, drawing water from Lake Havasu through a 336-mile diversion canal to the three counties. Over the course of the 20 years that it took to complete the project, there was rapid urbanization of the Arizona population into previously agricultural areas. This shifted the focus of the CAP away from agriculture and much more towards a municipal and industrial project, providing water for the cities of Tuscon and Phoenix.[70] In its totality, the project cost $4 billion, which must be partially repaid by Arizona water users. The CAP carries 1.5 maf of water to the three original counties, allowing life in the desert to thrive.

Recently, Arizona has attempted to diversify its water portfolio further and secure more future supplies by investing $28.6 million in the Brock (Drop 2) Reservoir project. The benefit for Arizona is that because of this investment in California, they will be able to use 100,000 of water annually starting in 2016.[71]

Another significant piece of Colorado River municipal infrastructure, that keeps Los Angeles and San Diego alive, is the Colorado River Aqueduct (CRA). This is a 242-mile system that diverts water from Lake Havasu in Arizona all the way to these California cities. It consists of two reservoirs, five pumping stations (which move the water a total of 1,617 vertical feet), 63 miles of canals, 92 miles of tunnels, and 84 miles of buried conduit and siphons, all of which allow 1.2 maf to be pumped from the Colorado River annually. The CRA was built between

1933 and 1941, and played a very significant role in Southern California's rapid growth after World War II.[72] It is run and regulated by the Metropolitan Water District (MWD) of Southern California.

There has long been conflict between California and Arizona about exact apportionments of water from the Colorado River, as well as what happens in times of surplus water. In the 1963 Supreme Court case *Arizona v. California*, California water rights on the Colorado River were finally adjudicated at 550,000 af/year as a fourth priority right and 662,000 af/year as a fifth priority right. This is because the water rights of the Palo Verde Irrigation District, Yuma Area, Imperial Irrigation District, and Coachella Valley Irrigation District (3.85 maf of California's 4.4 maf total apportionment) are senior to the MWD (formed in 1928).[73] However, in return for accepting these lower priorities, MWD has an exclusive right (for California) to accumulate up to 5 maf of water storage in Lake Mead, although this has not yet been implemented by the BOR.[74]

The MWD has also historically diverted any surplus Colorado River waters from Arizona and Nevada apportionments, and put it to beneficial use. Between 1986 and 1999, this surplus was anywhere between zero and 500,000 af annually, which had the potential to put California far over its 4.4 maf apportionment from the 1922 Compact. As the impacts of the present drought are felt, however, Nevada and Arizona are increasingly using their full apportionments, and MWD diversions are decreasing. In order to diversify their water portfolio, MWD also has a groundwater storage project with the Central Arizona Water Conservation District, which is only one part of a complex relationship of junior and senior water rights between Arizona and California.[75]

Case Study: The Proposed Aaron Million/Flaming Gorge Pipeline

The Lower Basin has historically demanded more water from the Colorado River than the Upper Basin, in large part due to the incredibly dry climate characterizing the region, but new developments in the Upper Basin prove that water security is desired everywhere. One example is the Flaming Gorge Pipeline, proposed by private developer Aaron Million as well as a coalition of small water utilities in Colorado and Wyoming. The proposed project would require construction of a 560 mile pipeline east from the Flaming Gorge Reservoir to southeastern Wyoming and south to various locations on the Front Range of Colorado. For comparison, the Central Arizona Project (CAP) is only 336 miles, and CAP is the largest and most expensive aqueduct ever created in the U.S. The Flaming Gorge Pipeline is predicted to cost $9.5 billion to construct, and accrue $217 million each year in operating costs.[76]

If built, the pipeline to the Front Range would supply the municipalities there with 225,000 additional af of water annually, which is the equivalent of a football field covered with a column of water 43 miles high. There is some debate about whether water to supply this amount actually exists on the Green River, as a 2007 study by the Bureau of Reclamation suggested that actual surplus supplies are closer to 165,000 af. Furthermore, in July 2011 the Army Corps of Engineers terminated an environmental impact review of the proposed pipeline, ruling that the purpose of the project fell more closely under the Federal Energy Regulatory Commission's (FERC) line of review due to possible energy generation as part of the project. After this ruling, FERC also ruled the proposal to be "deficient" and has requested greater specificity. Million and the coalition of small utilities continue to push the proposal, however, as they emphasize that the pipeline could potentially supply water to an additional 1.1-1.4 million new residents along the Colorado Front Range,[77] which nears growth estimates for the next 50 years.

All of these existing and proposed transbasin diversions of Colorado River water are two-faced, as they fulfill the necessity of a fueling a growing populace while further depleting the limited supplies of the Colorado River.

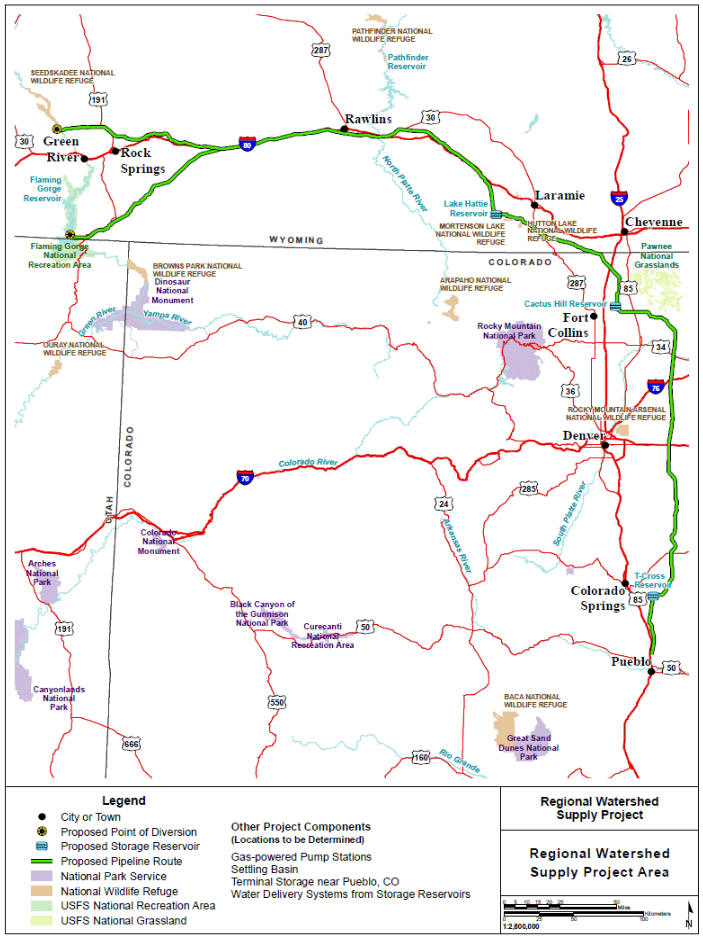

Figure 10, Aaron Million/Flaming Gorge Pipeline Plan. Source: Western Resource Advocates 2011.

Municipal and Industrial Water Use

The numbers are crystal clear when it comes to Colorado River supply and demand. The population is increasing, which leads naturally to increasing demand. The Pacific Institute recently published a report detailing municipal water use inside and outside the Colorado River basin, which found that although per capita use of water is actually declining in the basin, total overall demand continues to increase.[78] This is due to a population growth rate that outstrips the rate of decrease in water use. Figure 11 details the decline in gallons per capita per day (GPCD) for each state in the basin. These numbers can then be compared to Figure 3 earlier in this section; while not directly. It is evident that the GPCD percentage declines do not cover the massive population growth rates.

State	**GPCD Change (gallons)**	**GPCD Percent Change**	**Population Increase**
Arizona	-53	-23%	2,659,637
California	-51	-21%	6,548,506
Colorado	-47	-22%	1,548,817
Nevada	-107	-31%	1,343,930
New Mexico	-60	-27%	449,791
Utah	-84	-28%	928,966
Wyoming	20	10%	70,361

Figure 11, Decrease in GPCD in relation to population increase. Source: Michael J. Cohen 2011.

Municipal uses vary extensively from city to city, depending on people's needs, the climate, or water availability. The average human requires two quarts of water each day for basic survival. However, the U.S. average for a single family home is 80 gallons per person per day in winter, and 120 gallons in summer.[79] This is quite high compared to drought-stricken areas such as the Murray-Darling Basin in Australia, where an extreme lack of water has forced water use in cities such as Brisbane all the way down to 38 GPCD.[80] Water use in the Colorado River Basin, however, is even higher than the national average, due in part to a drier climate, as well as a higher consumptive pattern.[81]

Apart from industry, households are the main consumers of water in municipalities, especially in suburban regions with large lawns and properties. In cities such as Las Vegas and Denver, where the climate is not naturally conducive to luscious lawns, upwards of 50% of municipal water is often used on maintaining non-native grasses.[82] This is a consumptive use, as the water cannot be easily reclaimed for re-use downstream. Many efforts are being made, especially in Las Vegas, to replace turf with more water-efficient materials such as rocks and desert plants (Xeriscaping), but many people are hesitant to yield the aesthetic comfort of green lawns.

Using Las Vegas as an example of municipal water use, we see that about 40% of water goes to buildings (mostly non-consumptive) while 60% is used outside (consumptive). For Las Vegas, there is the added factor of both resorts and tourists. Contrary to popular belief, however, resorts are not huge water users; they only consume about 3% of Nevada's Colorado River apportionment, but provide 70% of Las Vegas's economic benefits. Furthermore, upwards of 80% of Las Vegas's permanent residents live in planned communities, which are culprits of large lawns and general water inefficiency (appliances). One of the largest consumptive uses of water in Las Vegas today (as many lawns are phased out in favor of Xeriscaping) is actually air conditioning, due largely to the warm, dry climate.[83]

The Pacific Institute study reports that even with a general decline in per capita municipal demand (people are using less water now than they did in 1990), agencies delivering water from the Colorado River now deliver approximately 6.7 maf annually, as opposed to the 6.1 maf that was the norm in 1990 due to an overall growth of urban population.[84] The following section discusses conservation and efficiency measures that are being pushed in order to decrease municipal water demand further. It is important to remember that at present, the driving issue is not vast overconsumption of water by municipalities, but rather the ballooning population of cities dependent on water from the Colorado River.

Challenges for Municipalities: Transbasin Diversions

With 45% of the Colorado River's waters leaving the basin to supply 70% of the population partially or fully reliant on the Colorado River,[85] transbasin diversions are a point of contention in water use. On the one hand, the cities are outside the basin; Los Angeles, San Diego, Denver, Albuquerque, Salt Lake City, and Colorado Springs, among others, as can be seen in Figure 12. On the other, increasing amounts of water leaving the basin to support these growing external population centers presently only means less water for those users on its interior.

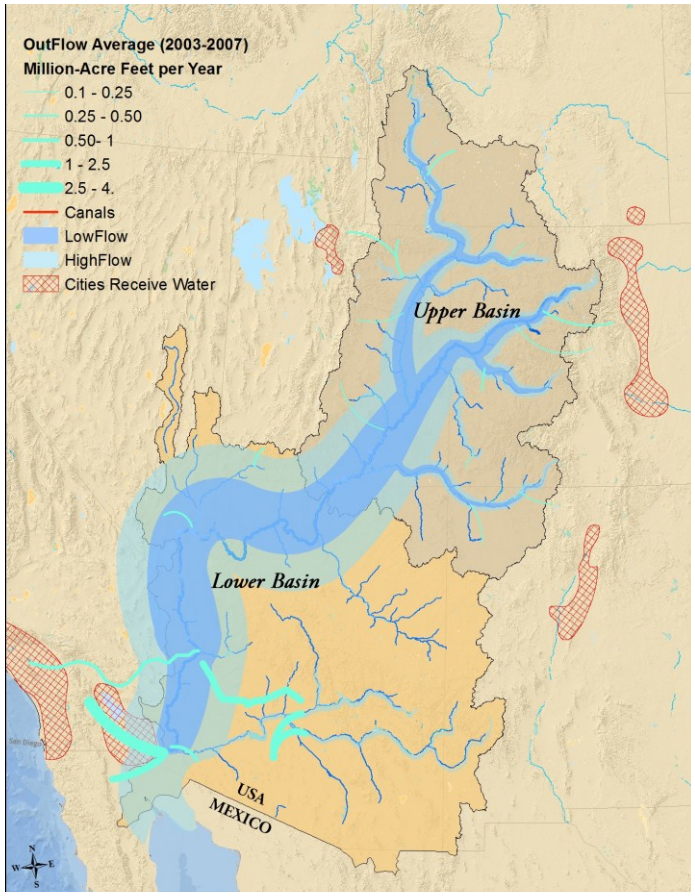

Figure 12, Out-of-basin diversions (see red hash marks). Source: State of the Rockies 2012 and Michael J. Cohen 2011.

Out-of-basin municipalities are also pushing for increased reliability of water sources, meaning the creation of more storage reservoirs. This is due in part to experience with shortages from the recent prolonged drought, as well as the desire to successfully support continued population growth in urban areas. Presently, 25% of Colorado River storage capacity directly supports municipalities, and this is only growing, especially as cities are able to acquire agricultural water rights that accompany their storage. However, reservoirs are both costly and inefficient, as they have a high loss of water due to evaporation and their costs must be paid for up front. In their recent report entitled “Filling the Gap,” Western Resource Advocates expands on the disadvantages of reservoirs, and pushes instead for decreasing the demand side of the equation through improved conservation measures.[86]

Also associated with the downsides of reservoirs are the pipelines that are needed to pump water out of the basin. These are costly to construct and are hugely energy-inefficient.[87] According to the Filling the Gap report, it is estimated that six pipelines that are currently being considered would each cost somewhere between $8 billion and $10 billion in just capital costs, not to mention operation and maintenance costs.[88]

One alternative to massive reservoir and pipeline construction is the creation of small, efficient reservoirs that are designed to take advantage of existing supplies and peak-season runoff, called "smart-storage."[89] These projects would work with the river and its natural flow variability, storing naturally-occurring downstream flows for later use. Their smaller size makes them less intrusive of the existing ecosystem, as well as less susceptible to major evaporation loss.[90]

Some cities are desperate for water, however, and will do anything to increase supplies through infrastructure. Las Vegas is a perfect example, in part because they are one of the leading cities in terms of conservation and low demand. Despite these conservation achievements, their reality as a metropolis in a desert requires water managers such as Southern Nevada Water Authority (SNWA) Head Patricia Mulroy to look into tapping the groundwater systems of other basins, including the Great Basin. Opposition to the proposed Las Vegas pipeline is fierce in the Great Basin, however, in part due to the pervasive notion that it would drastically alter the ranching lifestyle in the region by creating a zero sum environment; water taken by Las Vegas would no longer be available for Great Basin ranchers.[91]

The Filling the Gap report addresses just that question, of zero sum tradeoffs. By reviewing the water situation on Colorado's Front Range, they reveal four strategies—acceptable planned projects, conservation, reuse, and ag/urban cooperation—that will work together to decrease demand while simultaneously creating additional water supply.[92] While such strategies would require both sacrifices and cooperation, shortages are becoming enough of a reality that the benefits of comprise may soon outweigh any perceived disadvantages.

Chapter 6: An Analysis of Alternatives for Water Distribution

At some point, the questions of competing uses, supply and demand imbalances, and growing transbasin diversions boil down to a single question: is there enough water to go around? Can we find a way to equitably meet the demands (on a reasonable scale) of all users, while maintaining a healthy river system? Or will differing uses, overapportionment, and continued shortages out-compete one another, making it so that use by one stakeholder cancels out that of another in what is termed a zero-sum situation?

Balancing the Agricultural Tradition with Growing Demographic Pressures

Water distribution is the newest battleground for users of the Colorado River. At present, a standoff is developing between agricultural water users, who have regional history backing them, and municipal users, who are quickly growing in numbers. Agriculture holds the senior water rights, is often actually located within the basin, and has the title as largest user of Colorado River waters by a long shot—nearly 80%. There is also a deep history of agriculture present in the region, still very much felt by the agricultural community, and so while they may be small in numbers, they are strong in organizing against any movements to take away their water. Municipalities generally hold junior water rights, and have the disadvantage of often being located outside the basin—but this is where the people are, with an increasingly loud voice demanding water.

The topic is wildly charged, with each side on the defensive about who gets what water at what priority. If this present path is followed, then the Colorado River is headed for self-destruction; it is not feasibly sustainable. However, many experts believe that this relationship need not be zero-sum. In fact, this interface of users provides the perfect opportunity for a give-and-take relationship that has the potential to restore a semblance of balance to the Colorado River system.

Water Reuse and Conservation

One proposed solution is decreasing the demand side of the equation, which would mostly require efforts on the part of municipal water users. This would include heightened water conservation and reuse measures. Experts believe that reuse strategies are more promising, as conservation in the last decade has been startling effective and yet the continually growing population essentially negates this progress. There have been substantial per capita declines in water use, meaning that municipal deliveries would be nearly 2 maf lower than in 1990 *if* demand had remained constant[93] (see Figure 13). However, because of population increases, these demands were instead increased, hence the turn towards reuse as a more reliable strategy for water consumption reduction.

Reuse generally encompasses two different strategies. First, water can be physically reused by municipalities after treatment at a wastewater treatment plant, or after storage (direct reuse). Second, water can be returned to the river in the form of return flows for use by downstream users (indirect reuse). In this second situation, the upstream user is compensated for their water return.[94]

State	GPCD in 1990	GPCD in 2008	GPCD change	Percent Change
AZ	234	181	-53	-23%
CA	246	195	-51	-21%
CO	214	167	-47	-22%
NV	348	242	-107	-31%
NM	223	163	-60	-27%
UT	298	214	-84	-28%
WY	197	217	20	10%

Figure 13, Change in Gallons Per Capita Per Day 1990-2008. Source: Michael J. Cohen 2011.

Part of what direct reuse would entail is municipal infrastructure that is more friendly towards grey-water usage, for example in Colorado Springs where green lawns are sometimes watered with non-potable waters in order to cut down on overall consumption. There need not be a massive overhaul of all plumbing systems in municipalities, merely incentives in place to entice water customers to reuse, as well as methods that make reuse an easier practice. Giving big water consumers, especially industrial users, incentive to reuse waters in their various processes would likely have the most noticeable impact. Western Resource Advocate's "Filling the Gap" report indicated that an additional 199,000 af of water would be made available annually if Colorado Front Range water users were to engage in reuse practices.[95]

The main disadvantages to both conservation and reuse are their voluntary nature. There are some regulations in place in many cities fed by Colorado River water, such as sanctions on lawn-watering during drier, hotter months, but nothing that is stringent enough. It would be possible for water providers to introduce a tiered water rate structure, meaning that water would become significantly more expensive the more a user consumed; however, at present, this is less economically desirable for all involved parties. As Doug Bennett, Conservation Manager for the Southern Nevada Water Authority, said in reference to water conservation, "Conservation loves a crisis."

Increased Cooperation Between Municipal and Agricultural Users

The second approach to balancing the supply and demand equation of the Colorado River involves increased cooperation between agricultural and municipal water users. The simplest way of viewing the issue and solution is that agricultural users have a significant portion of the water rights, and therefore a significant portion of the water; municipal users have far fewer water rights, and therefore far less water. However, because irrigated acreage in many parts of the basin is decreasing (excluding the southern-most agricultural producers like Imperial Valley and Wellton-Mohawk), the need by agricultural users for that water is arguably decreasing as well. For example, there has been a decrease in irrigated acreage in Colorado from a high of 1.02 million acres in 1976 to only 840,000 acres in 2005.[96]

"Buy and Dry"

One way to use this imbalance of water rights and needs to provide increased water to municipalities is through a more traditional system termed "buy and dry." This is when municipal water users, who generally have a fairly high willingness to pay for water, buy up certain acres of agricultural land that are not productive enough to make them worthwhile to the farmer (or because the offer is more agreeable than producing crops would be). This purchase transfers the senior agricultural water right to the municipal user along with the land, which is appealing to municipalities as it gives them a sense of security in their water supply. However, it also permanently puts the land out of commission for agricultural purposes, which is often very unappealing to farmers who depend on the land for their continued livelihood.[97]

Already, buy and dry has been a significant hit to rural economy in many areas in the Colorado River Basin. Since 1987, farmers in Colorado alone have permanently sold 191,000 af of water to various suburbs, which is enough to support 382,000 families of four for a year. In terms of dried-up acreage, Colorado lost 400,000 acres permanently between 2000 and 2005, and USGS predicts that they will lose an additional 500,000-700,000 by 2050 if buy and dry continues.[98] Often, it is aging farmers that are selling their rights to cities because they are ready to retire and have no one willing to take over their farm or ranch.

In a March 2011 article by the Denver Post, Colorado Governor John Hickenlooper was quoted as saying " 'Water and agriculture are critical for the rural economy to flourish. Unlike many other states, and even some nations, we have the potential in Colorado to provide a sustainable food supply that is local and not imported. That's an asset we need to recognize and support.' "[99] This is especially crucial as urban populations in the basin grow, and more and more food is needed to sustain them.

Water Banking: the Most Economically, Socially, and Environmentally Agreeable Alternative

Instead of this socioeconomically undesirable method, more and more water managers are looking towards a combination of rotational fallowing and water banking to ease the process of transferring water from agricultural to municipal water users. Markets are an ideal tool to allocate a scarce resource, and therefore the creation of organized, regulated water banks composed of various willing agricultural water rights holders has the promise to be both more efficient and more socially acceptable.[100] As stated by authors Jedidiah Brewer, Robert Glennon, Alan Ker and Gary Libecap in their study "Water Markets in the West: Prices, Trading, and Contractual Forms," "The need to develop water markets for the smooth, incremental transfer of water across sectors with minimum transaction costs has increased over the past 20 years due to brisk population growth, urbanization, increased environmental concerns, and a rise in the economic contribution of services simultaneous with a relative decline in agriculture."[101]

What is Water Banking?

Water banks function essentially like a normal bank, only the commodity being managed and traded is less tangible and fluctuates more than most banks. Water banks facilitate agreements between users who are able to reduce water consumption cheaply (such as agriculturalists whose water costs are subsidized) and those who cannot (such as municipalities who have no other sources of water).[102] For ease of understanding, water banking transactions are generally classified as one of the following: a sale of water rights, a one-year (short term) lease of water rights, or a multi-year (long term) lease of water rights. Sales of water rights constitute a "buy-and-dry" situation, whereas leases are temporary and flexible.

In order for water markets to exist, there are a few structures that must be in place. First, water rights holders who are willing to forgo the use of their entitlement for a period of time are needed, as well as users who have a demand for water and will rent it. A system for monitoring release and delivery of water is necessary in order to insure safe and reliable transfers. Finally, an appropriate hydrologic capacity for water to either be stored or transferred is needed, in conjunction with a way to minimize damage to third party users, including environmental and instream flow needs.[103]

Water transactions that are facilitated by water banks are appealing to the lenders because they are temporary and voluntary, meaning that after the period of the agreement is up, these water right can be reclaimed. Furthermore, water banking makes economic sense; it allows a scarce commodity (regionally speaking) to be efficiently allocated by competitive markets, similar to any other valuable market good. Sellers must consider the opportunity cost of either irrigating their land and conserving their water (and subsequently leasing it to municipalities). On the demand side, municipalities must consider their willingness to pay for this water. For example, irrigation water in Colorado was between $28 and $100 per acre-foot in 2008, compared to the $9,000-$15,000/af that Front Range municipalities were paying to acquire new water supplies. [104] Economics argues that this massive discrepancy could be rectified by allowing the market to regulate supply and demand.

Advantages of Water Banking

The advantages to water banking over other strategies of water distribution are numerous, economically, environmentally, and socially speaking. In appealing to the economically-minded, water banking is *efficient*. It is arguably more efficient than some market-good markets, given the major disparity in what agricultural versus municipal water users pay for their respective supply.

Furthermore, the existence of a water bank, structurally speaking, reduces transaction costs among buyers and sellers who would be making the transaction anyways. The time and expense of locating contracting parties is subsumed by the third-party water bank itself. This is true also for negotiating the terms of the agreement; this would be done through the water bank, as opposed to either a long and arduous process between the two parties or them having to find an outside member to contract the negotiations out to. Finally, generally water banks also take on the task of monitoring performance of the lease. Having these three major tasks all managed by one entity (the water bank) drastically reduces the cost for the buyers and sellers of water. [105]

Other factors that tend to lead to smaller transaction costs are larger amounts of water being leased, if there is little to no opposition to the transfer (it goes through faster, although this is often not the case given the contentious nature of water in the west), and if the water rights is senior and high in priority.[106] Furthermore, water banks are advantageous in that unlike increased infrastructure, they rarely require any physical transfer of water, but involve diversion of water at a different place (usually) than its previous use. Banks should be appealing to water users because it is the users, and not government agencies or otherwise removed entities, that determine the most cost-effective means of allocating a scarce resource. This system is almost similar to a cap-and-trade procedure for greenhouse gas emissions; a certain amount of emissions (or water) are permitted in the system, and buyers and sellers can compete throughout a market to most efficiently allocate these.[107] Finally, because of the massive difference in the price of water for municipalities versus what agricultural users pay, the marginal benefit that comes from leasing water between the two is huge.

Disadvantages of and Current Concerns about Water Banking

Because they are a relatively new tool being developed for water allocation, there are still some kinks in water markets that need to be addressed in order for them to be as effective as possible. These kinks are not insurmountable obstacles, merely aspects that need to be taken into account especially if we are trying to apply water banking to the Colorado River Basin on a large scale.

The first concern is that water markets are more complicated than those for other non-market resources because of both the complex system of property rights that dictate water use and the interconnected nature of water as a resource. The physical properties of water complicate its legal regulation. Colorado River water is subject to simultaneous and sequential use (making it difficult to employ the exclusion principle and ensure exclusivity of use), mobility, is often unobservable (groundwater), and is variable with frequent uncertainty of supply.[108] Because these properties change so much from year to year, water must be carefully monitored in a water banking situation in order to ensure that all parties are getting their fair allotment and impacts to third parties are minimized. As long as these properties are adequately accounted for in this unique market, however, they are not a roadblock to its success.

Another large concern are the numerous externalities (costs that result from market activity but are not accounted for in the market) that potentially could result from a thriving water market. There are two main types of externalities in this case, technical and pecuniary. Technical externalities of water banking include the potential for increased groundwater pumping (as a substitute for farmers selling or leasing their surface water), as well as lost return flows if water rights are transferred out of a given watershed as a result of a lease.[109] Pecuniary externalities are more policy-centered, things such as a diminished agricultural economy (only on a small scale with leases, the concern is more with sales), shrinking government tax revenues when farmers fallow their fields, and a loss of rural political influence because a transfer of a powerful water right.[110] Again, these externalities are not an absolute roadblock, as long as they are recognized by the market and everything possible is done to account for them.

Finally, there are environmental and water quality concerns that could also impact the success of water banks. While it is very advantageous that a physical transfer of water is unnecessary in a water bank structure, the diversion of water from a different place than normal can potentially disrupt instream flow rights for environmental purposes. However, this can be countered with careful measurement and planning, and furthermore instream flow rights can be a part of water banking; water can, and has been, leased for environmental purposes. [111] Additionally, agricultural uses of water can use lower-quality water than is fit for municipalities, and therefore there is a concern of a disparity in water quality in transfers. This again can be countered through more stringent monitoring, and efforts to maintain a high level of water quality. [112]

The Economics of Water Banking

Water banking makes economic sense in the Colorado River Basin. Revenue-cost margins are shrinking quickly on traditional farming and ranching activities in the west. Water is often used to grow low-value or subsidized crops in this region, indicating little to no profit margin.[113] Because agriculture is a long-established livelihood, farmers in the west do not pay full price for the actual scarcity value of water here. According to various economic analyses, water use in western agriculture generally has *less value* than if it were used instead in rapidly growing western urban centers. For example, in California, an acre-foot of water used in the semi-conductor industry produces $980,000 in gross state revenue, whereas if that same acre-foot is used to grow low-value crops such as cotton or alfalfa, it generates a mere $60. Even when municipalities are offering very little for agricultural water, like the $225/af that San Diego was offering Imperial Valley farmers, it is still drastically more than farmers pay (those Imperial farmers were paying $15/af) and therefore both parties stand to gain.[114]

As previously mentioned about water quality for agriculture versus municipalities, water quality for municipalities is at a higher standard than that for agriculture. Part of the significant disparity in water prices between these two main users is accounted for by treating this lower-quality water. Distribution of this water to urban residents also accounts for some of this high cost. However, the size of the differentials in pricing indicates higher marginal benefits that are received by urban water users instead of rural users. Generally in a market situation, disparities of this size call for reallocation of the scarce resource, yet another indication that water banking could be quite successful in the Colorado River Basin.[115]

Why the Colorado River Basin is a Good Candidate for Water Banking

Because of its dry climate and the scarce nature of water in the West, the Colorado River Basin is ideal for the creation of various robust water markets. First, the severity of the situation suggests that this scarce resource *must* be allocated more efficiently, and soon. If a compact call ever occurs, the inequitable distribution of senior and junior water rights throughout the basin will mean that municipalities (junior rights holders) will have their allotment drastically reduced. Temporary transfers as heralded by water banks could increase water security for municipalities.

One concern with water banks is if they are made large-scale, spanning more than one watershed, unintentional impacts to third parties are likely to increase. However, the Colorado River Basin is ideal in that internal district water trades are certainly a possibility, especially in the Upper Basin where rural and urban regions are interspersed. Internal district water trades are lower cost, and are best done in areas where environmental conditions are fairly homogenous.[116] One example of this is the Colorado Big Thompson project, in which water allocations are "uniformly defined and proportionally adjusted as water supplies vary,"[117] the trading rules for water transfers are all the same, and there is only a single water district managing these transfers. This especially means that return flow effects are internalized because they stay within the system, and subsequently third party impacts are minimized.[118]

Colorado itself already has the most prominent water market in the western United States, followed closely by states such as California, Arizona, Nevada, and New Mexico (all Colorado River Basin states). In California, short term leases are the most prevalent because of the water market structure; in Arizona, Nevada, and New Mexico, sales are the most common form of water transfer between agriculture and municipalities. In non-urban states like Montana and Wyoming, transfers are not very common—the Colorado River basin states are better candidates given their mix of rural and urban regions.[119]

Evidence in Favor of Water Banking by Various Studies

Many studies have been done over the last few decades about western water transfers, and nearly all of them support the creation and continuation of water markets. Prices are higher across the board for agriculture to urban transfers than within-sector transfers, which reflects again supports the differences in marginal values between the two uses. [120] Studies also all indicate that the number of agricultural to urban transfers only continue to rise, especially in sales and multi-year leases as users look for more long-term water security. [121]

One study, conducted by Brown from 1990-2003 in 14 western states with an analysis 1,380 different water transactions, concluded that more water was traded in leases than in sales (leases doubled over that time period), leases involved larger amounts of water on average, municipal leases of water grew, and the most active leases were those of large governmentfunded projects for municipalities (such as the Central Arizona Project). From this, Brown rightly concluded that the west has an active, growing water market.[122]

A similarly extensive study by Brewer et al. found that price data currently unfortunately indicate a growing premium to purchase water rights, rather than to merely lease the water. However, these sales generally encompass small amounts of water, whereas leases are generally on a much larger scale.[123] For example, from 1987 to 2005, sales accounted for 67% of all transactions, but only involved 13% of the actual water traded. Conversely, leases accounted for only 30% of all transactions, yet transferred 83% of the water. They therefore concluded that there is certainly a fairly pronounced trend to acquire water for longer time periods.[124]

Therefore, while problems with water banks certainly do still exist, "most economics literature emphasizes gains from expanding water trading."[125] Most sources also conclude that water markets are more likely to be a good means of facilitating smooth water reallocation, better than non-voluntary regulatory reallocation.[126]

Already-Successful Water Banks

Water managers in the Colorado River Basin can look to other already-successful models in the creation and continuation of basin-specific water markets. The first example is in the Arkansas River Valley, which started up a system of pooled agricultural water rights for lease called the Super Ditch Program. In only the last 20 years, this region had dried up 70,000 previously irrigated acres because of water sales to Colorado municipalities. Instead of allowing this trend to continue, farmers banded together into a water bank so they could determine economically and legally what their water was worth, rather than being told of its value by thirsty municipalities. One farmer even thought about it in agricultural terms, stating that "leasing is a crop."[127] The only issue that has plagued the Super Ditch company has been in securing legal rights to transfer water outside of the Arkansas river basin; [128] otherwise, this effort has been relatively successful.

Another example of a thriving water market is in the Palo Verde Irrigation District of Blythe, California. Here, a popular fallowing program (which required around 25% of all land to be fallowed) has made it possible to lease water to the Metropolitan Water District of Southern California (MWDSC) for around $620 per fallowed acre. Previously, farmers paid a flat fee of $60 for each irrigated acre to obtain as much water as they wanted. One study author commented that "PVID provides a good example of how agriculture can maximize the value of its water while simultaneously staying business."[129]

Continuing Questions

Some questions about the structure, effectiveness, and feasibility of water banks in the Colorado River Basin still linger. For example, why is the extent of voluntary exchange still relatively limited? Researchers theorize that this limited scope may be partially explained by the special characteristics of water that raise the costs of defining and enforcing water rights. However, the general structures are inarguably in place, and all that is needed now is increased trust and involvement in these western water markets. However water banking is evidently the best strategy economically, environmentally, and socially for the efficient reallocation of water on the over-allotted Colorado River.

Chapter 7: Is the Colorado River Basin Faced with a Zero-Sum Struggle?

Decades of immense human ingenuity and vast sums of money have been invested in "taming" the Colorado River. This is often seen as one of the human wonders of the world: carving out immense reservoirs backed up behind gigantic dams, while diversion structures carry water hundreds of miles from the river itself to fertile agricultural regions and urban areas even beyond the hydrologic boundaries of the Basin. A steady supply of water over the decades, varying by the year according to drought conditions, is now rapidly being disrupted by growing demand for water to be put to "beneficial" uses. Colliding with the traditional definitions of "beneficial uses," new demands arise for maintaining in-stream flows to protect the fragile riparian areas and vast public lands of the region.

Many believe that the height of human engineering in the Basin is nearing an end, with a few remaining proposals for massive diversion increasingly being challenged by environmental concerns. The result: a situation that increasingly pits existing users against one another, as urban areas seek to obtain water dedicated to agriculture, and out-of-basin demands seek any remaining surplus or unused allotments to individual states.

It appears at first glance that additional water obtained by urban areas must now come from a decline in water use by agriculture (potentially signaling a decline in agricultural production itself). Any further water diversions, even pursuing remaining surplus allotments to individual states, must come at the expense of diminished in-stream flows, thus harming further rivers and their associated flora and fauna.

Should we see this collision of steady and perhaps dwindling water supplies, as climate changes occur, against rising human demands as the ultimate threat to the Basin as we know it?

Or are we witnessing in the vibrant experiments discussed above innovative opportunities for new techniques of water sharing and conservation? The tentative answer is that it remains to be determined, dependent on various users' willingness to compromise and cooperate. Encouraging signs of conservation and water sharing techniques give hope that our children will inherit a vibrant Colorado River.

While an enforced decrease in consumption via the 2007 Interim Shortage Guidelines, as well as reuse strategies, are clearly important as we enter an age of conservation, these alternatives alone are not enough to correct the future supply and demand imbalance on the Colorado River. Increasingly rapid population growth will only put further pressures on existing water supplies and ramp up demand, even if conservation is widely practiced by both agricultural and municipal water users. Instead, these methods should be combined with a serious investment in developing western water markets, specifically the practice of water banking. Temporarily transferring water between various users allows for its efficient allocation without permanently damaging any users, making it a clearly viable alternative for water distribution.

Water use in the Colorado River Basin *need not* be a zero-sum game. On its current trajectory, it could certainly be classified as such. However we are encouraged by promising alternatives for water conservation, reuse, and sharing of this scarce resource that together have the power to alter this path of destruction.

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