Quantification Task: A Description of Agriculture Production and Water Transfers in the Colorado River Basin

A Report to the CRB Water Sharing Working Grounp and the Walton Family Foundation

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Introduction

The Colorado River Basin (Figure 1) is one of the most critical sources of water in the West, spanning seven U.S. states and two states in Mexico. This river's remarkable reach includes providing water to more than 30 million people, irrigating nearly four million acres of agricultural land, and serving as the limiting resource for at least 15 Native American tribes, seven National Wildlife Refuges, four National Recreation Areas, five National Parks in the U.S. and a Biosphere Reserve in Mexico. The river's energy powers more than 4,200 MW of electrical capacity to households and industry. However, the river is at risk, because increasing water demands and climate change are jeopardizing water security.

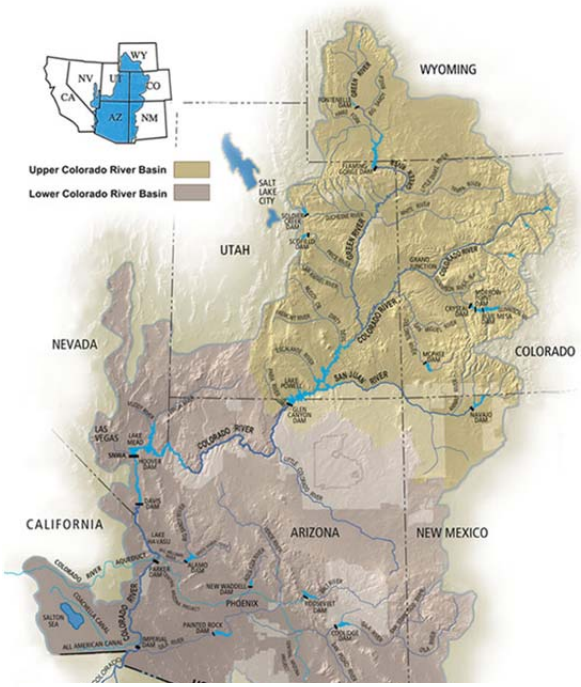

Figure 1. Colorado River Basin.
http://www.gcdamp.gov/aboutamp/crb.html

Stakeholders representing municipal, agricultural and environmental interests seek innovative opportunities to meet the challenges of increasing water scarcity in the Colorado River Basin (CRB). Innovative solutions require an understanding of the current status of water use in the CRB and its underlying trends. Particular attention is focused on agriculture in the basin, as this sector diverts the largest share of water from the CRB and is often seen as the source for future reallocation. Therefore, the purpose of this study is describing agricultural water use in the CRB and report the most recent activity in water transactions.

Data used in this report is drawn from three secondary sources: the U.S. Department of Agriculture's (USDA) Agriculture Census that surveys all farms and ranches at five year intervals; the USDA Farm and Ranch Irrigation Survey, a five year recurring sampling of irrigation practices across the U.S.; and the Water Transfer Database housed at the Bren School of Environmental Science and Management at the University of California, Santa Barbara. A single clearinghouse does not exist for water transactions in the CRB. Rather, a monthly trade periodical, *The Water Strategist,* reports western water transactions. To supplement this data, we relied on personal interviews with the U.S. Geological Survey, National Agriculture Statistics Service, U.S. Bureau of Reclamation and others.

Findings suggest that irrigated agriculture in the Upper CRB increased in 2008 when compared to 2002, a notable drought year. Urbanization is repurposing agricultural land and water to municipal use in the Lower CRB. Throughout the CRB, agricultural land ownership is fragmenting into many small farms, but agricultural production and water use is increasingly concentrated among large commercial producers. Investments in agricultural water conservation practices are substantial, but access to capital and costs are a primary barrier to further adoption. Water right sales and leases from agriculture to municipal water providers are increasing, but the size of each transaction and the number of transactions depends importantly on local conditions and institutions. Sales are the primary exchange mechanism, but leases are increasing in their frequency of use. Insufficient data exists to quantify the exact amount of agricultural water use in the CRB, or how this is changing over time. This is an opportunity for additional research and investment. A more robust quantification is necessary to maintain water security.

Agricultural Water Use in the Colorado River Basin

The following section summarizes agriculture's water use in the CRB as reported by the U.S. Department of Agriculture's National Agriculture Statistic Service (NASS). Two sources are of particular importance: the first is the Watersheds Report, which is a specific aggregation of responses to the U.S. Census of Agriculture into watershed and hydrologic unit codes defined by the U.S. Geological Survey. The second source is the Farm and Ranch Irrigation Survey (FRIS), which is statistical sampling performed at five year intervals by NASS to supplement the U.S. Census of Agriculture. The geographic and hydrologic scope of these reports is quite broad – the scope goes beyond the accounting stance of the 1922 Colorado River Compact that governs the allocation of the river's waters.[4]

Watersheds Report from the US Census of Agriculture

The USDA Census of Agriculture is a comprehensive effort to report the characteristics, management practices and demographics of farming operations with more than $1,000 in gross sales. Data is aggregated by NASS staff in many ways, including according to the United States Geological Survey (USGS) water resource region (2-digit Hydrologic Unit Code (HUC) level). These water resource regions are subdivided into subregions (4-digit Hydrologic Unit Code level) based on water flow patterns from the major rivers within the region. The subregions are further divided into basins (6-digit Hydrologic Unit Code level). Two water resource regions are considered in this analysis: the Upper Colorado (14) and the Lower Colorado (15). The geographic location of the water resource regions is found in Figure 2, and a list of the six-digit HUC's that comprise each basin are found in Table 1.

Table 1. The 6-digit HUC's that comprises Water Resource Region 14 and 15

Upper Colorado (14)	**HUC**		***Lower Colorado (15)***	**HUC**
Colorado Headwaters	140100		Lower Colorado-Lake Mead	150100
Gunnison	140200		Little Colorado	150200
Upper Colorado-Dolores	140300		Lower Colorado-Lake Mead	150301
Upper Green	140401		Bill Williams	150302
Great Divide Close Basin	140402		Upper Gila	150400
White-Yampa	140500		Middle Gila	150501
Lower Green	140600		San Pedro-Willcox	150502
Upper Colorado Dirty Devil	140700		Santa Cruz	150503
Upper San Juan	140801		Salt	150601
Lower San Juan	140802		Verde	150602
			Lower Gila-Agua Fria	150701
California Region (18)			Lower Gila	150702
Salton Sea	181002		Rio Sonoyta	150801
			Rio De La Concepcion	150802
			Rio De Bavispe	150803

[4] The distinction is important, as the data used for compact compliance is not comparable to the USDA sources. For example, tribal lands appear in USDA-NASS reports but are not part of the compact.

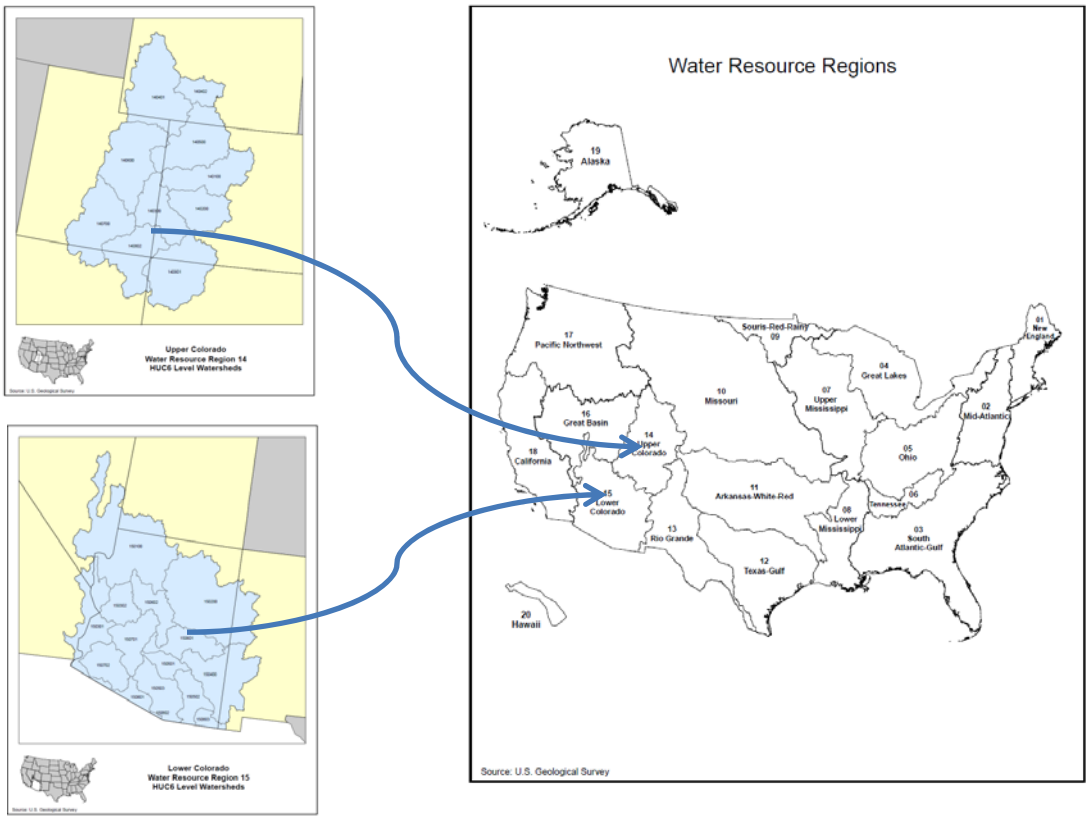

Figure 2. U.S. Geological Survey Water Resource Regions used by USDA-NASS – the Upper and Lower Colorado River Basins

In this section of the report, agriculture production practices and farming demographics are categorized by water resource region (WRR) or six digit HUC's. These statistics are considered representative of CRB agriculture, but two important regional caveats apply.

Imperial Irrigation District (IID)

California receives 4.4 million acre-feet of the Lower Colorado River's average annual flows, and 3.1 million acre-feet of this allocation are diverted to the Imperial Irrigation District (IID). The IID reported 495,000 irrigated acres in 2009 with a crop mix of field crops, high value vegetables and perennial crops (IID). These irrigated acres are not reported as part of the Lower Colorado water resource region (15), but instead are reported in the California Water Resource Region (18) and the Salton Sea HUC (181002). In this section of the report, the Salton Sea HUC agricultural statistics **are combined with Water Resource Region (WRR) 15 (the Lower CRB)** unless otherwise stated. Likewise, agriculture irrigation in the Coachella Valley Water District is tabulated with WRR 15.

Colorado Big Thompson (CBT)

In the West, transbasin diversions have been used to shift water from basins of relative surplus to basins of relative scarcity. The Colorado Big Thompson project (CBT) is a transbasin diversion that collects and stores water in the headwaters of the CRB and then shifts the water across the Continental Divide into

northern Colorado and the South Platte River Basin. This diversion conveys approximately 215,000 acre-feet of water to 630,000 acres of irrigated crops and to 30 cities. Two-thirds of the water units within the CBT are currently owned by municipal users, but ownership does not imply a municipal use – 60 percent of CBT water was delivered to an agricultural use in 2009. The agriculture statistics reported in Upper CRB do not include lands irrigated with the CBT project. Unfortunately, it is difficult to find detailed statistics linking CBT irrigation water to agriculture production since CBT water is commingled with other irrigation sources in the South Platte River Basin. For this reason, the CBT irrigated acres **are not included** in this report.

Overview of CRB Agriculture from the Watersheds Report

Irrigated agriculture in the CRB is diverse and generates sizable economic activity. Irrigated agriculture in the region includes, but is not limited to, lands irrigated from mainstem diversions of the Colorado River. The Watersheds Report does not distinguish between irrigation water sourced from the mainstem of the Colorado River and the water diverted from tributaries or groundwater resources.

The Colorado River Basin is divided into upper and lower basins by USGS in part because climactic conditions dictate differences in agricultural activity. According to the 2007 Watershed report, the Upper CRB (also referred to as WRR 14) consists of 1.36 million acres of irrigated cropland. Agriculture in the Lower CRB (also referred to as WRR 15) benefits from a longer growing season and closer proximity to large urban food markets and distribution centers. Cropping in the Lower CRB is more diverse and generates higher sales value per acre of irrigated cropland. Additionally, the lower basin enjoys year-long production, whereas the upper basin is limited to warm-season production. The 2007 Ag Census reports irrigated cropland in excess of 936,000 acres in the Lower CRB with most of these lands located in Arizona. The IID is not included in the Lower CRB, but it does receive water resources from the CRB (Figure 2). Specifics about each water resource region are found in the following text.

Agricultural Water Use in the Upper Colorado River Basin

Crop Mix Irrigated cropping in the Upper CRB directly supports cattle, sheep, equine and dairy production. More than 1 million animals were inventoried in the Upper CRB in 2007, and irrigated agriculture provides critical inputs for these crops. The 2007 crop mix can be characterized by hay crops (55 percent), irrigated pasture (37 percent) grains (5 percent) and other crops (4 percent). The crop mix has been stable over the last ten years with minor substitution between hay crops and irrigated pasture.

Irrigated Farms Irrigated crops were produced by 12,814 farms in 2007, which is an increase of 2,346 farms over 2002. As will be discussed in a subsequent section, the growth in farms occurs primarily among the smallest size classifications, perhaps due to the increased incidence of exurban farmsteads in the West, as well as due to intergenerational transfer from parents to multiple children. In the latter case, children may frequently be absentee landowners, and farm management is actually performed by a local operator with a rental agreement. In this instance, multiple farm entities result, but management decisions are centralized under local control. Irrigated farm numbers increased in every HUC in the upper basin (see Table 1 for a listing of HUC's) with the greatest percentage increase in the Upper and Lower San Juan HUC's.

Irrigated Acres Farmland under irrigation also increased between 2002 and 2007 from 1.17 million acres to 1.38 million acres. The greatest increases in irrigated acres are also reported in the Upper and Lower San Juan HUC's. Care must be taken when interpreting these descriptive statistics. The Census of Agriculture is a self reported survey and thus represents a snapshot of a point in time. Climatic conditions, such as depleted supplies of stored water, may mean that fewer irrigated acres are reported in a water short year as opposed to a year in which water supplies are more substantial. Certainly, a regional drought may have reduced irrigated acres in the Upper CRB in 2002 and increased acres may be the result of a return to normal precipitation patterns and water supplies. Interviews suggest that many acres in the Upper and Lower San Juan were fallowed because of the 2002 drought.

Agriculture Water Use in the Lower Colorado River Basin

Crop Mix Agricultural activity in the Lower CRB (including the IID) is more varied and generates greater sales per irrigated acre than in the Upper CRB. In part, the greater agricultural activity is the result of a longer growing season and closer proximity to large urban food markets and distribution infrastructure. Table 2 summarizes the Lower CRB crop mix in 2003 and 2008. Notable is an increase in hay production, a perennial crop, and a decrease in cotton production in the Lower CRB. Changes in the crop mix are likely due to economic profitability rather than water use, as alfalfa's season-long consumptive use of water is substantially higher than that of cotton.

Table 2. Crop Mix of Harvested Acres in the Lower Colorado River Basin and inclusive of the Imperial Irrigation District

	2003	2008
Hay Crops	30%	39%
Cotton	25%	15%
Vegetables	15%	11%
Wheat	13%	14%
Orchards	4%	3%
Pasture	4%	5%
Other	8%	12%

Irrigated Farms The Watersheds Report lists an increase of 613 irrigated farms between 2002 and 2007 in the Lower CRB, but it is worthwhile to separate out the changes by six-digit HUC's and the IID. Irrigated farm numbers increased in all HUC's except for the Lower Colorado (HUC 150301), the Middle Gila (HUC 150501), the San Pedro-Wilcox (HUC 150502), the Santa Cruz (HUC 150503), the Salt (150601), the Lower Gila – Agua Fria (150701) and the Lower Gila (150702), as well as the IID. These HUC's are primarily located in the lower-central portion of Arizona, an area in which municipal development was occurring rapidly.

Irrigated Acres Land under irrigation in the Lower CRB decreased substantially as indicated by the Watersheds report. In 2002, 1.6 million acres were reported as compared to 1.42 million acres in 2007. The IID's irrigated land was reduced by 106,000 acres in the same interval, in part due to water transfers, but also because farm managers may seek to fallow acres if it is economically advantageous to

cease production rather than take a loss on a particular crop. Irrigated acreage reductions were noted in ten of the fifteen HUC's for the Lower CRB, with the greatest share of irrigated acres declining in the Rio De La Soynota (43 percent reduction or 11,493 acres) and the Middle Gila (17 percent reduction or 26,298 reduction) in irrigated acres.

Trends in Farm Size, Efficiency and Management

The previous section uses Census of Agriculture data to depict the overall scope of CRB agriculture. Additional information on water use, adoption of conservation technology and management practices can be gleaned from the Farm and Ranch Irrigation Survey (FRIS), a stratified sampling of water use among farms. When combined with Census of Agriculture data, the FRIS is one of the most complete and detailed profiles of agriculture water use.

Notable differences between the FRIS and the Watersheds Report include:

- The FRIS is collected from a random sample of operations rather than a census of all operations. The sample is stratified by USDA-NASS to make it statistically valid and so that results are scaled to represent the operations in the Upper and Lower CRBs.
- The FRIS reports more comprehensive farm management data when compared to the Watershed Report. As an example, farmers are asked the water distribution method (i.e., gravity sprinkler, drip) for their irrigated cropland.
- The FRIS does not report data for specific hydrologic use codes as was done in the Agriculture Census. Thus, results are only aggregated to WRR 14 (upper) and WRR 15 (lower). Importantly, data from the CBT project **and** from the IID are **not** contained in this part of the report.

When examining the FRIS, it is clear that agriculture is evolving in the Colorado River Basin, and ownership is gravitating toward two farm categories: small acreages whose revenues are used to augment household income rather than as the primary source of funds, and large, commercial producers that are the source for the vast majority of agriculture production and farm gate sales. The following section describes the size distribution of irrigated farms by WRR.

Upper Colorado River Basin as Reported in the FRIS

The number of irrigated farms is increasing in Upper CRB, but the increase is not uniformly distributed among all sizes of operations. First, the largest number of farms falls into the smallest size classification of 1 to 49 acres (far left column of Figure 3) and this number is increasing between the 2003 (blue column bars) and the 2008 FRIS (red column bars). Increases in the number of farms are observed for the smallest and largest size categories, but not for the medium size categories (200 to 499 acres category excepted). It appears that farms are being fragmented into two groups: many small farms and a few large commercial farms. It may well be that the ownership of water rights is fragmenting similarly, but because water rights may be held by a mutual ditch company or other institution rather than by individual farms, more investigation is needed to determine if this is true.

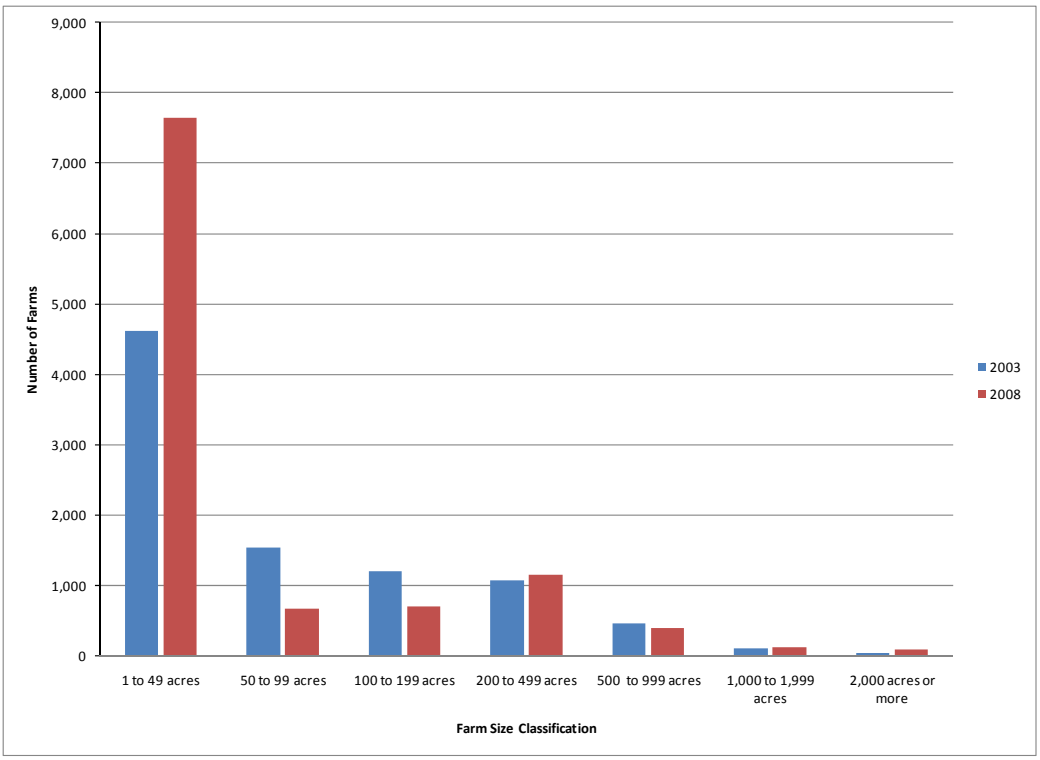

Figure 3. Number of Irrigated Farms by Size Category in the Lower Colorado River Basin during 2003 and 2008

The smallest size category represents the largest number of farms, but this classification does not crop the largest portion of irrigated acres. Instead, the larger size classifications crop more irrigated acres as is evident in Figure 4. As an example, the largest size classification (greater than 2,000 acres) accounted for 200,000 irrigated acres in 2003 in Upper CRB. The size classification's irrigated acres increased substantially in 2008 to more than 300,000 acres. In general, the smallest and largest size classifications increased their share of irrigated acres over the last 5 years, while the medium sized classifications decreased their amount of irrigated cropping (excepting the 200-499 size classification).

The FRIS reports that the total number of farms in the Upper CRB increased by 1,700 between 2003 and 2008, with small farms (less than 49 acres) accounting for 50 percent of the total number of farms in 2003 and a remarkable 71 percent of the total in 2008. This dramatic increase in the number of small farms follows a pattern of exurban development in the Intermountain West in which large parcels of agricultural land are divided into smaller, single-family operations with irrigated forage and pasture as the major agricultural activity and substantial off-farm income as a primary contributor to total household income. Small farms account for 9 percent of irrigated cropland in the Upper CRB, with the largest farms (2,000 acres or more) taking up 23 percent of the irrigated cropland. The middle size classifications (50 acres to 1,999 irrigated acres per farm) are becoming smaller in terms of the number of farms (28 percent in 2008) though they still crop 2/3 of the irrigated acres.

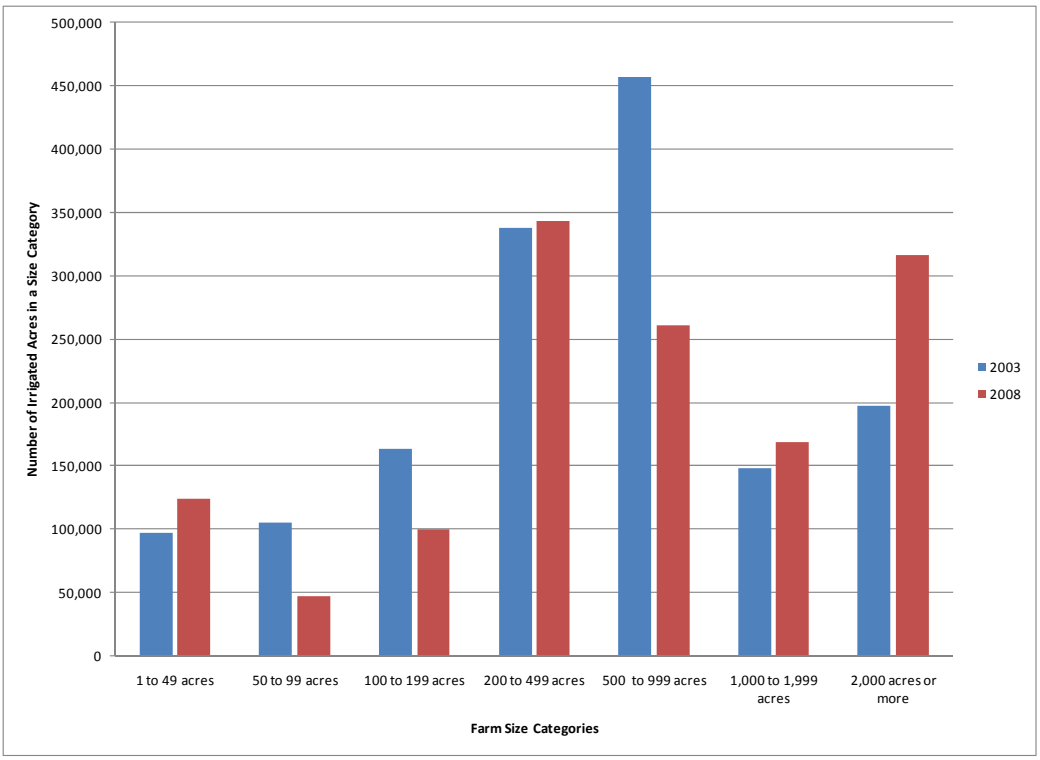

Figure 4. Total Acres Irrigated in the Upper Colorado by Size Category for 2003 and 2008

Lower Colorado River Basin as Reported in the FRIS

The Lower CRB follows a similar trend in farm size as observed in the Upper CRB. However, the irrigated acres are more concentrated in larger farm size categories.

Specifically, most farms in the Lower CRB are in the category of 1 to 49 acres, and the number of farms increased between 2003 and 2008 (Figure 5). The number of farms also increased in the 50 to 99 acre category, as well as the largest category of 2,000 or greater acres. The medium-sized farm categories all experienced declines in the total number of farms between 2003 and 2008.

Irrigated acres are heavily concentrated in the largest farm size categories in the Lower CRB in contrast to what was observed in the Upper CRB. Farms reporting more than 2,000 acres of irrigated cropping are controlling more than 520,000 acres in the 2008 FRIS, a 21 percent increase from the reported level of irrigated acres in 2003. Farms with 1,000 acres of irrigated cropland or more control nearly three-quarters of all irrigated land in the Lower CRB. Small farms constitute two-thirds of the farm numbers in the Lower CRB, but only control three percent of the irrigated acreage.

The trend toward an increased number of small farms and increased concentration of irrigated acres among large farms is consistent in both regions, although the initial distribution of farms and control of irrigated acreage differs. The result is a fragmentation of farm ownership and perhaps water rights ownership.

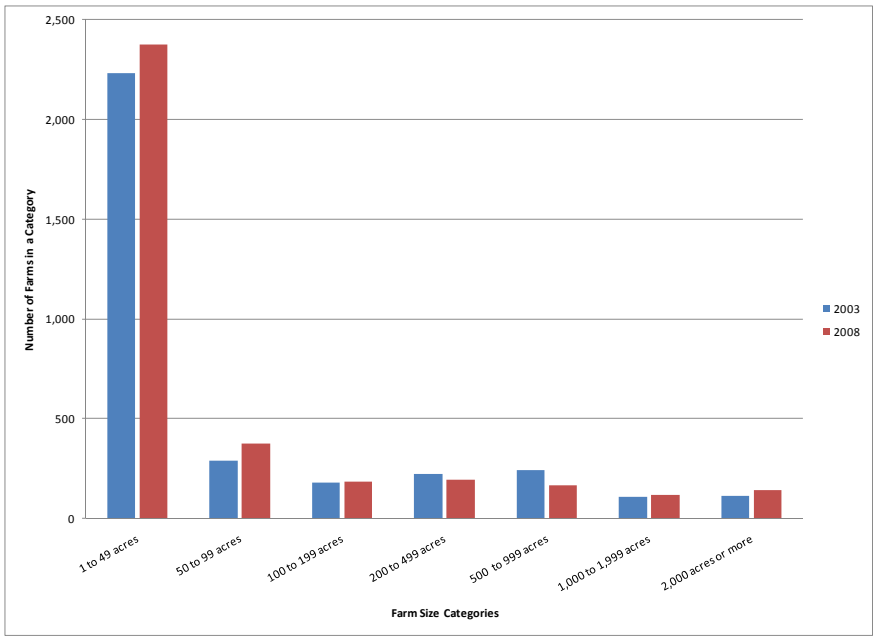

Figure 5. Number of Irrigated Farms in the Lower Colorado by Size Category for 2003 and 2008

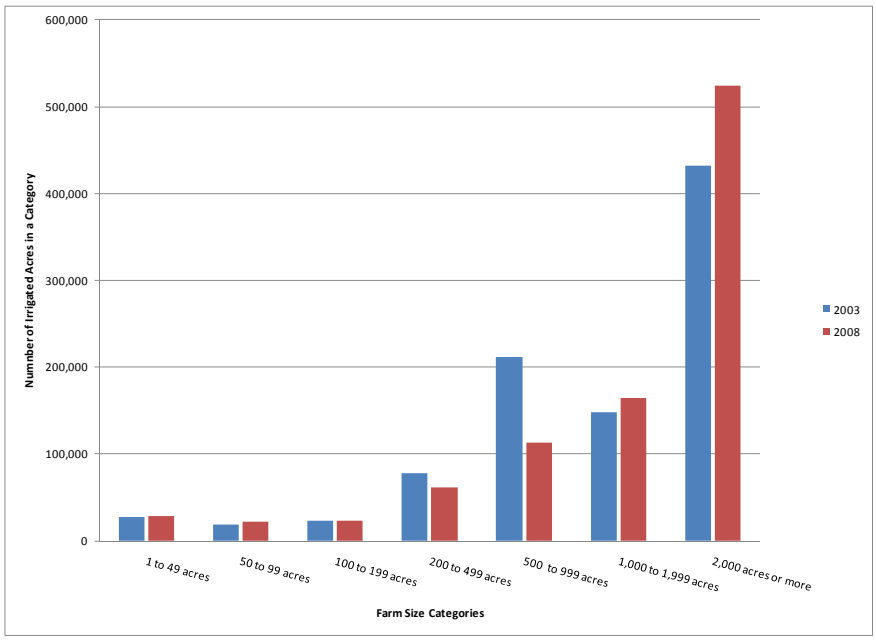

Figure 6. Total Acres Irrigated in the Upper Colorado by Size Category for 2003 and 2008

Fragmentation might also mean that irrigated cropping is becoming a less important source of household income for these owners, and it may be that the attitudes of these irrigators may differ from larger farms that see agricultural profits as the significant contributor to household income. Interestingly, fragmentation has not appreciably altered the crop mix since 2003.

Figures 4 and 6 suggest that irrigated lands are becoming more concentrated in fewer, relatively larger farms. Fewer decision makers might make it easier to target and accomplish improvements in water efficiency in application and conveyance, as well as habitat improvements. A next step is to better document the level of irrigation technology observed in the FRIS, the benefits of improved efficiency in application, and the barriers that might exist to improving efficiency.

Water Efficiency – Irrigation Application Methods in the FRIS

The FRIS asks survey respondents a variety of questions about how water is applied to irrigated cropland. The application categories include gravity, sprinkler (center pivot, sideroll, linear), drip or low flow irrigation and subirrigation. Application technology has important implications for water use in the CRB – after all, increasing efficiency in application can reduce the amount of water diverted, but it also reduces return flows to riparian habitats and recharge to alluvial aquifers. Improvements in irrigation ultimately alter the timing and pattern of water flows within the basin.

The primary application method in the Upper CRB is gravity irrigation (Figure 7), which is utilized on 73 percent of the irrigated acres reported in the 2008 FRIS, a slight decrease from what was reported in 2003. The remaining 27 percent of irrigated acres utilize sprinkler application. Drip and subsurface irrigation are not used in any significant way in the Upper CRB. Of the sprinkler types, sideroll irrigation is reported on 60 percent of sprinkler irrigated lands; however, the share of sideroll irrigation decreased by 15 percent between 2003 and 2008, and this share is replaced by center pivot irrigation.

Similar to the Upper CRB, the Lower CRB uses gravity irrigation for more than three-quarters of its irrigated cropland as reported in the 2008 FRIS (Figure 8). Sprinkler irrigation comprises 18 percent of application to irrigated cropland in this region and more extensive use of drip or low flow (5 percent) is noted. The share of irrigation application types has remained stable since 2003 with a slight decrease in sprinkler methods in favor of drip or low flow. Unlike the Upper CRB, center pivot irrigation makes three-fourths of the sprinkler irrigated acreage with nearly identical shares for solid set (9 percent), sideroll (9 percent) and linear (7 percent) in the remainder.

Improvements may be made to conserve on-farm water and energy use, and improving irrigation water application is one conservation measure. Farmers might also seek other conversation methods including implementing reduced or no tillage, leveling land, improving water conveyance, changing the crop mix and timing irrigations to conserve water. The FRIS asks respondents to indicate if they have improved water or energy conservation during the last five years, and then note the improvements that occurred as a result of the adopted practices. Table 3 summarizes benefits reported by farms engaging in improved conservation by water resource region.

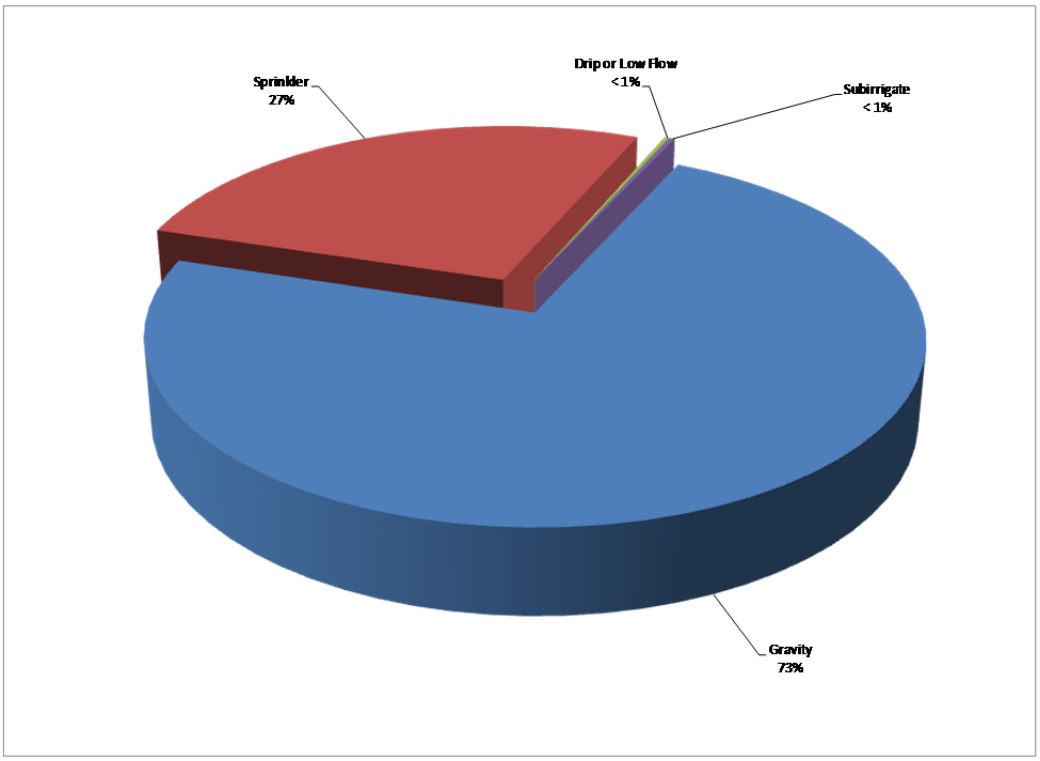

Figure 7. Irrigation Application Methods in the Upper Colorado River Basin in 2008

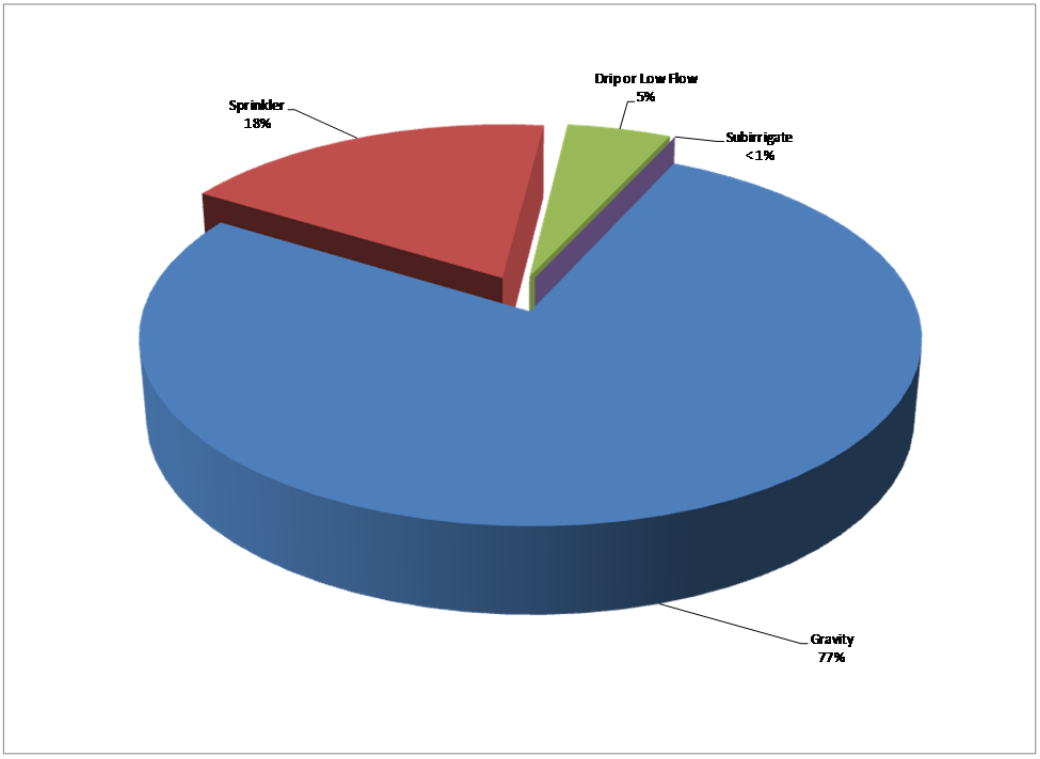

Figure 8. Irrigation Application Methods in the Lower Colorado River Basin in 2008

Table 3. Benefits in Improvements Made in Energy and Water Conservation in last 5 Years*

	Upper Colorado WRR 14		Lower Colorado WRR 15	
	2003	**2008**	**2003**	**2008**
Number of Farms Reporting	2,761	3,476	1,213	1,291
Number of Irrigated Acres Improved	502,148	525,153	479,263	520,077
Acre-feet of Applied Water Represented	829,455	1,066,886	2,194,766	2,833,633
Percent of Farms Reporting				
Improved Crop Yield or Quality	50%	59%	68%	64%
Reduced Energy Cost	10%	16%	34%	48%
Reduced Water Applied	40%	47%	62%	75%
Reduced Labor Costs	28%	41%	32%	54%
Reduced Fertilizer or Pesticide Losses	12%	15%	11%	30%
Reduced Soil Erosion	36%	37%	47%	59%
Reduced Tailwater	25%	34%	30%	39%
Other	21%	16%	6%	1%

*Information from the FRIS is based on a stratified sampling of surveyed responses, so Table 3's results are not the result of a census of all operations.

The upper portion of Table 3 summarizes adoption by listing the number of farms, number of acres improved and the acre-feet of applied water represented by respondents. Between 2003 and 2008, improvements increased in both WRR 14 and WRR 15. The size of improved acres is significant considering that the Upper CRB reports roughly 1.36 million irrigated acres in total and the Lower Colorado has slightly more than 930,000 in total.

The lower portion of the table is the proportion of respondents who note a particular benefit from the adopted practice. (Respondents may check all that apply, so the rows will not sum to 100 percent). The vast majority of respondents indicate that their improvements resulted in increased yields, and that the amount of water applied decreased, especially in the Lower CRB (62 percent in 2003 and 75 percent in 2008). The timing and pattern of return flows to the CRB River Basin were certainly influenced by the improvements – increased yields necessarily mean that season long consumptive use has increased, and reduced applied water is likely to result in decreased diversions/pumping from water sources as well as smaller return flows and diminished aquifer recharge. Positive environmental benefits from the improvements include reduced soil erosion and reduced loss of fertilizer and pesticide. The farms' profitability is enhanced by higher yields, reduced energy cost, and reduced labor and energy costs.

Respondents to the FRIS are asked to report the barriers that prevented them from adopting water or energy conservation practices. Localized drought may play a significant role in explaining these differences between years, as Table 4 illustrates. In the 2003 report, the barrier 'investigating improvements not a priority' was reported by less than 10 percent of respondents, but this increases to

more than 40 percent in the Upper CRB and nearly 50 percent in the Lower CRB in 2008. The recent liquidity crisis in agricultural lending may explain the dramatic increase in 'cannot finance improvements' between 2003 and 2008. Asymmetric responses between the Upper and Lower CRBs are of particular note. In the Upper Colorado region, the share of respondents indicating 'uncertainty about future availability of water' decreased, but it increased for respondents in the Lower CRB. Likewise, 'will not be farming long enough to justify improvements' was reported by 16 percent of respondents of the Lower Colorado in 2008, far above responses in 2003. The impacts of urbanization may play a role in the disparity – simply put, the Lower CRB is experiencing greater competitive pressure from growing cities for agricultural land and water.

Table 4. Barriers to Adopting Water or Energy Conserving Practices
Percentage of Farms

	Upper CO WRR 14		Lower CO WRR 15	
	2003	**2008**	**2003**	**2008**
Investigating improvements not a priority	9%	42%	8%	48%
Risk of reduced yield or poor crop quality	6%	4%	6%	15%
Physical field/crop condition limits system improvements	8%	9%	9%	12%
Improvements will not reduce costs enough to cover installation costs	19%	13%	11%	6%
Cannot finance improvements	12%	27%	8%	41%
Landlord will not share in cost	2%	2%	9%	6%
Uncertainty about future availability of water	15%	7%	13%	19%
Will not be farming this operation long enough to justify improvements	2%	4%	3%	16%
Other	6%	28%	11%	25%

Viewed as a summary, USDA data provides different narratives for the Upper CRB and the Lower CRB. In the Upper CRB, irrigated crop demand appears to be driven by livestock and dairy industries. Ownership is becoming increasingly fragmented with many small landowners in one category and a concentration of acres into a larger farm size in another category. Agricultural water use in the Upper CRB is likely to have increased in spite of a static crop mix, because irrigated acres have increased and yields improved, ensuring greater consumptive use by crops. However, quantifying agricultural water use accurately is difficult using existing secondary data, in part because the data is incomplete or the collection was not designed to be informative on this particular topic. Water conservation improvements have been made on more than 500,000 acres in the last five years, and these improvements have altered the timing and amount of diversions and associated return flows. Additional investment in water conservation practices may be hindered by a lack of financial resources and less urgency to conserve.

The Lower CRB enjoys a more diverse crop mix in part due to a longer growing season and its closer proximity to large urban centers. The Watersheds Report suggests a decrease in irrigated acres in the region, and reductions are not uniformly distributed. Indeed, fallowing is observed most frequently in lower-central Arizona near growing urban populations and in the IID. Urbanization is spurring demand for available land, so declining irrigated acres may have less to do with water scarcity than rates of land

conversion. While it is true irrigated acres have declined in the Lower CRB, water conservation improvements have tended to increase crop consumptive use, and alfalfa, a heavy water-using crop, has increased in overall acres and as a share of the total crop mix. Thus, it is difficult to determine if agriculture's water use is increasing in upper basin. As with the case of the Upper CRB, costs represent an important barrier to further improvement in water conservation, but so too is uncertainty about future water supplies and whether land owners will continue farming. Land ownership is shifting to many small farm owners, but the share of land and water resources is more heavily concentrated among the largest producers when compared to the Upper CRB.

Improved data collection and reporting will lend insight to the trends in agricultural water use in the Colorado River Basin. Specific suggestions include:

*Adjusting the USGS water use survey to include consumptive use and withdrawal estimates for each of the six digit Hydrologic Use Codes in the Upper and Lower CRB

*Aggregate Farm and Ranch Irrigation Survey data according to six-digit HUC and ensure a stratified sample by HUC

*Extend the FRIS to include a question on proportional water withdrawals so that researchers may learn if withdrawals are sourced from groundwater, surface water, direct diversion, canal system or reservoir

*Allow for the entire Census of Agriculture, including farm demographics, to be aggregated into six digit HUC's; this might be accomplished through a special tabulation of USDA-NASS personnel

*Extend Bureau of Reclamation consumptive water use estimates to distinguish between mainstem Colorado River consumptive use, consumptive use by tributary and consumptive use by alluvial and non-alluvial aquifer depletions

Water Transfer Overview

Water is a scarce resource in the Colorado River Basin and the rights to its use, for all intents and purposes, are fully allocated. As water demands change, water rights will be transferred in order to meet needs.

For CRB farmers and ranchers, water rights are an asset that generates financial returns from irrigated cropping. In this context, water is a capital asset, and the decision to sell an asset depends importantly on anticipated profits. The anticipated profits from irrigated agriculture often, but not always, form a reservation price for water right holders who may choose to sell. In contrast, the offer price of the water buyer depends on their own projected revenues and costs that include the conveying, storing and treating the resource. Voluntary transactions occur when the offer price exceeds the reservation price.

Expected profits are not the only ingredient in a water transfer decision, and two other factors deserve specific attention. First, urbanization not only creates demand for water resources from agriculture, but also competes with the agricultural sector for land. The decision to transfer water may be an afterthought when the true driver of the transfer was the decision to develop agricultural land into an

urban landscape. This is particularly true near the urban-rural fringe that surrounds growing cities, and we might expect transfers to accelerate as housing developments blossom. Secondly, the average age of a farm and ranch owner/operator continues to advance and is currently greater than 62 years in the Colorado River Basin. The decision to transfer water may have as much to do with adding liquidity to retirement assets as it does with agricultural profitability.

The following section focuses on the size and frequency of water transactions in the Colorado River Basin between 1988 and 2008. Data is the drawn from the Water Transfer Database housed at the Bren School of Environmental Science and Management at the University of California, Santa Barbara. A single clearinghouse does not exist for transactions in the Colorado River Basin states, rather a monthly trade periodical *The Water Strategist* reports on water transactions that occur in the West. The Bren research team categorizes transactions ranging from 1987 – 2009 and reports them in an Excel spreadsheet. This study has reduced the transactions accordingly so that:

- Transactions are limited to the period from 1988 –2008 as it appears that reporting is not complete in 1987 and 2008 was the reporting year for the FRIS
- The Bren database records transactions throughout the West; however, to the extent possible, transactions reported in the current study reflect transactions that occurred in the Colorado River Basin. This means that transactions are included for Arizona, California, Colorado, Nevada, Utah and Wyoming. Transactions that are reported in the Bren database for New Mexico all appear to take place in the Rio Grande Basin rather than the Colorado River Basin, so New Mexico transactions are not included. An additional research opportunity is to verify that each transaction in the data set is in the Colorado River Basin, but this has not been completed at this time.

The adjusted dataset includes 3,291 transactions and approximately 23.5 million acre-feet (AF) transacted. The following section is an overview of transactions by state, year and transaction type (sale, lease and exchange), as well as the principle use of buyer and seller (agriculture, environment, municipal).

Colorado River Basin Water Transactions

All transactions used in this analysis are illustrated in Figure 9, which lists the total acre-feet transacted in each year with column bars, and the number of transactions within a year is represented by a line. The number of transactions follows an increasing trend from 1988 to 2008, but the volume of acre-feet traded within each year ebbs occasionally and then increases again. These cycles tend to follow periods of economic growth with particular peaks of acre-feet traded in 1991, 1994, and 2000. A smaller volume of water has been traded in recent years, in spite of a peak number of transactions, suggesting that the average size of transactions is falling.

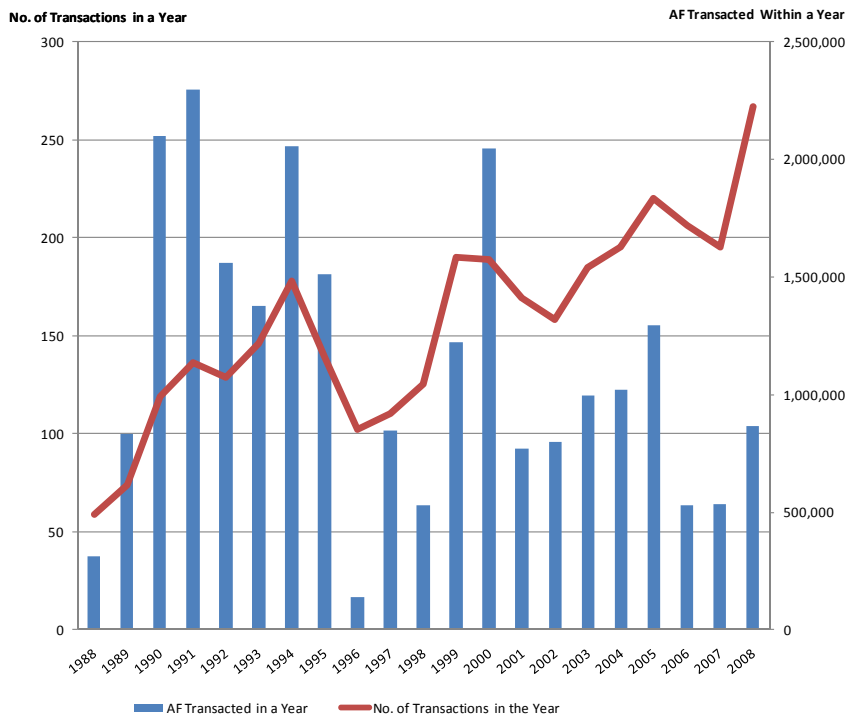

Figure 9. Yearly Volume and Number of Selected Transactions (1988 – 2008)

Individual state transactions follow a similar pattern. In most states, the number of yearly transactions has been increasing since 2003. Intensive transaction activity is observed in 1990 - 1995 in Utah, in Colorado from 1993-1995, California from 1991-1992 and Arizona from 1994-1995. The differences in timing may reflect regional differences in rates of municipal development. The differences do not seem to correlate to noteworthy periods of poor profitability in irrigated cropping that occurred in the years 1997, 1998, 1999, 2002, and 2006. In this sense, it may be that buyers rather than sellers were driving these voluntary transactions.

Sales, Leases and Exchanges

The Bren database categorizes transactions into three types: sales, leases and exchanges. In the time period 1988-2008, sales constitute the largest share of the number of transactions (68 percent) but only 11 percent of the volume of acre-feet transacted via sales. Leases comprise 25 percent of the transactions, but 85 percent of the volume of transactions.[5] Leases are of varying lengths, and while a few instances of 100 year leases exist, 78 percent of leases are for one year, and nearly 90 percent of all leases are ten years or less. Exchanges represent only 3 percent of the number of transactions and roughly 6 percent of the volume of acre-feet transacted.

Examination of transactions over time suggest that sales are occurring less frequently than before, and leases and exchanges are relied upon more frequently. Figure 10 represents the number of water right

[5] In this study, the water quantity in a lease is reported in terms of the expected average annual flow.

sales within a year and the amount of acre-feet transacted. Most recently, the number of sales has declined, unlike the number of leases and exchanges that have taken place (Figures 11 and 12). Perhaps the decrease in sales reflects a moderating rate of urbanization, reduced expectations of future demands, greater diversification in water supply sources, and the beginnings of a liquidity crisis in public finance.

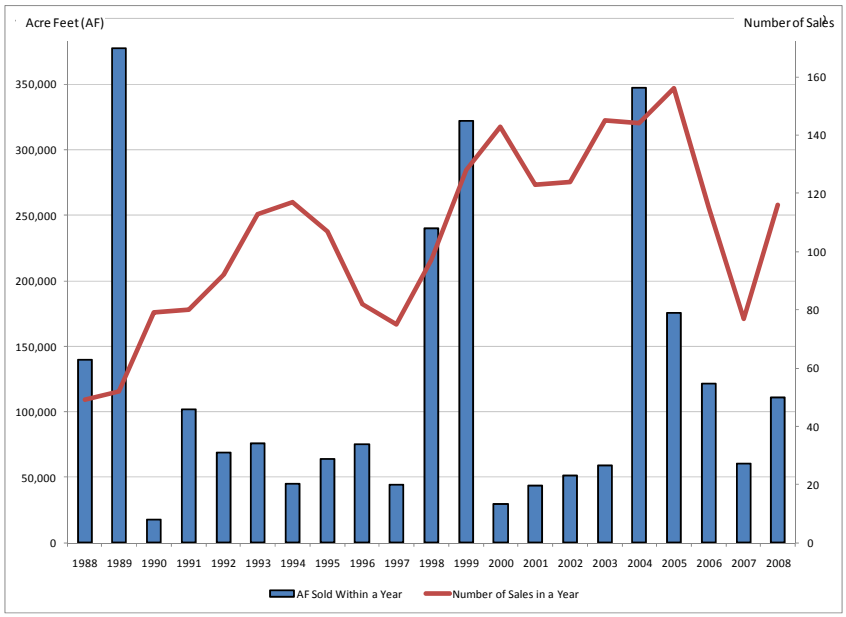

Figure 10. Sales of Water Rights and Acre-Feet Transacted (1988 – 2008)

Lease transactions are increasing in number, especially after 2004, but the amount of water transacted has decreased substantially since the mid-1990s except for in 2000 (Figure 11). Exchanges, which make up a small proportion of all transactions, increased substantially from 2005 – 2007 (Figure 12). Future analysis might be able to uncover factors driving the shift toward shorter-term transactions in lieu of outright purchase of water rights. It may be that actual water demand has not met forecasted expectations, either because of decreasing migration to the West or because municipal users have been able to moderate demand through conservation. It may also be more costly to acquire water via sales because of increasing costs to store, convey and ship water, particularly when large-scale investment in infrastructure are needed. Lastly, the risk of failing to acquire firm supplies through temporary transactions has lessened vis a vis the cost of purchasing water rights. From a seller's perspective, leasing water preserves the option value of selling the water right later for an increased future value.

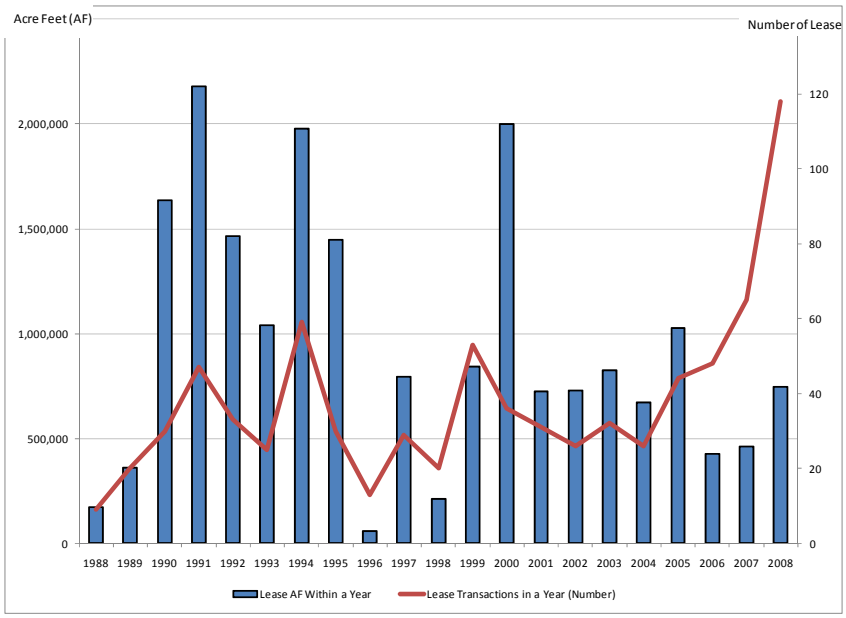

Figure 11. Number of Leases and Acre-Feet Leased Within a Year (1988-2008)

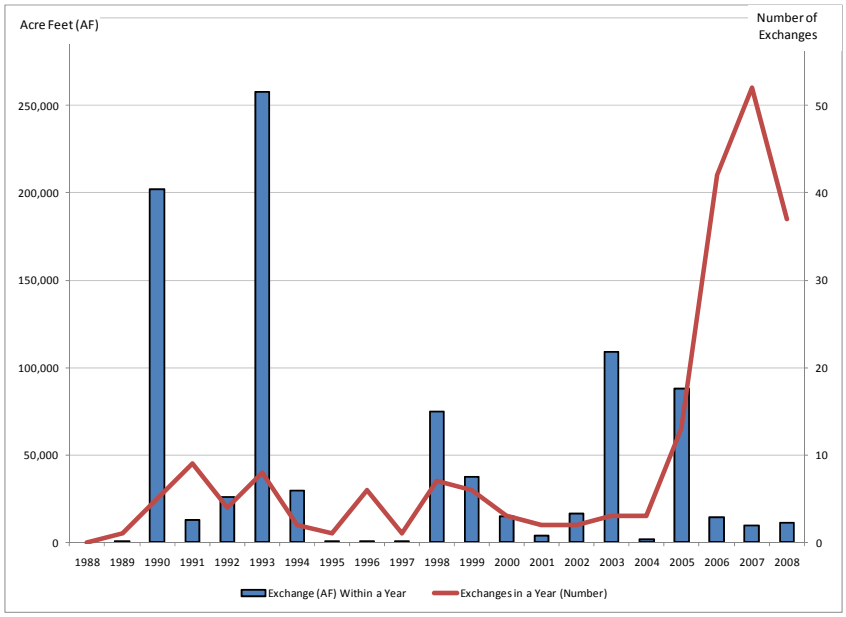

Figure 12. Number of Exchanges and Acre-Feet of Exchanges with a Year (1988-2008)

An interesting comparison between water right sales and leases can be made when these transactions are summarized into volume categories. Figure 13 illustrates the comparison by charting volume categories on the horizontal axis and the percentage of transactions that fall within these categories measured as columns bars. Sales of water rights tend to be grouped in the smaller size categories with slightly more than 75 percent of all sales falling into categories of 100 AF or less. In contrast, leases involve much larger transaction sizes – less than 10 percent of all leases are less than 100 AF in size.

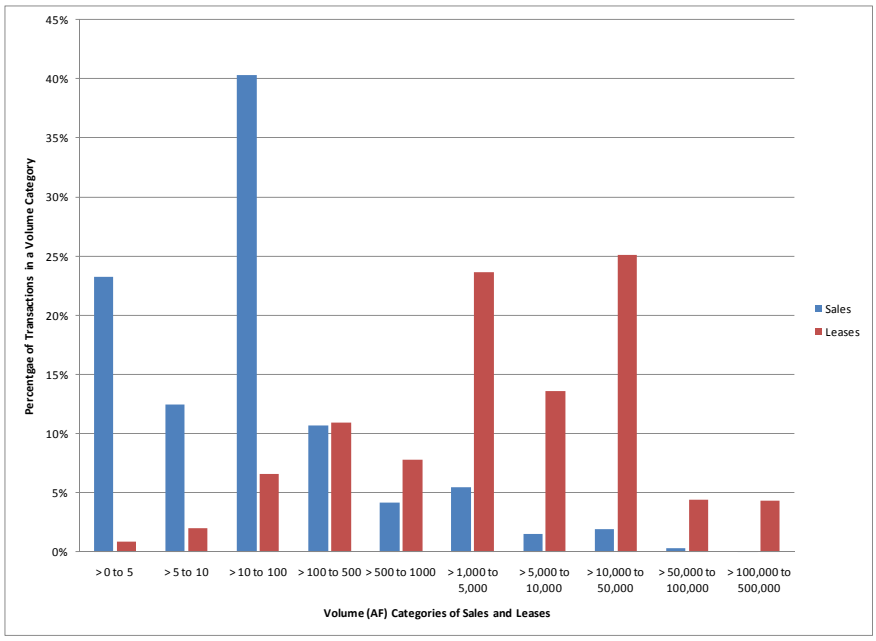

Figure 13. Sales and Lease Transactions by Acre-feet Category (1988-2008)

Comparing Transactions in Different States

The size of a transaction will depend importantly on expectations of future water demand, the perceived scarcity of local water resources, and the costs to collect, convey, store and treat water, as well as the transactions costs related to water right adjudication or change of use. It's no surprise that the size of transactions (e.g., sales, leases and exchanges) might be different between states that have different rates of urbanization, different climates, disparate concentrations of water rights among holders (i.e., ownership is far more fragmented in Colorado when compared to California) and distinct legal institutions. An example of this is found in Figure 14, which illustrates water right transactions in Colorado and California according to volume category.

Transactions in Colorado tend to be much smaller than those experienced in California, perhaps because the vast majority of Colorado transactions occur under the CBT project. Within the CBT, water rights may be exchanged with relatively low transactions costs, which increases the frequency of transactions and makes smaller transactions more economically palatable. Of the transactions examined in this study, approximately 64 percent occurred in Colorado and 20 percent occurred in California. However, far more acre-feet were transacted in California relative to Colorado and other states (Table 5).

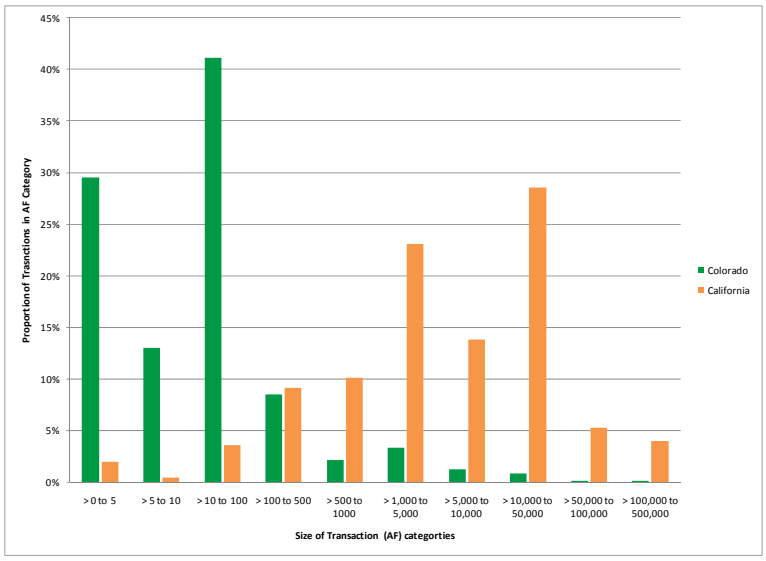

Figure 14. Colorado and California Water Right Transaction by AF Size Category (1988-2008)

Table 5. Percentage of Transactions and Percentage of Acre-feet Transacted in Each State (1988-2008)

	Arizona	California	Colorado	Nevada	Utah	Wyoming
Number of Transactions (1988-2008)	218	644	2,113	177	77	61
Percentage of Transactions (1988-2008)	7%	20%	64%	5%	2%	2%
Percentage of Acre-feet Transacted (1988-2008)	36%	53%	6%	1%	2%	2%

Water Transactions in which Agriculture is the Supplier

Agriculture continues to divert and use the vast majority of water in the West and the CRB. With supplies fully appropriated, reallocation among users is one means of meeting increasing demands among agricultural, environmental and municipal interests. Agriculture was the source of at least 82 percent of the transactions recorded in the Bren database between 1988 and 2008, and agriculture supplied 68 percent of the acre-feet of water that was transacted. Figure 15 indicates the pattern of transactions through time in which agriculture provided water to other parties, including agriculture interests.

While it is true that transactions sourced from agriculture are increasing in recent years (Figure 15), it should be noted that transfers do not necessarily imply a movement away from agricultural use. Of the transactions in which an agricultural water right holder was the supplier, about 44 percent of the acre-feet that were transacted went to an agricultural entity, followed by municipal use (29 percent) and environmental use (26 percent). [6]

[6] It should be noted that any one transaction might involve an agricultural, environmental and municipal use because *The Water Strategist* reports transactions as a bundle rather than apportioning based on the actual water right holder. An alternative analysis might consider only transactions in which a single receiver is present, but this would miss combination transactions. This study has chosen to report all transactions rather than reducing the sample size.

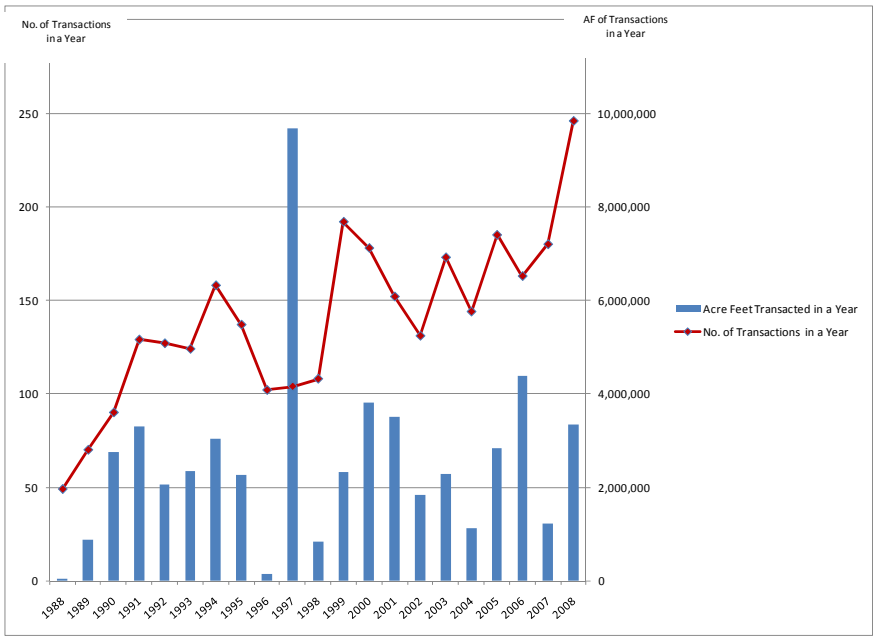

Figure 15. Number and Acre-feet of Transactions in which Agriculture is the Supplier

The previous transactions included sales, leases and other exchanges of agriculture water rights. As might be expected, sales are the most frequently reported type of transaction, but over time leases and exchanges have been gaining popularity (Figure 16). The incidence of each agricultural transaction type varies by state. Water sales are the most popular form of transaction in Colorado and leases occur more frequently in California and Wyoming.

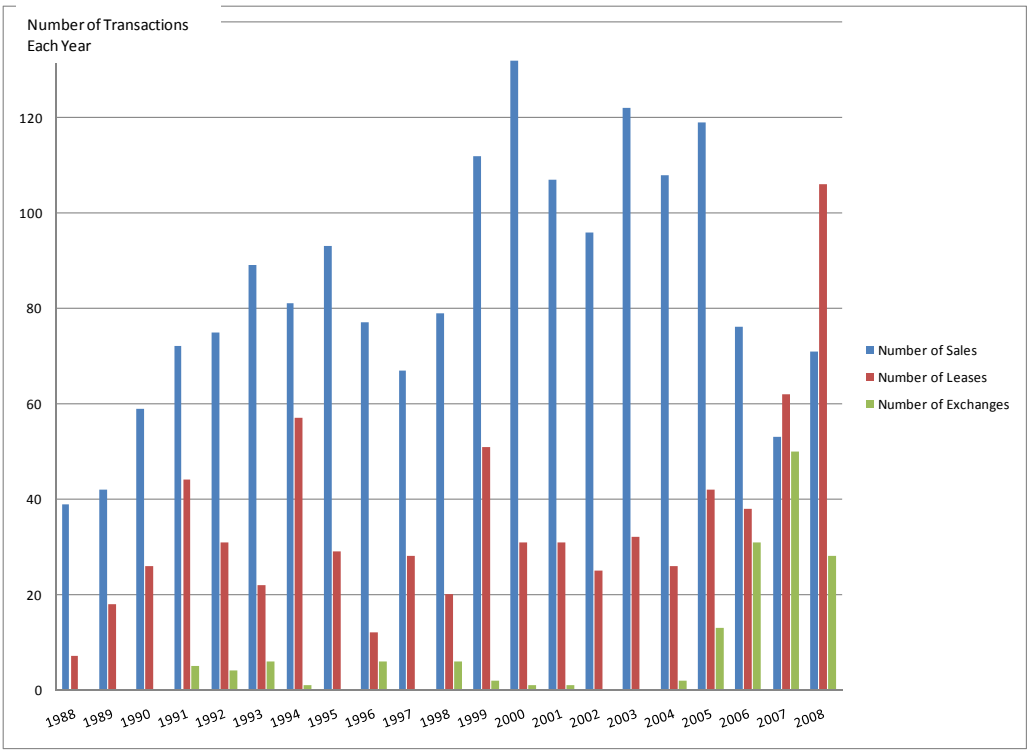

Figure 16. Number and Type of Transaction when Agriculture is Supplier

Of particular interest are sales of water rights from agriculture to municipal use. These voluntary transactions may be the result of increasing urbanization in the West and are linked to the reduced acreage in irrigated cropping illustrated earlier in the report. As noted in Figure 17, the number of sales from agriculture to urban interests follows an increasing trend from 1998 to 2008, but the acre-feet transacted is declining. Perhaps municipal suppliers are beginning to seek less permanent transactions for meeting increasing demands as the cost to transfer water becomes more expensive. Likewise, planners' expectations for population growth may be adjusting downward, and these water providers are seeking a broader portfolio for securing water supplies that include conservation and reuse.

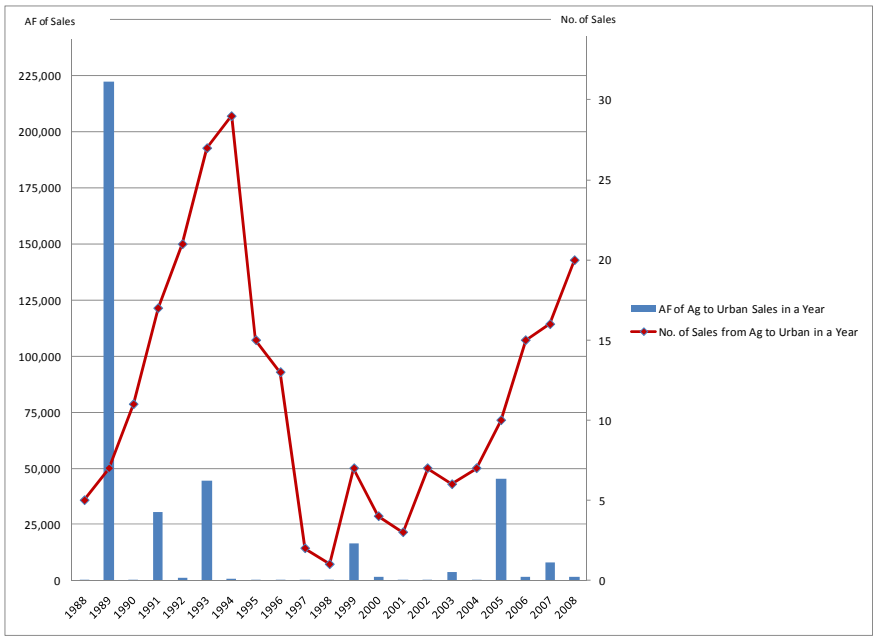

Figure 17. Volume and Number of Transactions from Agriculture to Municipal Water Right Holders

Study Summary and Limitations

The Colorado River is a vital resource of water for agricultural, environmental and municipal interests. Increasing demands among users and climate variability are driving a reallocation of use that will persist for some time. This study provides some insights to stakeholders and policymakers about the current status and trends of water use in the basin with particular attention to agriculture, the largest water diverter and consumptive user. Summary points include:

- Irrigated agriculture in the Upper CRB is not declining - irrigated acres increased slightly between 2002 and 2007. However, in particular areas (most notably lower-central Arizona), a significant reduction in irrigated agriculture has occurred. This may be a product of land conversion near a growing urban area as much as it is water scarcity.
- The distribution of farms is trending toward an industry with many small irrigated farms that produce a smaller share of household income, and fewer large farms that support the majority of irrigated cropping. It is unclear how this might influence future conservation and water management practices or how it might influence future water transactions.
- It can be argued that agriculture's consumptive use of water increased in the CRB in the time period from 2003 to 2008 due to increased irrigated acres, a crop mix shifting toward more water-using crops and increasing yields. Consumptive use is declining in areas with fewer irrigated acres. The water applied by agriculture may well have decreased with the shift toward sprinkler and drip irrigation technologies.
- Water transactions are increasing in the CRB, but the average size of transactions is declining. The number and volume of water transacted varies according to state, in part due to differential rates of urbanization and institutional structures.

- Sales are the most frequently used transfer mechanism, but a greater volume of water is transferred using leases. The trend is toward increased leasing and decreasing use of sales as a transfer mechanism.
- Agriculture is the predominant water right holder in the CRB, and agriculture water right holders are most often the supplier in a transaction. Agricultural users are the most frequent receivers of water in transactions, but municipal to agricultural transactions are increasing.

Limitations

This study makes use of three secondary data sources: the USDA Census of Agriculture, the USDA Farm and Ranch Irrigation Survey, and water transactions data compiled by the Bren School of Environmental Science and Management at the University of California, Santa Barbara. Inference drawn from this data is limited by its scope and the manner in which it is summarized. More specifically:

- Agricultural statistics represent a snapshot in time and are not a dynamic portrayal of events. As an example, significant drought in the CRB may mean that irrigated cropping in 2002 was less than might be expected under a "normal" water year. Similarly, economic returns can influence the amount of cropland that is irrigated versus that which is fallowed.
- It is difficult to link irrigated cropping statistics to the source of water. In particular, irrigation water may come from river diversion, reservoir storage, alluvial groundwater or confined aquifer sources, if not a combination of all of these. As a result, it is difficult to use these statistics to draw conclusions of how the mainstem flows of the Colorado River Basin are impacted by changes in irrigated cropping reported in this study.
- The Farm and Ranch Irrigation survey is very useful in providing insight into some of the production practices used on irrigated farms in the CRB. However, it is a stratified sampling of farms and not a census of practices. Water use statistics do not include data on water conveyance (ditches, canals, pipelines) other than on-farm application. A future opportunity is to use the USDAS-ERS-ARMS survey data to uncover additional insights into management practices. This data is available for use only in special tabulations or with special training and access at a limited number of locations.
- The water transactions data are limited to the states of AZ, CA, CO, NV, UT and WY, but the recorded transactions need not fall in the hydrologic range of the CRB. This is an opportunity for future research.
- Care needs to be taken when linking the ownership of a water right to the use of that right. This document reports ownership by agricultural, environmental and municipal use, but it need not be the case that the water is used for that purpose. As an example, 66 percent of water units in the Colorado Big-Thompson project are owned by municipal entities, but 60 percent of water deliveries are made for agricultural use. In Colorado at least, water designated as a "municipal" use may actually be used for irrigation.

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