Water Sustainability in the Rockies:

Agriculture to Urban Transfers and Implications for Future Water Use

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THE 2007 COLORADO COLLEGE STATE OF THE ROCKIES REPORT CARD

Water—or more specifically the lack of it—has greatly shaped the American West. From the early settlers lured by the promise that "rain follows the plow" to recently arrived suburbanites expecting lush lawns and fountains in desert communities, access to clean, reliable water has dominated the region's economy, culture, and settlements. In the *2007 Colorado College State of the Rockies Report Card*, we examine water allocation in the Rockies, with emphasis on current water use patterns and agriculture to urban transfers.

The eight-state Rockies Region receives on average 30 inches of annual precipitation. However, as any resident or visitor to the Rockies knows, water availability varies widely by place, season, and year. Winter alpine snowpack melts into streams, rivers, and reservoirs, with some of this water diverted as far away as California or the eastern flank of the Rockies. In other places, scarcely any precipitation falls, and agriculture or human settlement would be impossible without a massive water transfer and pumping infrastructure. Las Vegas, for example, with its continuously running fountains and green golf courses, receives less than five inches of precipitation per year. Rocky Ford, Colorado, a town discussed later for its transfer of water rights to the city of Aurora, receives less than 12 inches a year. Figure 1 and Table 1 illustrate the general precipitation patterns in the Rockies relative to the rest of the U.S. This region shows minimum precipitation values among the lowest in the U.S. and a wide range in statewide precipitation.[1] The insert map shows that many of the counties have, on average, less than 20 inches of annual precipitation, the threshold below which irrigation is essential to grow crops. To compensate for low and sporadic precipitation, the region has historically transferred

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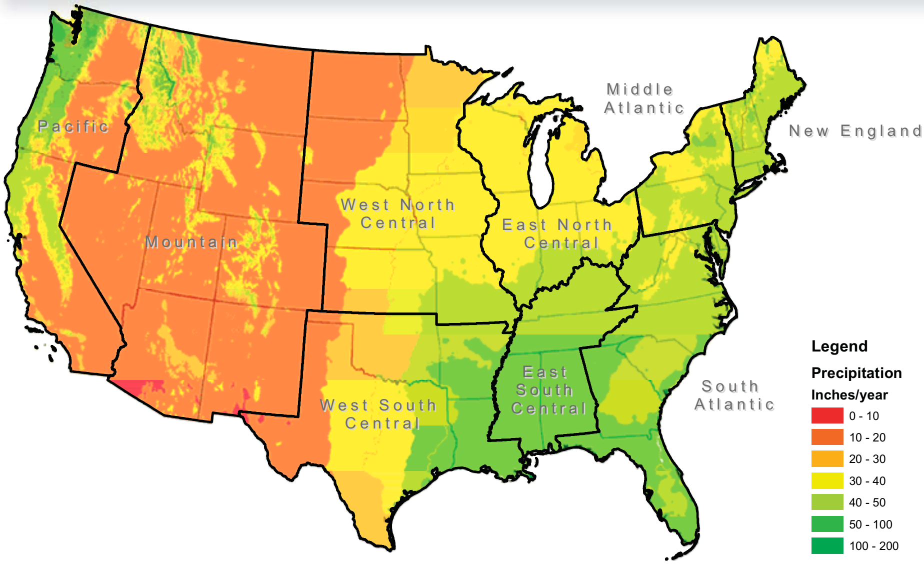
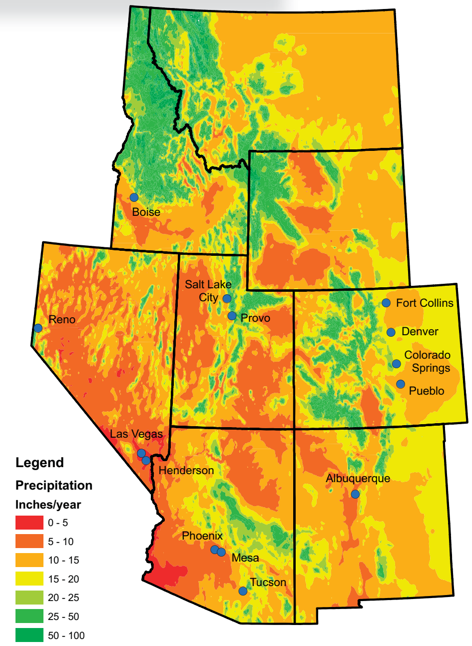
Figure 1
Average Annual Precipitation for the Conterminous United States and the Rockies, 1961-1990
Source: National Atlas of the United States





Only cities with populations greater than 100,000 are shown (2000 U. S. Census)

Table 1
Average Annual Precipitation in the U.S. by Region, Inches per Year
Source: National Atlas of the United States

Census Division	Mean	Minimum	Maximum
East North Central	32.6	27.5	42.5
East South Central	56.7	32.5	85.0
Middle Atlantic	43.9	30.0	65.0
Mountain	30.1	5.0	110.0
New England	48.8	32.5	110.0
Pacific	51.1	5.0	200.0
South Atlantic	49.7	32.5	110.0
West North Central	30.9	12.5	55.0
West South Central	38.5	10.0	75.0

water from areas of abundance (e.g., areas of alpine snowpack, major rivers, or aquifers) to areas of scarcity (semi-arid plains and deserts). These water transfers are increasingly important as urban areas rapidly develop in arid and semi-arid climates.

With increased population growth, how will the Rockies share water among several competing needs? One useful concept provided by hydrologists at the U.S. Geological Survey (USGS) is "water sustainability," which accounts for variable water supplies and balances human and environmental needs. As stated by Anderson and Woosley, "a sustainable water supply for a community ideally would provide enough water to support population and economic growth and be sufficient to endure protracted periods of drought."[2] They also note that for true water sustainability, water must be provided to natural hydrologic and ecological systems, such as groundwater recharge or riparian habitats:

> *Water availability traditionally has meant securing a volume of water to meet a current and projected demand on the basis of existing and projected usage. An added challenge today for water and natural-resource managers is that water is expected to be available for non-extractive uses, such as maintaining groundwater levels beneath riparian areas, preventing freshwater-saltwater interfaces from migrating landward, maintaining flows and water temperatures to support fishery needs, or restoring flooding to dammed rivers – all uses requiring prescriptions for which there is little historical precedent or experience.*[3]

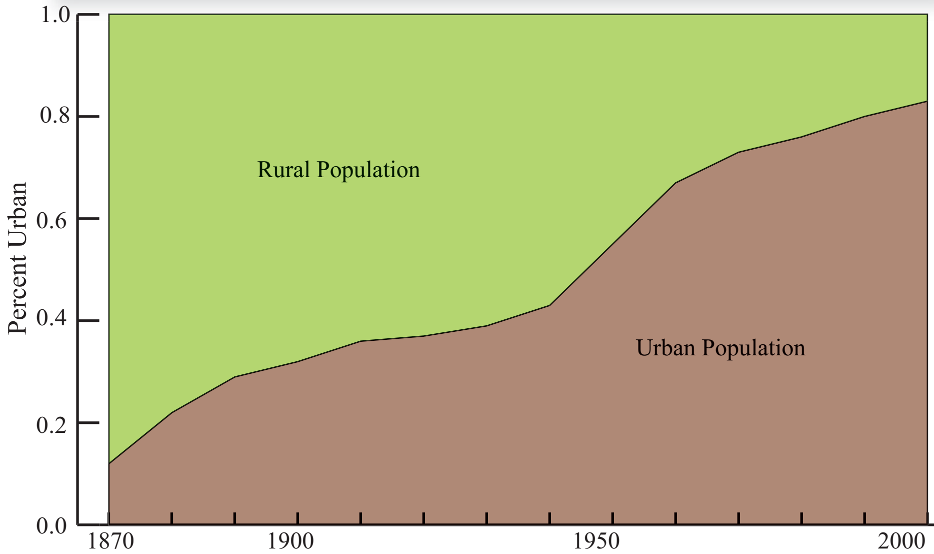
While providing adequate water to natural systems should ensure greater reliability of future water sources, it also is another demand on a limited resource.

Although present water use in the Rockies is dominated by irrigation, as discussed below, future regional population growth will likely exceed that in other regions and will be concentrated in urban areas. The Rockies Region includes many of the fastest-growing states in the U.S., such as Nevada, Arizona, Colorado, Utah, and Idaho.[4] Despite its rural agricultural heritage, 83 percent of the Rockies population was classified as urban in 2000, and this percentage continues to increase (Figure 2). However, agricultural water use is much greater than current urban water consumption. For the Rockies Region, just 7 percent of agricultural water use is equivalent to twice the municipal water use in 2000, and this percentage varied from 1 percent in Montana to 30 percent in Nevada.[5] Further development of urban areas will increase demands for the region's limited water, likely removing more water from agriculture while also requiring greater urban conservation efforts for a sustainable future.

New urban water demands, combined with historically low agricultural commodity prices, have allowed urban financial resources to out-bid agriculture, resulting in transfers of water from agriculture to cities. These water transfers may involve the purchase or

Facing Page Photo: Homestake Creek in the White River National Forest, site of Homestake Reservoir. © Ken Papelo, courtesy of the Rocky Mountain News

Figure 2
Percent Urban vs. Rural Population of Rockies States 1870-2000
Source: U.S. Census Bureau



lease of agricultural water rights by municipalities. Permanently removed from agricultural lands and rural areas, water diversions to cities can harm rural economies by diminishing tax revenue, reducing retail trade associated with agriculture, and spurring emigration of rural residents. But creative new tools and techniques are being developed to help urban and rural areas successfully coexist by sharing water.

While these tools are being developed, both sides must examine their water consumption and the associated impacts on water supply and quality. Sprinkler irrigation of agricultural fields, for example, can result in water losses of only 20 percent, depending on the relative humidity, air temperature, wind speed, and irrigation system used.[6,7] Agricultural practices use can also degrade water quality, via nitrate runoff from fertilizer use, pesticide runoff associated with weed or disease control, and salinization of discharge water. Urban areas also often use water in ways that flout conservation concerns. Thirsty lawns and evaporative losses consume more than half of domestic household water use in arid climates. For example, outdoor water use in Scottsdale, Arizona, accounts for 72 percent of residential water consumption.[8] Urbanization can also degrade water quality, through storm-water discharges, industrial releases of aquatic toxins, and sewage discharges.

The *2007 Colorado College State of the Rockies Report Card* addresses these issues. First, we consider water use in the Rockies by examining the dominant water use categories, patterns in other U.S. regions and the Rockies, and changes in water use through time. Second, we discuss water allocation strategies, including agriculture to urban transfers and conservation initiatives. In future reports, we will focus on other key dimensions of water sustainability, including water for natural ecosystems, water use for recreation and tourism, and water quality in the Rockies.

Estimated Water Use in the United States

Before discussing future water use in the Rockies, we must consider regional water use patterns in the United States as a whole. The USGS estimated that in 2000 total water withdrawals nationwide equaled 408 billion gallons per day (Bgal/d).[9] These withdrawals originated either from surface water (e.g., rivers, streams, lakes, and reservoirs) or groundwater (e.g., aquifers), which, in 2000, comprised 79 percent and 21 percent of total water withdrawals, respectively.[10] The USGS further divides water withdrawals into eight water use categories: public supply, domestic supply, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric power.

In 2000, thermoelectric power accounted for the largest percentage of water withdrawals in the United States (48 percent of the total), followed by irrigation (34 percent), public supply (11 percent), and industrial uses (5 percent) (see Figure 3). Cumulative water uses for domestic supply, livestock, aquaculture, and mining accounted for less than 2 percent of the total.[11]

As shown in Figure 4, total water withdrawals largely stabilized between 1980 and 2000. From 1950 to 1980, withdrawals increased 144 percent from 180 to 440 Bgal/d.[12] In 1985, total withdrawals dropped to 399 Bgal/d. Withdrawals have fluctuated by less than 9 Bgal/d between 1985 and 2000,[13] despite population increases. Changes in irrigation and thermoelectric power withdrawals largely account for this trend.[14] Nationwide, the number of irrigated acres has followed water use patterns, doubling from 1950 to 1980 and remaining constant from 1980 to 2000; a 7% increase in irrigated acres occurred from 1995 to 2000.[15] Water withdrawals for thermoelectric power plants have also stabilized since 1980, thanks to regulation of this industry and technological advances. As a response to both federal legislation requiring stricter water quality standards and concerns over water shortages, the thermoelectric power industry has largely switched from once-through cooling systems to closed-loop systems that can recycle the water in their systems, withdrawing additional water only as needed to replace losses.[16]

The number of U.S. residents served by public water supplies has also increased. The nation's population grew by 85 percent (151 to

Figure 3
Share of Total Water Withdrawals in the United States by Category, 2000
Source: U.S. Geological Survey

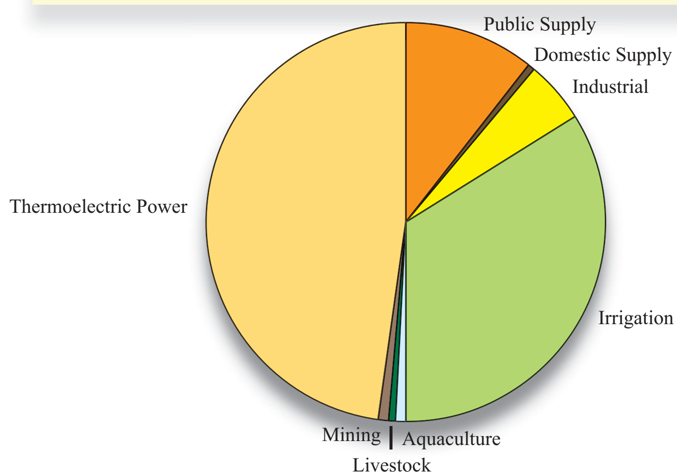


Figure 4
Trends in Population, Total Water Withdrawals, and Selected Categories, 1950-2000
Source: U.S. Geological Survey

281 million people) between 1950 and 2000, while during the same period the number of persons served by public water supplies tripled.[17] By the USGS definition, a public water supply can be either publicly or privately owned and supply water for domestic, industrial, commercial, or other purposes. However, in contrast to direct water withdrawal by a private user, the public water supply must provide water to at least 25 people or have a minimum of 15 service connections.[18] The growth trend in public supplies may relate not only to population growth but also to urbanization. As more Americans move to cities, the amount of water supplied by public entities has replaced self-supplied withdrawals from wells.

Estimated Water Use in the Rockies Compared to the U.S.

Figure 5 shows the geographic distribution of water withdrawals by U.S. region. Of the nine U.S. Census divisions, the Mountain Division (which corresponds to the eight-state Rockies Region) was responsible for 15.7 percent of total water withdrawals, ranking third behind the South Atlantic Division (16.9 percent) and the Pacific Division (15.9 percent).[19]

Water withdrawal patterns in the Rockies differ from those in the rest of the nation, as illustrated in Figure 6. Irrigation comprises the largest water use in the Rockies, equaling 87.2 percent in 2000. Thermoelectric power accounts for only 1.2 percent of total withdrawals, ranking fourth behind irrigation, public supplies, and aquaculture.[20] As shown in Figure 7, the historical trends in regional water use revealed (1) declining irrigation water use in the 1990s and (2) declining total water withdrawals over the same period. The correlation between total water withdrawals and irrigation withdrawals demonstrates the importance of irrigation in the West. Declines in agriculture in the agriculture sector may be one explanation for reduced irrigation withdrawals; the *2006 Colorado College State of the Rockies Report Card* notes that the region lost

Figure 5
Share of Total Water Withdrawals by Census Division, 2000
Source: U.S. Geological Survey

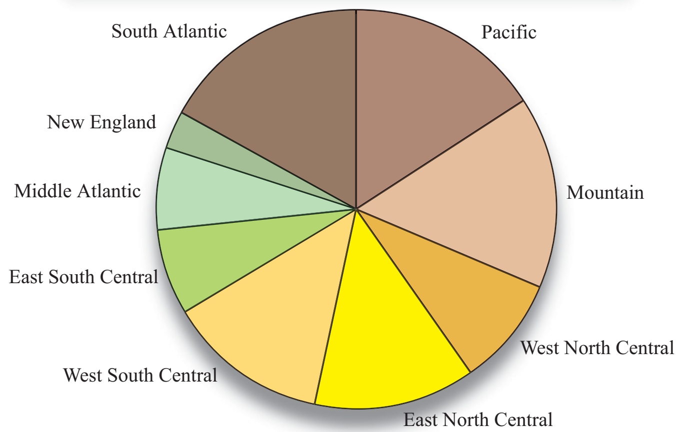


Figure 6
Water Withdrawals in U.S. by Census Region, 2000
Source: U.S. Geological Survey

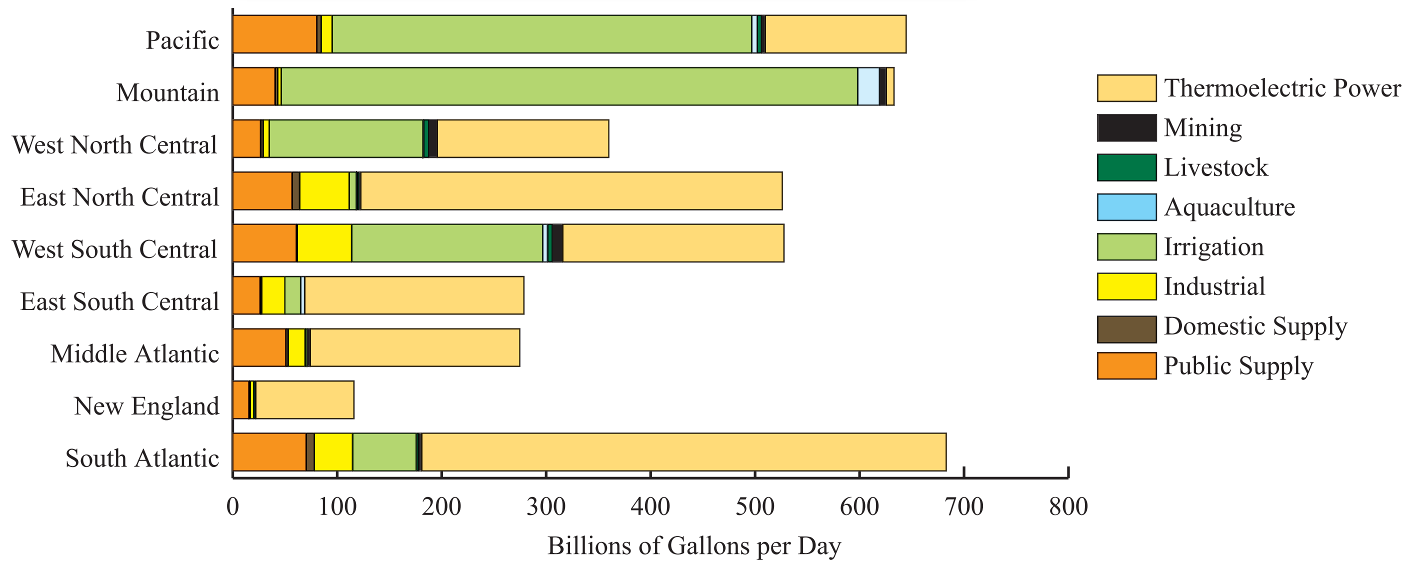


Figure 7
Change in Population, Total Water Withdrawals, and Irrigation Withdrawals in the Rockies, 1985-2000
Source: U.S. Geological Survey

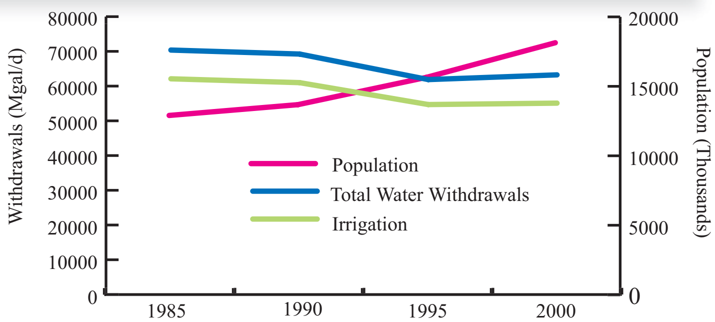


Figure 8
Change in Population and Public Supply Withdrawals in the Rockies, 1985-2000
Source: U.S. Geological Survey

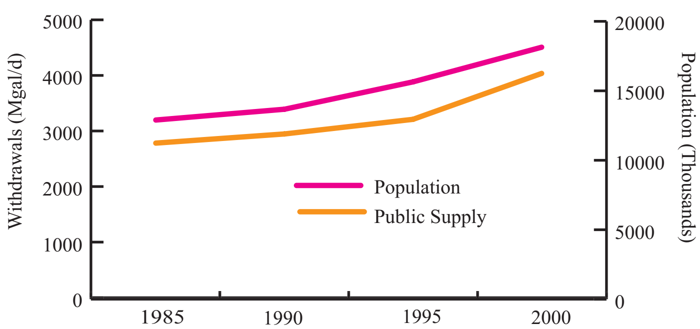
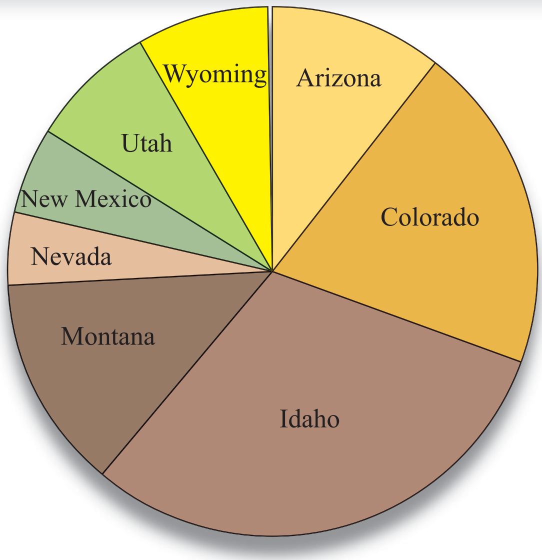


Figure 9
Share of Rockies Water Withdrawals by State, 2000
Source: U.S. Geological Survey



140,000 acres of farmland and ranchland annually from 1992 to 2002.[21]

Public supply withdrawals in the Rockies Region have increased steadily since 1985, but at a much higher pace than the national average (Figure 8). From 1985 to 2000, public supply withdrawals grew by 45 percent in the Rockies, approximately 2.5 times greater than the national average of 18 percent.[22] This high growth corresponds with the higher population growth in the Rockies relative to the U.S. average (2.8 times the national average) from 1980 to 2000.[23]

Estimated Water Use in the Rockies

Within the Rockies, Idaho had the highest total water withdrawals in 2000, equal to 30.7 percent of the total (Figure 9).[24] As shown in Figure 10 and Table 2, the majority of the Idaho withdrawals were for irrigation (87.7 percent of total withdrawals).[25] This large volume of irrigation withdrawals makes sense, considering that Idaho has the highest number of irrigated acres in the West and the fifth highest in the nation.[26] Colorado and Idaho together account for 50.9 percent of irrigated acres and 50.7 percent of total water withdrawals in the Rockies.[27] Idaho ranks second nationally in irrigation withdrawals, behind only California.[28] Thus, irrigation withdrawals dictate state water use patterns in the Rockies Region.

Public supply is the second highest water use in the Rockies, but only represents 6.4 percent of the region's total use. Arizona has the highest public supply withdrawals in the Rockies (27 percent). Combined, Colorado and Arizona account for 49 percent of the region's public supply withdrawals.[29] Although public supply represents a small percentage of total water use in this region, the accelerating and concentrated demands for reliable water supplies for the region's urban centers will create more tensions with agricultural water users.

Agricultural Transfers, Farm Economics, and Water Scarcity

Water use data collected by the USGS indicate the importance of agricultural water use in the Rockies. One option to address urban water supply problems is agricultural water transfers. Water transfers from agricultural to urban uses have been increasing in Western states due to urban growth, the declining agricultural economy, and groundwater overdraft concerns.[30] Other pressures on traditional water supplies include recent drought, fully appropriated rivers (where all water is reserved for existing water rights and other legal requirements such as interstate compact delivery requirements), and the decline of federal funding for large water projects. The lack of new water projects results in no additional storage capacity, providing abundant surface water during early spring but limited supplies in late summer.

Agricultural economics has been strongly affected by two factors: the decline of agriculture's profitability relative to other sectors and the concentration of agricultural operations into larger and more efficient units. In 1940, farm employment accounted for 26 percent of total employment in the Rockies, whereas in 2003 farm employment equaled only 2.6 percent of total employment.[31] The average farm size in the Rockies has also increased due to mechanization and economies of scale. In 1920, the average farm size was 528 acres, compared to 2,034 acres in 2000 (the historical maximum was 3,043 acres in 1975).[32] More efficient, larger farms and improvements in agricultural technology and inputs have led to higher crop yields and lower commodity prices, which have, in turn, promoted larger farms. Drought, natural disasters, and crop and livestock diseases have forced many smaller farms and ranches out of business.[33] For example, melon growers in Rocky Ford, Colorado, have suffered from low prices, storm damage, a salmonella scare, recurring drought, and warmer temperatures that harmed critical crops.[34] The significant economic pressures placed on agriculture over the last several decades have increased the importance of agriculture to urban water transfers.

Another motivation for agricultural water transfers is the ownership of senior water rights by Western farmers and ranchers. Since the early 1900s, most of the rivers in this region have been fully appropriated. To obtain a new water source, a city must purchase water rights from another entity (unless the city already owns undeveloped rights). The market value of the water right is largely determined by seniority. Seniority is based on the year the water right was established (known as the "priority date" or "appropriation date"): an 1865 water right is senior to an 1870 water right. Each year, the water user with the most senior right may use their full allocation, assuming the water source can provide it. Then the user with the next senior right can use their allocation, and so on. In times of water scarcity, junior right holders might not receive part or all of their allocation. Because the Homestead Act of 1862 attracted ranchers and farmers to Western lands in close proximity to rivers, these early settlers generally obtained the most valuable, senior rights.

Climate factors, including cyclical droughts and the possibility of human-induced global climate change, will also influence future water availability. Climate change may affect precipitation rates, the amount of snowpack available for spring runoff, and the timing of snow melt in the Rockies. *The 2006 State of the Rockies Report Card* featured a climate model showing a 50 percent reduction of April 1 snowpack by 2085, assuming

Figure 10
Water Withdrawals in the Rockies by State and Category, 2000
Source: U.S. Geological Survey

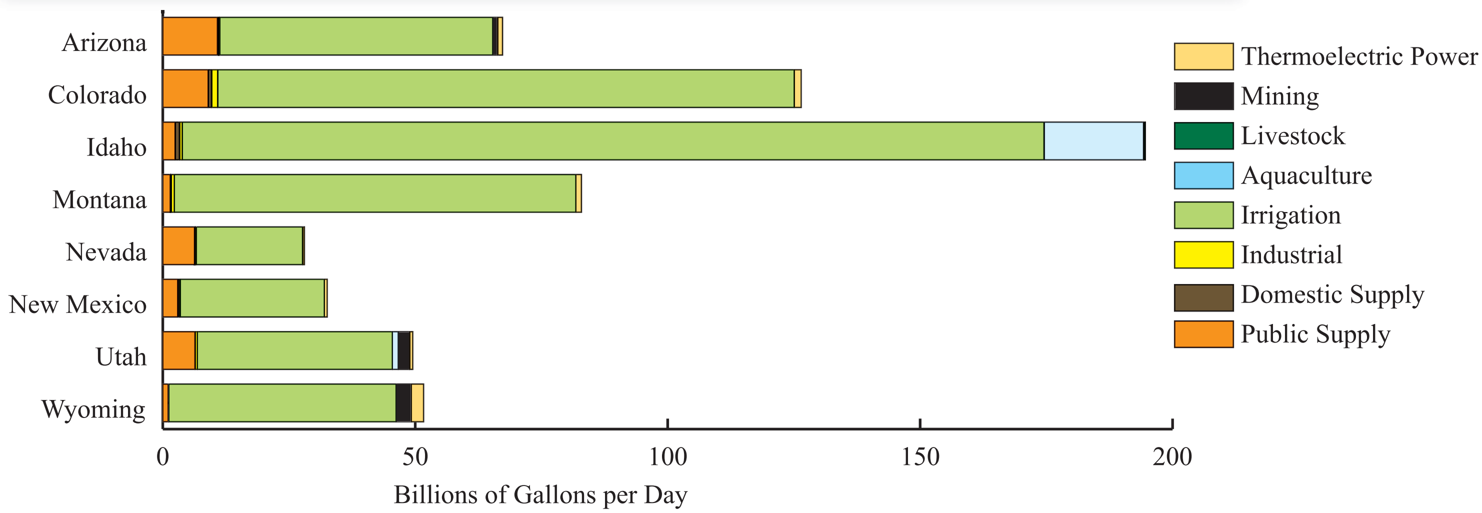


Table 2
Rockies State Water Use by Category (percent), 2000
Source: U.S. Geological Survey

State	Public Supply	Domestic Supply	Industrial	Irrigation	Aquaculture	Livestock	Mining	Thermoelectric Power	Total Mgal/d
Arizona	16.1%	0.4%	0.3%	80.3%	0.0%	0.0%	1.4%	1.5%	6,729
Colorado	7.1%	0.5%	1.0%	90.3%	0.0%	0.0%	0.0%	1.1%	12,645
Idaho	1.3%	0.4%	0.3%	87.7%	10.1%	0.2%	0.0%	0.0%	19,460
Montana	1.8%	0.2%	0.7%	95.9%	0.0%	0.0%	0.0%	1.3%	8,292
Nevada	22.4%	0.8%	0.4%	75.1%	0.0%	0.0%	0.0%	1.3%	2,805
New Mexico	9.1%	1.0%	0.3%	87.9%	0.0%	0.0%	0.0%	1.7%	3,257
Utah	12.9%	0.0%	1.0%	78.0%	2.3%	0.0%	4.5%	1.3%	4,950
Wyoming	2.1%	0.1%	0.1%	87.2%	0.0%	0.0%	5.8%	4.7%	5,166
Percent of Total Usage	6.4%	0.4%	0.5%	87.2%	3.3%	0.1%	1.0%	1.2%	100.0%

"business as usual" carbon dioxide emission growth rates and a medium sensitivity climate model.[35] An example of potential climate change impacts on the Rockies Region is shown for the river basins in Figure 11 and Table 3, including winter temperature, annual precipitation, and snowpack (as of April 1). Although major changes in snowpack are projected, the impacts on annual precipitation are more modest and range from river basins that may have increased total precipitation (e.g. the Pacific Northwest and Missouri) as well as some expected to have lower levels (e.g. the Arkansas-White-Red). Such projected variability will likely impact future water supplies, making the acquisition of senior water rights even more important to reduce users' risk of water shortages during times of drought.

Reliance on non-renewable groundwater also contributes to water supply problems. Many groundwater sources are not replenished by surface water flows. At the time of founding, many cities in the Rockies tapped into non-renewable groundwater given its close proximity and large apparent capacities. For example, the Denver Basin Aquifer, which serves a large portion of Colorado's Front Range, was estimated to contain approximately 300 million acre-feet of water (an acre-foot generally can serve one to three households for a year).[36] What planners and developers did not consider was that lowering the water table through groundwater withdrawals leads to higher pumping costs.[37,38] Several states in the Rockies are currently addressing the problem of decreasing groundwater supplies. For example, Arizona has sustainable pumping requirements for groundwater, and Idaho has limits on new groundwater pumping from the East Snake Plains Aquifer. Given these concerns related to over use and depletion of groundwater sources, other water sources are increasingly sought.

As noted above, irrigation currently dominates water use in the Rockies. However, farmers have suffered both from natural events such as droughts and from economic factors such as low profit margins. Given the scarcity of Western water resources, the transfer of water from agriculture to cities could be an important means of addressing water availability problems. The "agricultural reservoir" is the largest existing source of water in the Rockies (see discussion above), but such transfers have long-term implications and it is unknown how they will affect rural economies and communities.

The Evolution of Western Water Transfers

Water transfers have a long history in the Rockies and have evolved since the 19th century. Early transfers were known as "water farming," by which cities would purchase a farm, leave the land fallow or lease water back to an irrigator while waiting to convert the associated water rights. In 1891 the legal precedent for transfers in Colorado was established by the Colorado Supreme Court, approving an irrigation water transfer to Colorado Springs.[39] In the 1970s and 1980s, the cities of Aurora and Thornton, Colorado, bought most of the irrigation water rights in rural South Park, Colorado, approximately 90 miles to the southwest.[40] In Arizona, water farming became more and more common with groundwater depletion in the 1970s and 1980s.

With the declining economic importance of agriculture, water rights have become a sort of pension or bail-out plan for many farmers in the Rockies. However, the drying up of agricultural land has significant implications for rural economies. One example is the property tax base of Morgan County, Colorado. In 2006, 400 junior wells were shut down to protect senior surface water rights,[41] with estimated property value losses of $30 million as once-irrigated lands were reclassified as dry land.[42]

Figure 11
River Basins and Major Rivers

The secondary costs of water transfers have spurred public outcry in rural areas and increased awareness of equity issues. Following the 1985 transfer of Rocky Ford Ditch water from rural Rocky Ford to urban Aurora, Colorado, the city of Aurora addressed third-party impacts of the water transfer by reseeding the affected land with native plants and compensating rural Otero County for lost tax revenue as irrigated lands were reclassified as lower value dry lands.[43] While many cities have pursued various types of equitable solutions to water transfers, the general public frequently blames the region's growing cities and limited conservation efforts. However, lower commodity prices are what promote water transfers for struggling farmers That in turn degrades the rural economy and further pushes small operators off the land.

Economic Impacts of Water Transfers

Although the agricultural sector has declined in economic importance in the Rockies, agricultural areas have responded quite differently to the economic impacts of water transfers. Howe and Goemans studied the impact of water transfers in the South Platte Basin and Arkansas river basin of Colorado. Several factors related to water transfers and the regional economy

Table 3
Change in River Basin Region Temperature, Precipitation, and Snowpack, 1976 to 2085

River Basin Regions	**Winter Temperature**, Degrees Celsius			**Precipitation**, Centimeters (cm) Per Year				**Snowpack**, Centimeters (cm) of Snow Water Equivalence on April 1			
	1976	2085	Change, 1976 to 2085	1976	2085	Change, 1976 to 2085 (cm)	Change, 1976 to 2085 Percent	1976	2085	Change, 1976 to 2085 (cm)	Change, 1976 to 2085 Percent
Arkansas-White-Red	-0.7	4.4	+5.1	42	40	-2	-5%	4.3	2.0	-2.3	-53%
California	2.7	7.8	+5.1	23	25	+2	+7%	0.6	0.0	-0.6	-100%
Great Basin	-2.4	2.9	+5.3	31	32	+1	+4%	2.8	0.5	-2.3	-83%
Lower Colorado	5.0	9.8	+4.8	32	34	+2	+5%	1.2	0.0	-1.2	-99%
Missouri	-6.3	-1.0	+5.3	42	46	+4	+10%	6.7	4.6	-2.1	-31%
Pacific Northwest	-6.2	-1.6	+4.6	71	82	+11	+15%	20.3	10.7	-9.6	-47%
Rio Grande	1.2	5.8	+4.6	37	40	+3	+7%	9.8	3.5	-6.3	-65%
Texas-Gulf	4.4	8.8	+4.5	43	44	+1	+3%	-	-	-	-
Upper Colorado	-5.7	-0.3	+5.3	39	41	+2	+6%	8.8	4.1	-4.7	-53%

contributed to a much larger impact in the Arkansas Basin than in the Platte basin. Specifically, the economic impacts depended on (1) the size of the transfer; (2) the vitality of the region's pre-transfer economy; and (3) the ultimate destination and use of the transfer (e.g., inside or outside the basin, new water use or not).[44] In the Arkansas Valley, 88 percent of the water transfers were large (114,320 acre feet were transferred from 1980–1995 and left the basin). In contrast, in the South Platte Basin, transfers were generally smaller and stayed within the basin. The Arkansas River Basin also had a less robust pre-transfer economy than the Platte River basin. The resulting impacts on income and taxes in the basins were estimated at $187 per acre foot and $83 per acre foot, respectively.[45]

The concentration of agriculture also affects the economic impact of water transfers. For example, in the six counties in Colorado's Lower Arkansas Valley (Bent, Crowley, Las Animas, Otero, Pueblo, and Kiowa), the proportion of farm income (1 percent) was double the Colorado average (0.5 percent) for 2004; excluding Pueblo County, the region's farm income jumps to 6 percent of total personal income (Table 4).[46] This demonstrates the importance of agriculture in the Lower Arkansas Valley. In past decades, this area has experienced large water transfers from the basin (see above), including the Rocky Ford purchases and a 100,000 acre-foot purchase from the Colorado Canal (1985). Figure 12,[47] which shows the decrease in irrigated acres from 1997 to 2002 in these counties, suggests the impact of water transfers. Although such transfers provide short-term economic benefits to struggling farms, the long-term and regional impact of lower tax revenues, weaker retail sales, and population losses threaten the economic vitality of the Arkansas Valley.

Alternative Water Transfer Strategies

Water transfers need not harm rural areas to provide water to a municipality, and new water strategies have been developed to benefit both town and county. Some of the methods that have been developed include interruptible supply agreements, rotational fallowing (or "crop management") arrangements, water banking, alternative cropping or irrigation practices, and purchase/lease-back arrangements. Cities have also initiated conservation programs to extend their water supplies and limit drought impacts.

Interruptible supply agreements (ISAs) allow cities (or other water users) to contract with water rights holders for use of the right in times of drought.[48] Agreements may include an individual payment during a drought, annual payments, or a "signing bonus." ISAs are helpful in supplementing urban supplies only when necessary, rather than transferring a right permanently at the risk of drying up agricultural land and harming rural economies. However, ISAs are not a long-term solution for municipalities; ISAs can create problems such as landscape management (e.g., weed control with no water available for agricultural pesticides) during urban drought periods, and they are not feasible if the water transfer infrastructure does not already exist.[49]

Rotational crop management agreements are established by a group of farmers who agree to periodically fallow portions of their lands, transferring a consistent water supply to the buyer. These agreements provide supplemental annual base water sources to urban areas, reduce demands on aquifers, and decrease agricultural land dry-up rates. The major limitations of rotational crop management agreements include higher transaction costs than permanent land dry-up, and lower water availability during drought years (the agricultural provider might be a junior right holder, in which case a portion of the allocation might not be available). Similar to ISAs, an existing water infrastructure must also be in place to deliver the water.[50]

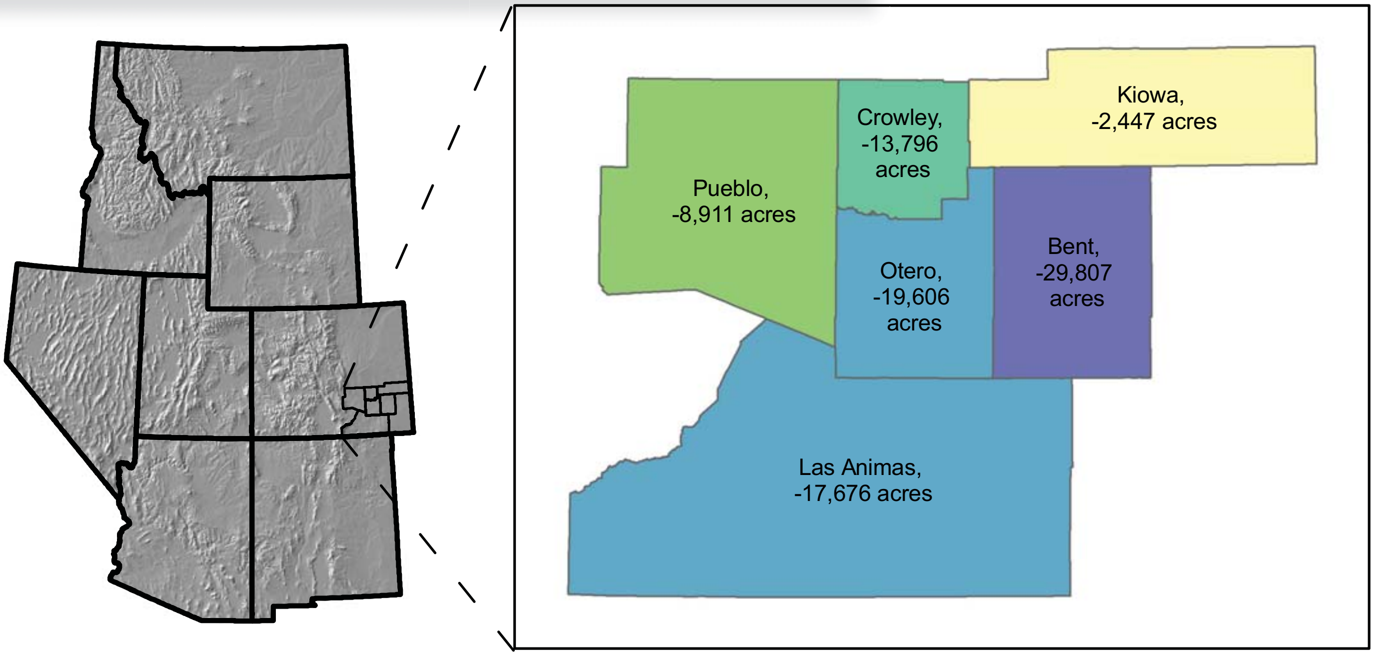
Water banking is another useful transfer tool. Water banks serve as an intermediary between water users and rights holders, allowing unused water rights to be leased for present or future use. Water banks allow users to store excess water for their own future use and protect against excess water loss. Given that agreements can be short-term in nature, water banks also protect downstream users as well (i.e., water can be released from the bank). As one example, Idaho's Water Supply Bank consists of two types of water banks: storage water rights and direct flow rights (see Case Study 1: Idaho Water Bank).[51] Water banks can also be used to satisfy interstate water compact obligations by budgeting water in groundwater and surface water banks. For example, Nevada and Arizona have a groundwater banking agreement by which unused portions of Nevada's Colorado River allocation are to be stored in Arizona's groundwater aquifer. The water banking agreement will allow Nevada to start using its "credits" toward water withdrawals in 2007 and allows Nevada to store excess Colorado River water for future water use.[52]

The biggest drawback of water banks is their reliance on non-use; if water banks are solely direct-flow right based and there is no additional storage capacity then water availability is not guaranteed; if everybody uses their water in a given year none is available for leasing.[53] Successful water banks rely on adequate storage capacities to hold the banked water. However, water banking provides an open-market solution and may avoid potential conflicts among users. For example, water banks cannot harm downstream users by excessive "deposits." It is possible to store only the amount of water equal to the former consumptive use, which protects return flows to the system.

Table 4
Farm Income as a Percent of Total Personal Income in the Arkansas Valley and State, 2004
Source: Bureau of Economic Analysis, Regional Economic Information System

County	Percent Farm Income
Pueblo County	-0.06%
Crowley County	20.25%
Kiowa County	35.31%
Otero County	3.69%
Bent County	4.67%
Las Animas County	-0.69%
Arkansas River Valley	1.05%
Colorado	0.45%

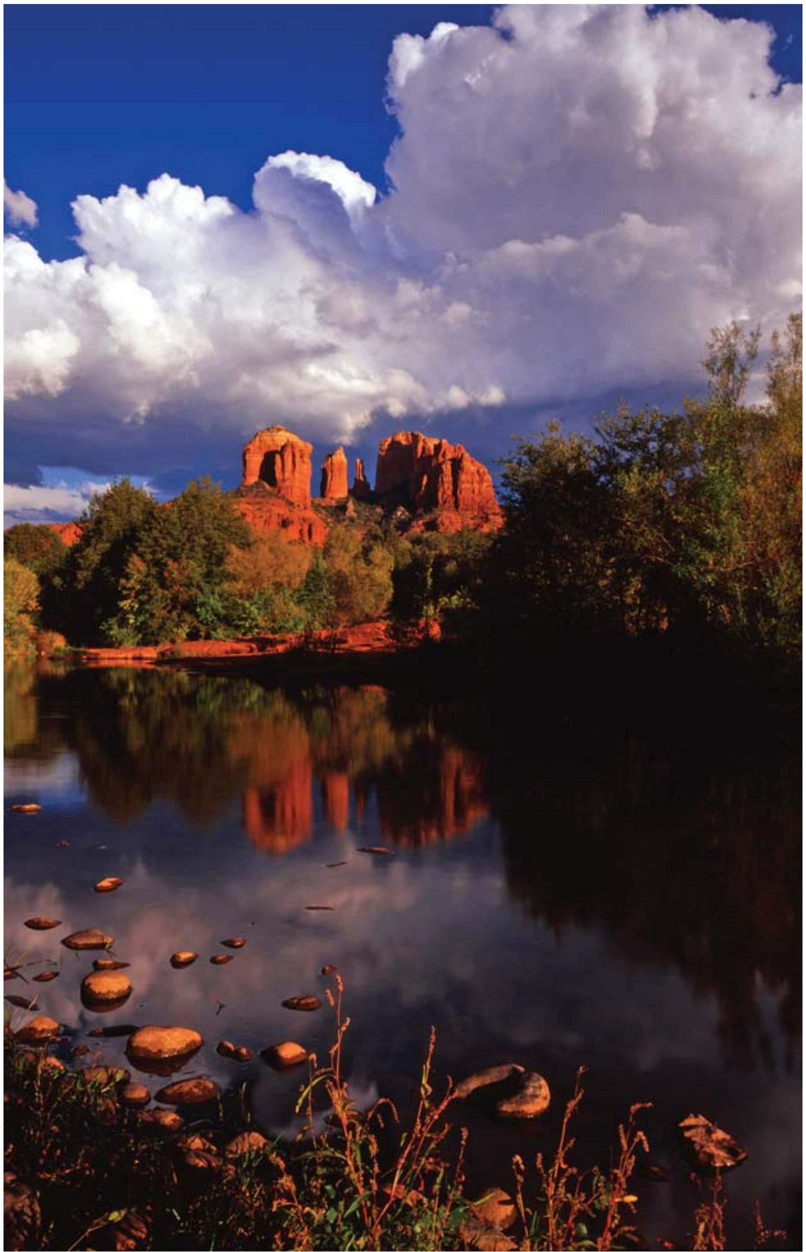
Figure 12
Change in Irrigated Acres in the Arkansas River Valley, 1997-2002
Source: Bureau of Economic Analysis, Regional Economic Information System



Another water transfer tool is alternative crops or water conservation measures. By reducing their consumptive use (e.g., by converting alfalfa to drought-tolerant grasses or adopting new irrigation methods), farmers can increase revenue by selling the water they save. Changes in consumptive use must be verified by the state engineer or water court prior to the transfer (see Case Study 2: Prior Appropriations Doctrine by State). As one example, the city of Aurora, Colorado, used a water conservation strategy during its second purchase from the Rocky Ford Ditch (see Case Study 3: Aurora). A potential risk to farmers is the high cost associated with increasing irrigation efficiency. For example, converting from flood to center-pivot irrigation includes a $568 per acre capital cost and $80 per acre annual cost.[54] While conservation can "free" water for other uses, high infrastructure costs make it unfeasible to implement conservation strategies during drought years alone.[55]

An additional water transfer strategy is called "purchase and lease back," where a municipality purchases land or its associated water rights and then leases them back to the land's user (such as a farmer or third party). The municipality gains access to some or all of the water in the future. As one example, the city of Parker, Colorado, purchased land from farmers in Logan County, Colorado, and leases back the purchased land. Ideally, all of the water in this area will not be consumed by Parker, keeping the land in production in between rotational fallowing.[56] However, the usual practice is complete consumption by the city when necessary. Often a transition period is allowed before additional land and water sales, as the rural agricultural economy is ultimately replaced.[57] Therefore, many lease-back programs represent interim stages prior to the permanent dry-up of agricultural lands.

Many of these strategies offer positive alternatives to permanent loss of agricultural land, which often has unexpected consequences for growing urban areas. For example, near



Phoenix, Arizona, the open space buffer created by surrounding farms reduces the urban heat island effect and mitigates the city's higher surface temperatures.[58] Rotational crop management arrangements could help address micro-climate issues by keeping most farms in production every year and alternating the amount of fallow land. For farm operators, benefits of fallowing include rotational crop management payments that may then be invested in potential improvements to field irrigation systems and improvements (e.g., laser-leveling) that will increase future water conservation.[59]

Conclusions

Despite the increasing trend toward agriculture to urban water transfers, supplying clean water to the Rockies' growing population remains an urgent problem. As previously discussed, the number of irrigated acres in the Rockies decreased (6 percent) between 1997 and 2002. While most water use in the Rockies Region is devoted to irrigation (87.2 percent in 2000) and adequate water exists for urban transfers, agricultural land is declining faster than anticipated.[60] In Colorado, the Statewide Water Supply Initiative (SWSI) estimated that while the state's population may grow by 65 percent between 2000 and 2030 (1.7 percent per year), 185,000 to 428,000 irrigated acres could be lost by 2030 due to water transfer projects, urbanization of irrigated lands, and other agriculture water losses (adjusted for some potential increase in irrigated acres if new water supplies are developed).[61] The 2002 Census of Agriculture estimate for irrigated land out of production (470,000 acres in 2002) does provide some context, but this estimate is based on a drought year, so some portion of this fallow land will likely return to production.[62] The decline in irrigated land raises new concerns about the economic vitality of rural areas and the cultural heritage lost. Are we trading rural agricultural lands under cultivation for urban water uses that have higher market value? Can small farms thrive through equitable water transfers and the development of more efficient irrigation techniques? Conservation and creative water sharing methods can potentially benefit the Rockies' people, land, and environment, but the demands of a growing population will likely create new tensions.

We end this review of agriculture versusHigher urban water uses in the Rockies as we started, by reflecting upon the concept of "sustainability." Helpful perspectives are provided in a Western Governors' Association's report on "water needs and strategies for a sustainable future":

> *While water resources are available for growth in the aggregate, they are essentially fully "appropriated" under regimes that have vested private property rights in water right holders. New uses to accommodate growth must largely rely on water obtained from changes to existing uses of surface and ground water, with limited opportunities to develop new supplies. In many instances, this will result in the reallocation of water to "higher valued uses" with accompanying third party impacts that must be considered, such as adverse consequences for rural communities and the environment.*[63]

This common theme of water sustainability increasingly permeates analysis of water in the Rockies. Limited in supply and often spatially separated from "higher value users," water has and will continue to be a fundamental challenge for the Rockies. How this limited, variable and potentially shrinking supply is managed in the face of myriad challenges ranging from climate change to rapid urban growth will largely determine not only the sustainability but also the "livability" of the Rockies so valued by millions of residents and visitors alike.

Case Study 1: Water Banking and Transfers in Idaho

The Idaho Water Supply Bank is one of the longest tenured water banks in the Rockies. Since 1930 the bank has served as a water exchange market, allowing for the temporary exchange of water rights between users.[1] The bank is involved in transactions of natural flow rights (e.g., the rights to surface water from a stream) and water storage rights (e.g., in reservoirs or aquifers). The price of the water is primarily based on where the water is going to be used. In the case of stored water, the price is determined by rental pool committees that operate the four rental pools of the Idaho Water Supply Bank.[2] Ten percent of the bank's revenue goes to the Idaho Department of Water Resources and the rest goes to the person holding the right.

Over the past five years, water banking activity in Idaho has increased for several reasons, mostly relating to drought, population growth, and a change in economic priorities regarding water allocations. On April 30, 1993, the state government amended a moratorium on new consumptive use to include the Boise River Basin and the East Snake River Plain and tributaries (it already included the Snake River Basin).[3] This regulation was continued by former Governor Dirk Kempthorne (now U.S. Secretary of the Interior), in Executive Order 2004-02 in relation to the East Snake River Plain Aquifer.[4] This halt to new consumptive use hampered certain industries, especially Idaho's fast-growing dairy industry. New industries have had to either establish a non-consumptive use (such as water left in the stream for fishing or recreation), mitigate for their impacts by providing other sources of water, acquire new rights (i.e., by transfers from other uses), or purchase rights from a municipal water provider that has extra water.[5] The moratoriums, combined with the drought and the decline in agricultural profitability, have prompted the recent increases in water transfers.

The Idaho Water Supply Bank facilitates temporary water rights transfers. As in other states, a transfer through the Idaho Water Supply Bank can take several years; however, the bank allows for purchasers of the water right to use that water during the processing time.[6] Developers and industrial dairies are using water banking to temporarily secure rights while they complete the transfer of new rights. As other areas of the West explore water banking as a means of alleviating water allocation problems, Idaho's water bank will serve as a good model due to its long tenure and relative success.

Case Study 2: Summary of the Prior Appropriation Doctrine and Its Implications on Water Transfers

History:

The Prior Appropriation Doctrine of water law evolved during the mining boom of the 19th century.[1] Miners who needed water for their operations struck a claim to water just as they would to a mine site.[2] This doctrine contrasts with Riparian Doctrine, by which the owner of property adjacent to a waterway has the right to reasonable use of the water.[3] In many ways, however, the riparian doctrine is unsuitable for the arid and semi-arid West because it allows water use only on adjacent lands, meaning that only those lands could receive the irrigation water necessary to grow crops.

The Prior Appropriation Doctrine responded to the need to divert water farther from surface sources and to concerns that streamside owners would monopolize water use.[4] Because Prior Appropriation allows for the diversion of water from a river or stream to non-adjacent lands, vast areas of Western lands could receive critical water supplies. There are four components to a water right within the Prior Appropriation Doctrine: the intent to appropriate, capability of diversion and control, beneficial use without waste, and priority.[5]

As Hobbs notes, "A water right is a property right that arises solely by the act of placing water, theretofore un-appropriated, to the appropriator's beneficial purpose."[6] This evolved to include the intent to appropriate: the essential difference between a conditional water right and an absolute right. An absolute right is one that is actually put to use, while a conditional right is one that will later be put to beneficial use.[7] Holders of conditional rights have to prove due diligence or progress in placing the water under beneficial use. This rule is designed to prevent hoarding of water rights over many years for the purpose of speculation. The only exception to the rule is cities (via the Great and Growing Cities Doctrine), which can keep the water right in anticipation of future growth (but still have to prove diligence every six years). Once the right has been appropriated and diverted, it must be used beneficially, which is in a sense the most important part of the doctrine. Whether or not a water right is recognized depends on whether it is being beneficially used.[7] Beneficial use is generally defined as use "without waste," but the definition of beneficial use is constantly changing across the Rockies Region, and current definitions vary by state. For example, some states (New Mexico is one example) do not recognize an in-stream flow as a beneficial use unless it is for a purpose such as recreation.

The priority date or seniority of a water right largely determines its value. Once water is put to beneficial use, it is generally recognized as senior to future uses. Conditional water rights similarly rely on a priority date. Conditional rights receive the date of the original intent or plan to appropriate water. The relative priority of many agricultural water rights drives today's market in water transfers.

Implications for Water Transfers:

The most important part of the water rights transfer is arguably the no-injury/non-impairment clause. Water rights are usufructuary, meaning that there is the right to use the water beneficially, but the water itself is a public resource. When a water right is transferred, only the beneficial historic consumptive use is transferred, and downstream users must be protected from injury. Downstream junior users have the right to the river as it existed when they appropriated their right.[9] Water transfers, especially those out of a basin, can have serious impacts on downstream users and communities including the loss of property tax base, degraded water quality, and loss of jobs. States take various impacts into account, but the most common and the basis for no-injury is the change in stream flow.[10] The legal implications of water transfers in many cases require serious litigation. In Colorado, for example, all transfers are decided in water courts.[11] Colorado is the only state in the Rockies to use water courts to adjudicate all transfers. (See Matrix: Prior Appropriation Doctrine-Key Differences Between States)

Prior Appropriation Doctrine – Key Differences Between States

State	Water Transfer Application Agency[12]	In-Stream Flow Rights details[13]	"Public Interest or Welfare"[i14]	Basin of Origin Protection for Out-of-Basin Transfers[15]	Basis for Protesting Transfers[16]
Arizona	Department of Water Resources	1941, public government or public interest groups	language in statutes, but no specific definition	No-injury, non-enlargement of water right	Anyone, preference given to water rights holders
Colorado	Water courts	1973, CWCB[17]	Not defined clearly	No-injury, non-enlargement	Anyone
Idaho	Department of Water Resources	1974, IDWR[ii]	12 concerns must be addressed [iii]	Arizona plus consistency with public interest	Anyone, preference given to water rights holders
Montana	Department of Natural Resources	1969, MDNR or private transfer	Might apply in reasonable use cases	No-injury, beneficial use	Downstream water rights
Nevada	Division of Water Resources	1988, public or private	Yes, case by case (state engineer)	No-injury, public interest	Anyone, preference given to water rights holders
New Mexico	State engineer	1998, public or private[iv]	Yes, both surface and groundwater	No-injury, conservation interests, public interest	Anyone, preference given to water rights holders
Utah	Division of Water Rights	1986, Division of Wildlife Resources	1989 Supreme Court ruling [v]	Same as Idaho	Anyone, preference given to water rights holders
Wyoming	Board of Control[vi]	1986, state[vii]	Case by case	Non-enlargement, no-injury	Anyone, preference given to water rights holders

[i] The public interest and welfare definitions vary from state to state. Some are defined by statute, some are case by case, etc. This is different from the Public Trust Doctrine, which could play a larger role in future water decisions.
[ii] The only way a private entity can hold an in-stream flow right is temporarily through Idaho's Water Bank System.
[iii] Statutory public interest concerns include: local economic impacts, impacts on recreation, fish, and wildlife, and compliance with air, water, and hazardous substance rules.
[iv] In New Mexico in-stream flow rights are not considered beneficial except for specific purposes such as for recreation or wildlife habitat.
[v] Requires rejection with unreasonable detriment to recreation, environment, and public welfare.
[vi] Includes the state engineer and the superintendents of the four water districts
[vii] In Wyoming this is only for fisheries.

Case Study 3:
Aurora, Colorado: Water Transfers from Agriculture to Urban Uses

Background:

Aurora, Colorado, has long been involved in purchasing water from agricultural users. At the time of its founding in 1891, Aurora (then named Fletcher) relied on groundwater and the Denver Water Board for its water. However, the town soon experienced problems with the groundwater supply, and Denver placed restrictions on Aurora's growth as well as the amount of water it would supply. In response, Aurora began looking for new water supplies. Together with Colorado Springs, Aurora helped build the Homestake Reservoir (completed in 1967), located across the Continental Divide near Leadville, Colorado. The pipes from Homestake now carry billions of gallons of clear mountain water to Aurora's growing developments.[1] Aurora also began purchasing water rights from ranchers in Park County, a predominantly rural county to the west. These purchases were complex both legally and socially and had large impacts on the communities of Park County. In the 1980s Aurora went searching for additional water to the south in Colorado's Lower Arkansas Valley, where the city began to acquire water from agricultural users.

Issues:

In a water transfer, benefits and costs will accrue to both the buyer and the seller. However, especially when transferred water leaves the basin of origin, there will also be third-party effects and most of the positive aspects will affect the purchasing basin, and most negative aspects will affect the selling basin.[2] Many state laws protect the basins of origin to varying degrees; some laws even require compensation for lost tax values and reseeding of fallowed land. Despite such protections, many areas have experienced drastic economic and social changes. This is true for various areas in the Lower Arkansas River Valley, where municipalities including Aurora have purchased large amounts of water. In Crowley County a large proportion of agricultural water was transferred to Aurora and Colorado Springs in the 1970s and 1980s, resulting in major impacts on the ranching community. Like other parts of the Arkansas Valley, Crowley County has seen a drop in land value; land in the Arkansas Valley is worth much more with irrigation ($1,700/acre) than without ($300/acre).[3]

Aurora has made several efforts to lessen the impact of its agriculture to urban water transfers. It has been leasing water from the Rocky Ford/Highline Canal, allowing farmers to stay in production except when the city needs the water (usually during drought years when farming is difficult anyway). In the second transfer from the main Rocky Ford Canal, Aurora purchased 1.78 acre-feet of water per acre of land, gave back half an acre-foot to some farmers, and assisted with the installation of drip irrigation systems and crop changes. These conservation measures allowed farmers to improve their productivity and product quality while using less than one-third of the water they had used originally.[4] Farmers on approximately 1,000 of the 2,800 acres of purchased land have asked to participate in this program so they can continue crop production. Aurora also created a $1.5 million trust fund for the Rocky Ford School District to make up for reduced tax revenue.[5] In a sense this was a bonus to the school system because the state also makes up for a portion of the lost revenue. Finally, in compliance with state law, Aurora reseeded the dried up lands with native grasses to prevent weed development and dust.

Future Challenges:

Aurora, as part of its intergovernmental agreement with the Southeastern Water Conservancy District, an Arkansas River basin water agency, for the next 37 years (originally 40 years in the 2003 agreement), will not transfer any more water out of the Arkansas Valley than what is already being transferred. Aurora will have to look to other basins for its water, such as the South Platte basin that houses the city. Currently, Aurora is pursuing new agreements that will provide its residents with water while not unduly harming the farmers from whom they buy/lease the water.

Significance for the Rockies:

Historically, Aurora's agriculture to urban transfers of water rights have been controversial. Aurora has made major efforts to become a leader in the pursuit of creative agreements designed to benefit both parties involved in water transfers. Aurora is growing rapidly and will likely always face criticism for allowing such growth without having enough water of its own. How Aurora will address the needs of its residents and the needs of the farmers from whom they receive water will set an example across the Rocky Mountain region.

Case Study 4: Innovative Approaches to Conservation:

Background:

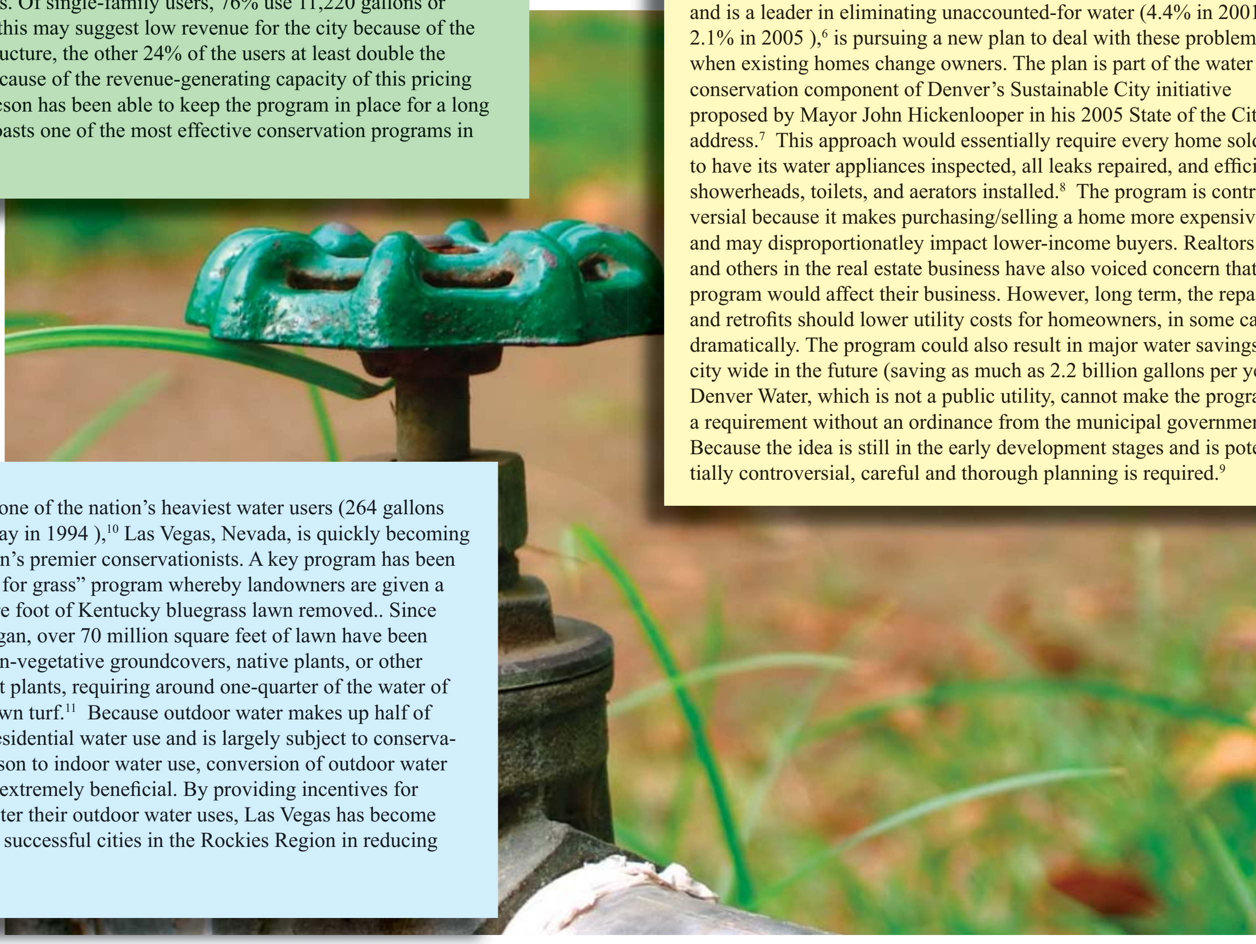
Conservation is an essential tool in the efficient use of water in the Rockies. Though sometimes controversial, especially the concept of conserving for growth, developing the conservation ethic is imperative, and many cities in the Rockies are experimenting with innovative approaches to promote conservation among their citizens. Examples include Tucson's aggressive water pricing structure, Denver's pending time-of-sale retrofit program, and Las Vegas' "cash for grass" program, outlined below.

Tucson:
Basic capitalist economics teaches that markets and prices are the best allocation tools. With water this may be true, but cities are often only allowed by law to price water to cover their costs. The law does, however, generally allow for increasing block rate structures as long as the low blocks are low enough to offset revenue from higher blocks.[1] In Tucson, single-family consumption of 11,220 gallons per month (g/m) is charged only $22.45, while the consumption of 22,440 g/m is charged $80.35; the water bills progressively increase from there, with 29,920 g/m equaling a $134.35 bill and 37,400 g/m equaling a $199.05 bill.[2] The city is currently increasing rates at 5% per year through 2011 to meet projected revenue needs.

Partly due to this rate structure, Tucson's single-family water use, which is the majority of the water use in the city, is one of the lowest in the Rockies. Of single-family users, 76% use 11,220 gallons or less.[3] While this may suggest low revenue for the city because of the block-rate structure, the other 24% of the users at least double the revenue.[4] Because of the revenue-generating capacity of this pricing structure, Tucson has been able to keep the program in place for a long period and boasts one of the most effective conservation programs in the Rockies.

Denver:
In every municipality, some water goes into the system and disappears, unregistered by the meters. This water is referred to as "unaccounted-for water" and is a large source of water waste in the Rockies. Western Resources Advocates, in their Smart Water Report, calculated that in the 13 Southwestern cities it surveyed, 118,732 acre-feet of water went unaccounted for in 2001, ranging from 1.3% (Mesa, AZ) to 12.3% (Albuquerque, NM) of all system deliveries.[5] Such water is lost through leaks in the delivery system, firefighting, pipeline flushing, and poorly functioning meters. Old fixtures and indoor leaks, while not contributing to unaccounted-for water, are also large wastes of water.

Denver Water, which pioneered xeriscape dry landscaping methods and is a leader in eliminating unaccounted-for water (4.4% in 2001, 2.1% in 2005),[6] is pursuing a new plan to deal with these problems when existing homes change owners. The plan is part of the water conservation component of Denver's Sustainable City initiative proposed by Mayor John Hickenlooper in his 2005 State of the City address.[7] This approach would essentially require every home sold to have its water appliances inspected, all leaks repaired, and efficient showerheads, toilets, and aerators installed.[8] The program is controversial because it makes purchasing/selling a home more expensive and may disproportionatley impact lower-income buyers. Realtors and others in the real estate business have also voiced concern that the program would affect their business. However, long term, the repairs and retrofits should lower utility costs for homeowners, in some cases dramatically. The program could also result in major water savings city wide in the future (saving as much as 2.2 billion gallons per year). Denver Water, which is not a public utility, cannot make the program a requirement without an ordinance from the municipal government. Because the idea is still in the early development stages and is potentially controversial, careful and thorough planning is required.[9]



Las Vegas:
Although once one of the nation's heaviest water users (264 gallons per capita per day in 1994),[10] Las Vegas, Nevada, is quickly becoming one of the nation's premier conservationists. A key program has been the city's "cash for grass" program whereby landowners are given a dollar per square foot of Kentucky bluegrass lawn removed.. Since the program began, over 70 million square feet of lawn have been converted to non-vegetative groundcovers, native plants, or other drought-tolerant plants, requiring around one-quarter of the water of conventional lawn turf.[11] Because outdoor water makes up half of single-family residential water use and is largely subject to conservation in comparison to indoor water use, conversion of outdoor water to other uses is extremely beneficial. By providing incentives for consumers to alter their outdoor water uses, Las Vegas has become one of the most successful cities in the Rockies Region in reducing outdoor usage.

Significance for the Rockies:
While some conservation programs are applicable region wide, others may not be. The city leaders of Denver, for example, might not want to reduce outdoor water use to the extent that Las Vegas has because Denver's water supplies are extremely variable and lawns can serve as a supply source during drought; that is, the city can enhance its available water supply by restricting outdoor use.[12] Las Vegas is guaranteed its Colorado River allotment, and it has a wastewater credit program which increases incentives for consumers to also conserve water used indoors, the least consumptive of water uses.[13] Time-of-sale retrofits have yet to be used on a wide scale, so their true effectiveness remains unknown. Finally, water rate structures such as Tucson's are increasingly being utilized across the Rockies. Conservation programs, while sometimes controversial, are also essential as populations grow in the dry Rockies Region. Despite differences in municipal characteristics, several cities have implemented distinct and successful programs that can serve as models for other municipalities and regions.

Facing Page Photo: Irrigation ditch that draws water from the Colorado River. © Ken Papelo, courtesy of the Rocky Mountain News

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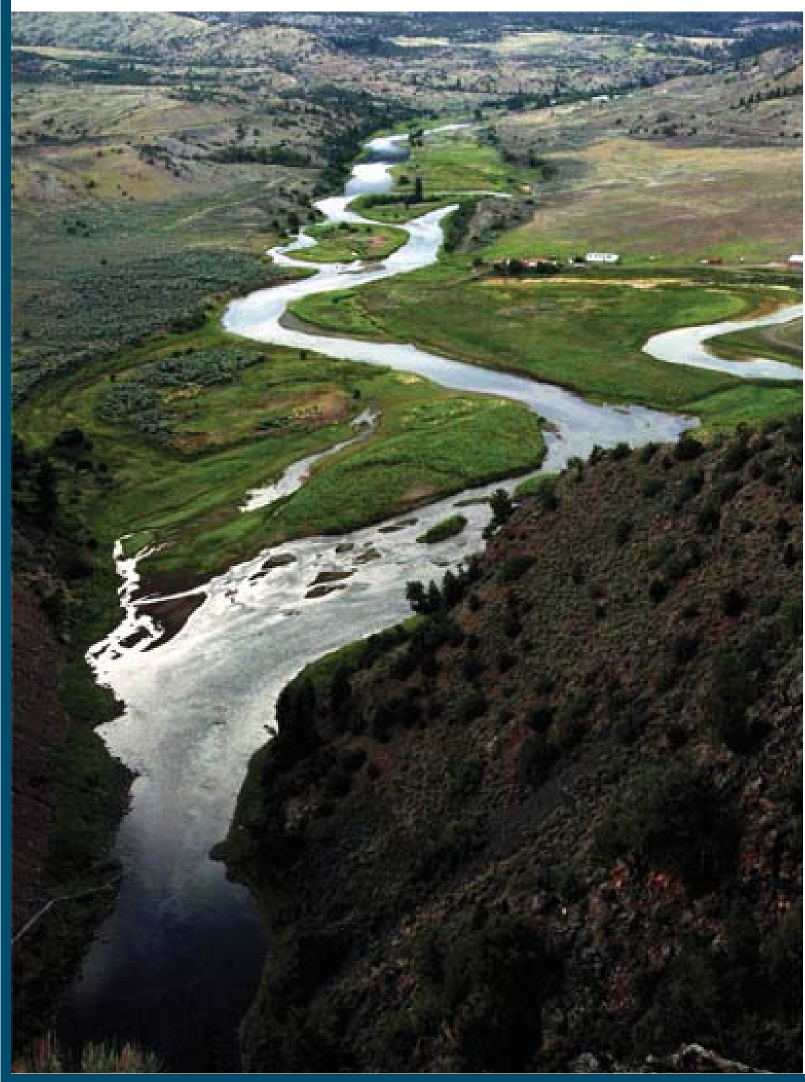

Photo: The Colorado River near Radium, Grand County, Colorado.
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