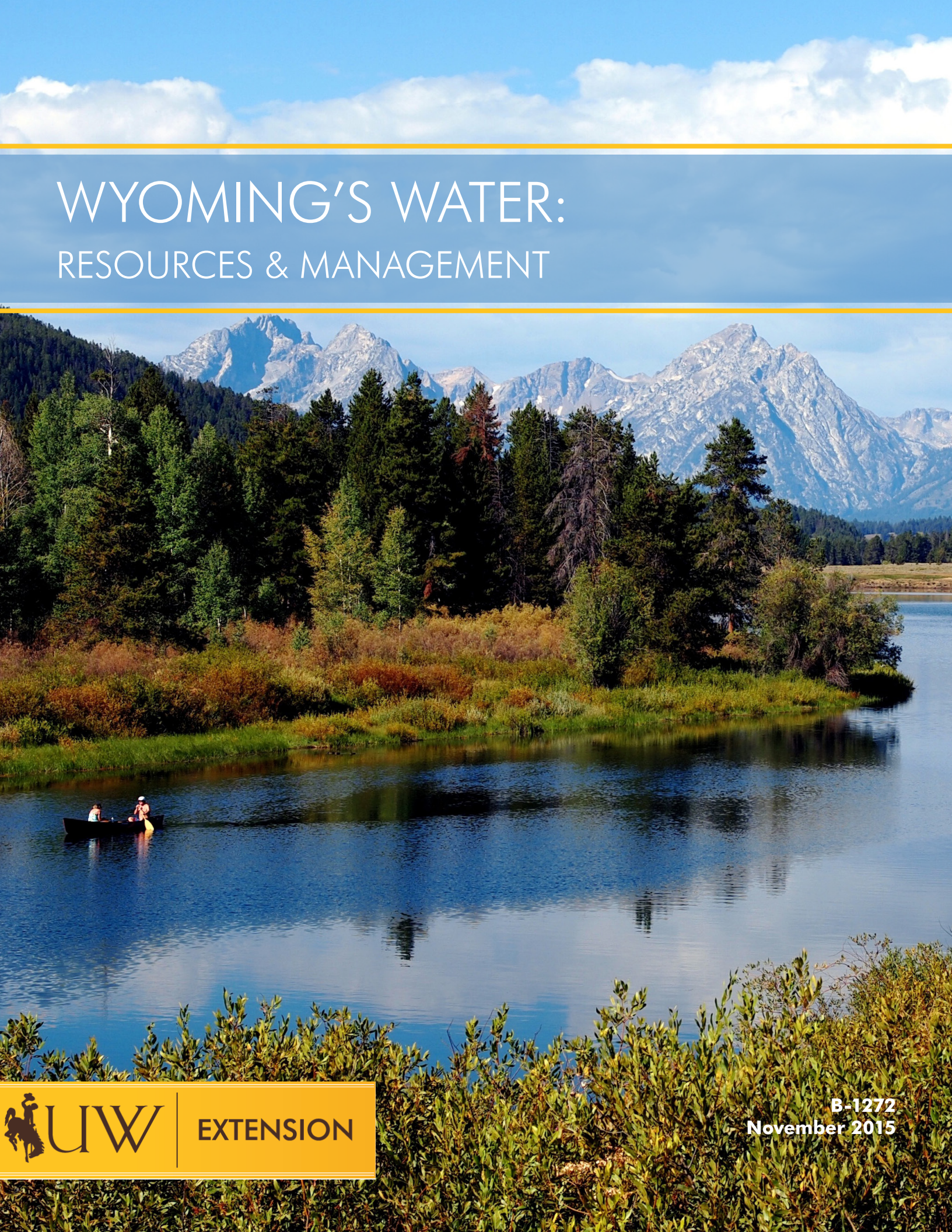
WYOMING'S WATER:
RESOURCES & MANAGEMENT



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WYOMING'S WATER: RESOURCES AND MANAGEMENT

Kristi Hansen, Water Resource Economics Specialist, University of Wyoming
Chris Nicholson, Director of Water Resources Data System, University of Wyoming
Ginger Paige, Water Specialist, University of Wyoming

Editor: Steven L. Miller, College of Agriculture and Natural Resources, Office of Communications and Technology.
Graphic Designer: Tanya Engel, College of Agriculture and Natural Resources, Office of Communications and Technology.

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WYOMING'S WATER:

RESOURCES AND MANAGEMENT

WATER IS AN IMPORTANT RESOURCE IN Wyoming and vital to its economic and social sustainability and growth. Located in the Rocky Mountain region of the western United States, Wyoming is dominated by mountain ranges and high elevation plains. It is the tenth most extensive state but one of the least populated. Annual average precipitation can vary from over 36 inches in the high elevation mountains to as low as 6 inches in the lower elevation plains; however, the state has a semi-arid climate with an annual average precipitation of only 16 inches compared to the national (contiguous U.S.) average of 30 inches (NOAA 2015). Wyoming's location and climate means there can be significant spatial and temporal variability in available water resources. As such, understanding the amount of available water and its management are important issues for the state and downstream water users.

This bulletin presents the current status of Wyoming's water resources and an overview of water management and planning in the state. The topics focus on Wyoming's available surface and groundwater supplies and water uses by sector. The bulletin also includes information regarding snowpack and water storage; water rights; state water management and planning agencies, their roles and strategies; and current topics regarding Wyoming's water, including the Governor's Water Strategy.

WYOMING WATER BASINS

Wyoming is a headwaters state that provides water for four major river basins of the United States (see Figure 1). Approximately 72 percent of Wyoming's land area drains into the Missouri-Mississippi basin by way of the Yellowstone, Wind, Bighorn, and Shoshone rivers in the Big Horn Basin; the Tongue, Powder, Belle Fourche, Cheyenne, and Niobrara rivers in the Powder River Basin; and the North Platte and Laramie rivers in southeastern Wyoming.

Approximately 17 percent of Wyoming's land area drains into the Green-Colorado River Basin by way of the Green and Little Snake rivers in southwestern Wyoming.

Approximately 5 percent of Wyoming's land area drains into the Snake-Columbia River Basin in the Pacific Northwest by way of the Snake and Salt rivers in northwestern Wyoming.

Approximately 2 percent of Wyoming's land area drains into the Great Salt Lake Basin

Figure 1
Wyoming—Headwaters to the Major River Systems of the Western United States

Source: Wyoming Water Resource Data System (2015).

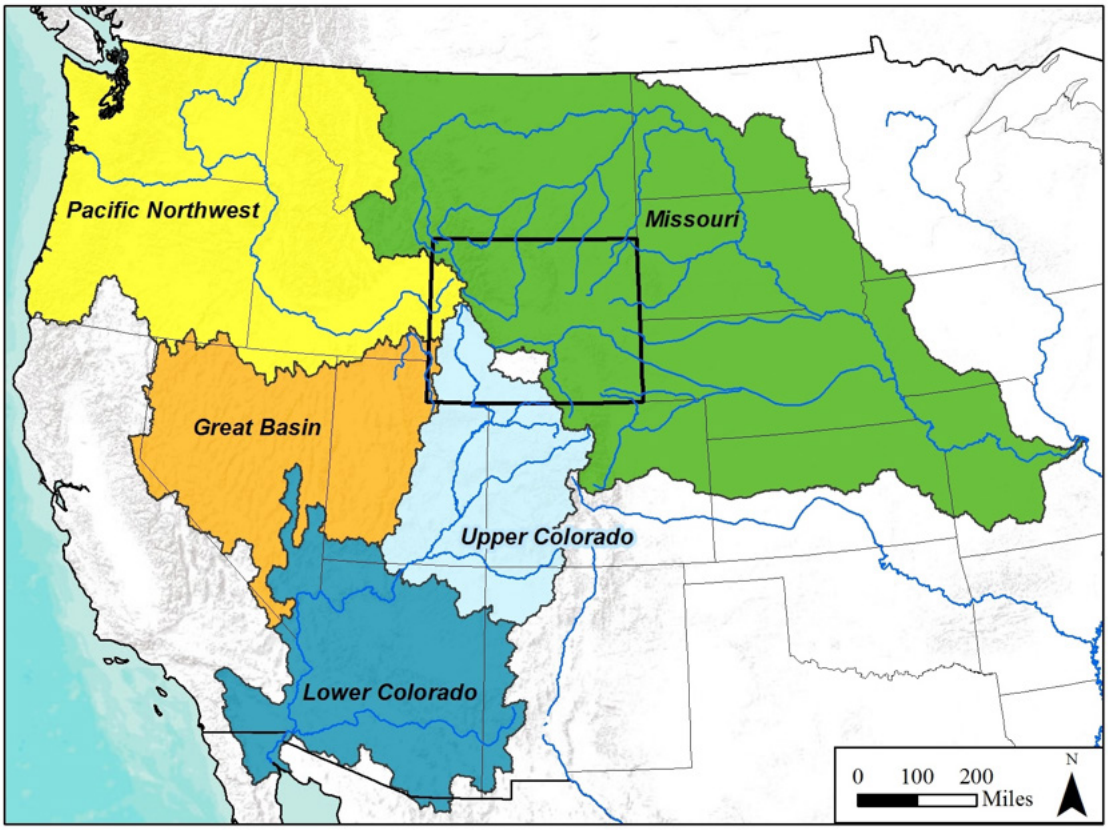
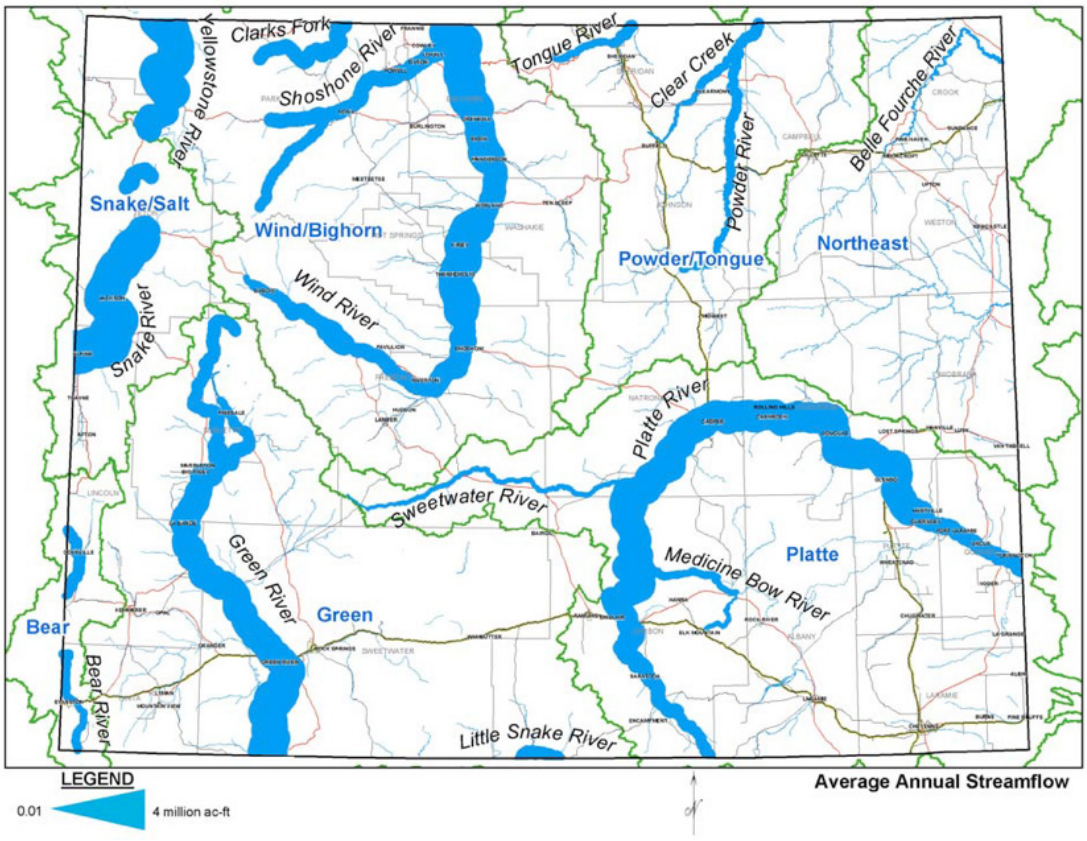


Figure 2
Average Annual Streamflow for Wyoming River Basins

Source: Figure 4-4, WWC (2007).



by way of the Bear River in southwestern Wyoming.

The remaining 4 percent of Wyoming's land area is in the Great Divide west of Rawlins. This is a closed basin; streamflow in the Great Divide does not leave the basin. The average annual natural streamflow for Wyoming's river basins are shown in Figure 2.

WYOMING'S CLIMATE

Like other western mountain regions, Wyoming is characterized by numerous micro-climates because of its basin and range topography. Many regions of the state lie above 5,000 feet in elevation. Higher elevation locations can experience more extreme swings in temperature and precipitation over short time periods than lower elevations, so temperature and precipitation patterns in Wyoming can vary markedly across short distances. One part of the state can be experiencing a drought while others are experiencing above-average precipitation.

Wyoming's climate has a large amount of year-to-year variability (Figure 3). Wyoming's average annual temperature has been increasing since 1970. 2012 is the warmest year in the 120-year period-of-record. Precipitation also varies greatly, and the early 2000s saw several years of consecutive drought. 2012 has so far been the driest year on record.

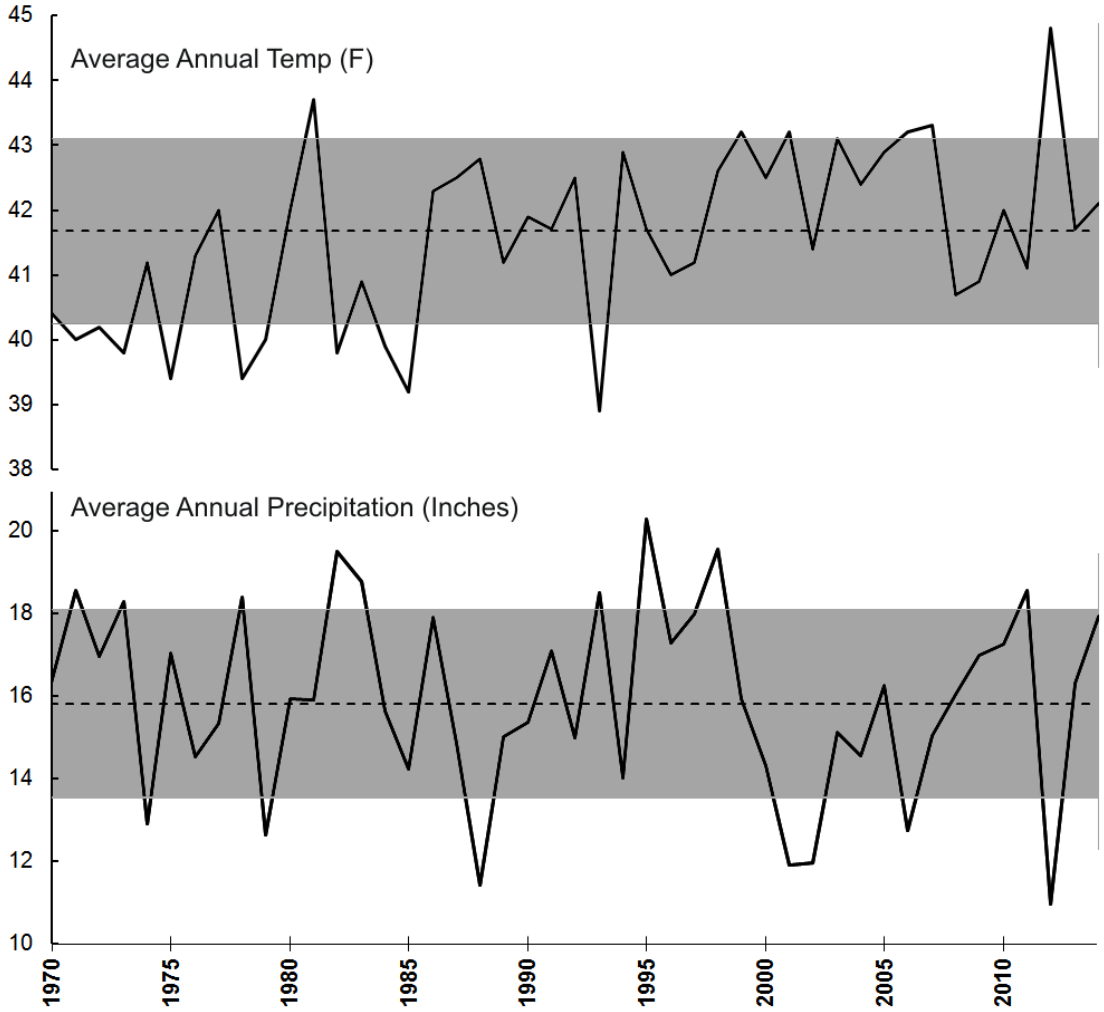


Figure 3
Temperature and Precipitation Trends in Wyoming from 1970 to 2014*

*Dotted line indicates 120-year period of record average and the gray is +1 and -1 standard deviation.

Source: Wyoming Resources Data System (2015).

WATER RESOURCES

Large water volumes are generally measured in acre-feet (af) in the U.S. One acre-foot is 325,851 gallons. It is the amount of water needed to cover 1 acre of land with 1 foot of water. A good rule of thumb is that one acre-foot is adequate to provide two households with water for one year.

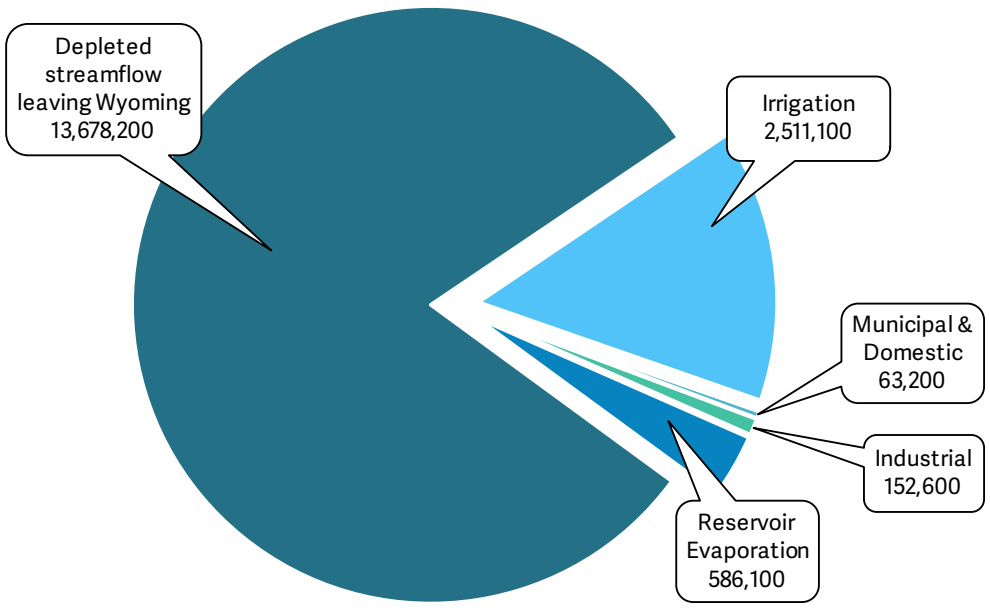
The water quantities described in this bulletin are from Wyoming's river basin planning process unless otherwise noted. This planning process is coordinated by the Wyoming Water Development Commission (WWDC). Wyoming's most recent statewide water plan dates from 2007 (WWC 2007). Several river basins have since then updated their water plans, and updates for other basins are in progress. The statewide numbers below are derived from an updated collection of tables maintained by the WWDC *(http://waterplan.state.wy.us/plan/statewide/tables/tables.html)*.

Surface Water

Despite receiving on average only 16 inches of precipitation annually (NOAA 2015), approximately 17 million acre-feet (maf) of total annual flow is produced within the state under normal conditions (WWC 2007). Like many other semiarid western states, Wyoming derives 70 percent of its surface water from high-elevation snowpack, which acts as a natural reservoir (Pierce et al. 2007; Svoboda et al. 2002). This snowpack sustains rivers, streams, and man-made reservoir levels late into the water year. In addition to snowpack, several rivers bring water into the state including the Laramie and North Platte rivers in southeastern Wyoming; the Little Snake River in south central Wyoming; the Blacks Fork, Henry's Fork, and Bear rivers in southwestern Wyoming; and the Clarks Fork River in northwestern Wyoming. Based on consumptive uses and reservoir evaporation, Wyoming consumes, under normal conditions, approximately 3.3 maf of its surface water annually, with another 13.7 maf leaving the state (WWC 2007). Figure 4 indicates quantities of Wyoming's surface

Figure 4
Wyoming's Surface Water Resources (Consumptive Use, in Acre-Feet)

Data Source: WWDC 2011 updated data tables http://waterplan.state.wy.us/plan/statewide/tables/tables.html.



water allocated to various uses in the state and downstream.

Groundwater

Groundwater is found throughout Wyoming, though its relative availability and quality varies across basins. Substantial quantities of good-quality groundwater are generally found in alluvial aquifers associated with perennial streams or in areas near mountainous zones where ample amounts of precipitation recharge aquifers via exposed bedrock formations. The groundwater in these areas originates largely as rainfall or snowpack in the state's mountain ranges. The water released during snowmelt in late spring and early summer infiltrates the ground surface to recharge underlying aquifers or generate runoff that contributes to stream and river flows. In contrast, useable groundwater resources are frequently limited or of poorer quality in the interior areas of the state's semi-arid basins, and communities there may need to pipe municipal water supplies from distant wells and springs. Groundwater development is ultimately dependent on the costs incurred to extract, treat, and deliver sufficient quantities to meet the needs of intended users while remaining in compliance with current environmental regulations and senior water rights.

WATER USE BY SECTOR

Consumptive Uses

Four major consumptive uses are identified in Wyoming: agricultural, municipal and domestic, industrial, and evaporation (WWC 2007). For water resource management and policy purposes, consumptive use is defined as water removed from an available supply (both surface and groundwater) without return to the system. This is a much broader definition than the definition of "consumptive use" that refers to the quantity of water directly used by vegetation.

Agriculture

Agriculture is the largest single consumptive use in the state. Average annual diversions of surface water for irrigated agriculture are estimated to be 6.9 maf, though this amount varies from year to year depending on available surface water supplies (WWC 2007). Approximately 490,000 af of groundwater are estimated by the U. S. Geological Survey to be withdrawn by irrigated agriculture each year (Maupin et al. 2014). The amount of water actually consumed by agriculture is substantially less than this combined total due to conveyance losses, evapotranspiration, and agricultural runoff. Average annual consumptive use from surface water is estimated to be 2.5 maf on average, though it varies with water year and type of crop (WWC 2007).

Irrigated agriculture accounts for 80-85 percent of total consumptive use in Wyoming. Irrigated cropland acreage varies between 1.4 and 1.6 million acres from year to year depending upon available surface water supplies. Approximately 40 percent of the roughly 5,000 farms and ranches in Wyoming irrigate primarily alfalfa/grass hay and irrigated pasturelands for livestock production. Distribution of irrigated cropland by crop for 2012 is shown in Figure 5. Over two-thirds of irrigated acres in Wyoming are flood-irrigated; most of the remainder are irrigated using sprinkler systems (USDA 2014).

Future development of water for agriculture largely depends on physical and legal access to water supplies and ability to secure funding for infrastructure investment. Since 2000, the State of Wyoming (WWDC) has spent millions of dollars on irrigation rehabilitation and reservoir projects to augment water supplies (WWDC 2015). Rehabilitation projects include lining canals to prevent seepage loss. Reservoir projects have focused on elevating the height of dams and spillways to increase storage and adding

riprap to banks to prevent seepage loss (WWDC 2015).

Agricultural water users generally do not consume the entire amount of the water they apply to agricultural fields. A portion of the water not used by the plants is returned to the stream systems as overland flow or through the subsurface. These return flows are an important component of agricultural water use in the state and can contribute to maintaining late season flows in some streams.

The amount and timing of return flow to a stream can be difficult to quantify as it depends on several factors, including irrigation method (flood versus sprinkler); local soils and geology; flow paths (surface and/or subsurface); and crop water needs. According to one study that quantified return flow in the New Fork Irrigation District in the Upper Green River Basin over a three-year period (Wetstein et al., 1989), approximately 60-70 percent of the applied water returned to the stream. In this case, the irrigation water is temporarily stored in a shallow gravel aquifer and released back to the stream, with up to 7-10 percent considered as late-season return flow. Additional studies are underway to quantify agricultural return flow in other Wyoming locations.

Note that other water users also do not consume the entire amount of the water they divert. A portion of their diverted water is also returned to the stream and/or groundwater in the form of return flows, though the percentage of return flows from other uses tends to be lower than for agriculture.

Evaporation

The second largest consumptive use in Wyoming is reservoir evaporation, which amounts to 586,000 af annually, or 18 percent of all depletions (WWC 2007). Wyoming relies on reservoir storage in many of its basins to meet downstream water obligations and to address local water rights and needs during periods of drought. Though counted as a consumptive use, reservoir evaporation is an unproductive water loss rather than a beneficial use.

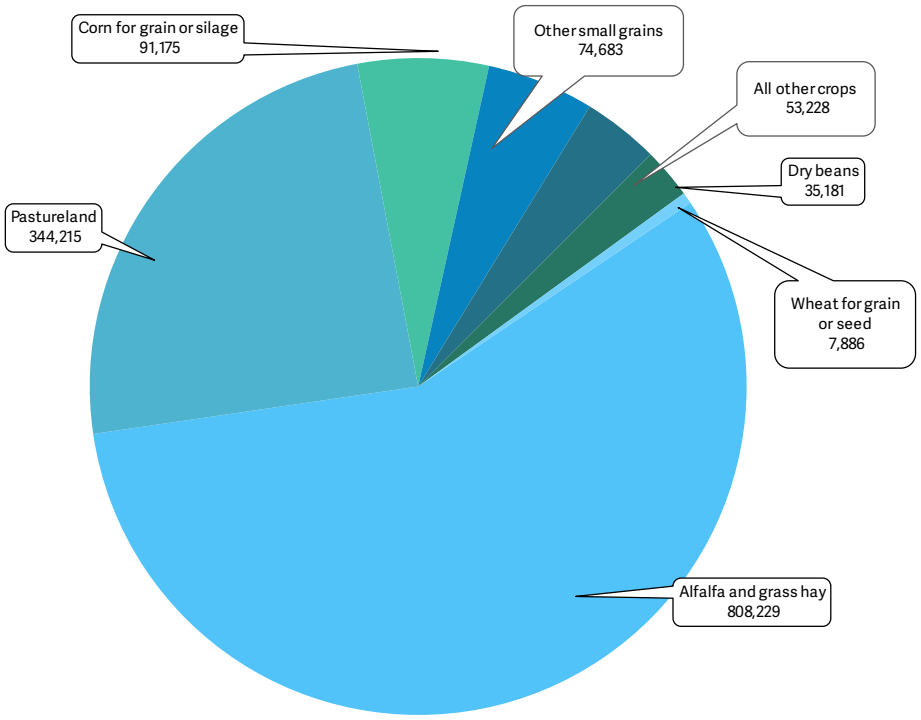


Figure 5
Acres of Irrigated Crops Grown in Wyoming

Data Source: USDA (2014).

Industrial

Industrial water use accounts for approximately 361,000 af annually, 72 percent of which comes from groundwater. Mining and mining reclamation is the largest use of industrial water (112,000 af) followed by coal-fired electric plants (73,000 af) and conventional oil and gas extraction (70,000 af). Manufacturing uses only about 745 af annually in the state.

The 30-year industrial water demand projections show potential increases to as high as 450,000 af and decreases to as low as 249,000 af per year. The Wind/Bighorn River Basin currently has the highest industrial water use, primarily from mining activity. It is also projected to have the highest industrial water demand in the future (WWC 2007).

Municipal and Domestic

Approximately 44 percent (63,200 af) of combined municipal and domestic water use in the state comes from surface water supplies and 56 percent (80,436 af) from groundwater. Wyomingites use an average of 215 gallons of water per person per day. Municipalities use approximately 41,000,000 gallons (126 af) per day of surface water and 36,000,000 gallons (110 af) per day of groundwater. Rural domestic water users that are not part of public water systems typically have their own private groundwater supplies, which account for approximately 52,000,000 gallons (160 af) per day statewide. Of all the basins in Wyoming, the Green River Basin has the highest municipal, domestic, and stock water use. This is because 70 percent of municipal surface water withdrawals in the Green River Basin are exported to Cheyenne, which is in the Platte River Basin. Thirty-year projections for municipal, domestic, and stock water uses anticipate an increase in surface water use from 63,000 af in 2007 to between 101,000 af (low-scenario projection) to 138,000 af (high-scenario projection) for 2040 (WWC 2007).

Groundwater Use

Groundwater comprises approximately 13 percent of total water withdrawals for the state. Groundwater uses include drinking water, agriculture and livestock production, industry, mining, and thermoelectric power. Irrigation accounts for 71 percent of groundwater withdrawals in the state. Approximately 10 percent of irrigation water comes from groundwater (Maupin et al. 2014). The degree to which groundwater is used for agriculture varies across the state. Some areas in southeastern Wyoming that rely heavily on groundwater for agriculture overlie formations of the High Plains Aquifer System and are experiencing declines in groundwater levels (McGuire 2013).

Approximately 61 percent of Wyoming's drinking water supply comes from groundwater, either from public supply systems or domestic wells (Maupin et al. 2014). In many areas, groundwater is the only viable source of water because surface water is not present or is unsuitable for use. Shallow (less than or equal to 500 feet deep) aquifers supply water for most rural households and are also commonly used for stock, irrigation, and industrial use.

Non-Consumptive Uses

A non-consumptive use of water is one in which water is used for some purpose but not consumed, so that the water remains available for use downstream. Non-consumptive uses include hydropower, recreation on streams and lakes, and in-stream flows for fisheries. Much of the surface water generated in Wyoming is used in a non-consumptive way as it flows in our streams before it leaves the state. Although non-consumptive uses do not reduce the quantity of water in a stream, they may change the quality, location, and timing of flows in ways that affect downstream users.

Hydropower

Hydroelectric power generation is an important non-consumptive use of water in

Wyoming. In 2012, the generating capacity of large hydroelectric facilities on Wyoming rivers was 303 megawatts (MW) (893,470 megawatt-hours actual energy production). This is 3.4 percent of the total power capacity available in Wyoming and 1.8 percent of actual energy production (EIA 2012). There are 13 major hydropower plants in Wyoming: six on the North Platte River, four on the Shoshone River, two on the Wind River, and one on the Green River. Three additional hydropower dams are on reservoirs that extend into Wyoming, though the hydropower facilities themselves are in adjoining states (WSGS 2014).

A number of smaller hydro facilities are on smaller rivers and irrigation canals, and there is potential for more of these small facilities. One recent study concluded that Wyoming had 2,840 technically feasible small hydropower projects with a total of 507 MW potential capacity. Although only a smaller number of these would generate sufficient revenues to cover the costs of construction and operation, some potential small hydro facilities on creeks and canals are technically and economically feasible (Wade et al. 2015).

Although quantity of water is virtually unchanged, the presence of hydropower can alter the timing of flows. A reservoir manager may store then release water when there is high demand for power generation. Storing water in a reservoir also generally increases its temperature, thus altering water quality. Both factors may affect downstream riparian vegetation, fish, and wildlife, as well as other downstream users. Hydropower is just one use to which reservoirs in Wyoming are managed. They are also managed for flood control, irrigation, recreation, and augmenting instream flows during certain times of year to improve fish and other wildlife habitat.

Environment

Environmental uses of water include sufficient flows and quality for the maintenance and protection of healthy streams and wetlands as well as fish and wildlife species that depend on them. Humans also depend on the healthy functioning of stream and wetland systems for, among other things, water purification (clean drinking water), regulating runoff and water supply (flood control), water storage (minimizing drought impacts), and agriculture (water infiltration and soil water storage). Many recreational uses of water, for example boating and swimming, rely fundamentally on the presence of sufficient streamflows, reservoir water levels, and/or water quality.

Instream flow refers to water flowing in streams and is generally considered a non-consumptive, permitted beneficial use. An instream flow water right is the legal means to protect water in streams for the benefit of fish based on the same laws used to protect other kinds of water rights. In 1986, the state of Wyoming enacted legislation defining "instream flow" as a beneficial use of water (Wyoming Statutes, Sections 41-3-1001 to 1014). The law allows for instream flow applications to be filed and granted for unappropriated water originating as natural flow or from storage in existing or new reservoirs. Only the state of Wyoming can own an instream flow water right. 130 applications have so far been filed for instream flow water rights on stream segments in Wyoming; approximately 2 percent of all stream miles in the state have an instream flow water right. For natural flow sources, water used for instream flow purposes is limited to the minimum needed to "maintain or improve existing fisheries."

Recreation

Water-based recreation is another important non-consumptive use of water in Wyoming. Examples of water-based recreation include boating, fishing, waterfowl hunting, and swimming. Even though many recreational

benefits do not possess a water right, they do contribute to the well-being of Wyoming's residents and bring economic benefits to the state through tourism. For example, hunters and anglers are estimated to have spent over $700 million in Wyoming in 2000 (WWC 2007).

The non-consumptive nature of many environmental and recreational water uses complicates efforts to quantify and compare them with more conventional consumptive uses; however, human activities are placing increasing pressure on our natural resource base. Recognizing these non-consumptive uses and quantifying them where possible is important, given the value of tourism to the state's economy.

In 2012, the WWDC commissioned a study (Harvey 2012) to recommend how best to incorporate environmental and recreational water uses into the state's basin planning process. The report recommends recreational and environmental water uses be identified and mapped and then assigned to one of three categories:

1. Protected water uses, which are recognized and protected from incursions by traditional water uses. Examples include minimum flow requirements imposed and enforced by state agencies and federally protected wetlands.

2. Complementary water uses, which are not protected but are unlikely to be affected by other water users in the future. One example is environmental use in the highest reaches of a watershed, where new consumptive uses are unlikely to be developed.

3. Competing uses, which are not protected and are likely to be affected by other water users in the future. One example is downstream environmental use, which may be constrained at any time by somebody who files a water right for a beneficial, consumptive use.

This exercise recognizes that environmental and recreational uses are important to the state and that some are more at risk than others of disappearing.

SNOW PACK AND RESERVOIR STORAGE

Since the majority of Wyoming's water supply originates as high-elevation snow, understanding the timing of snowpack melt-out and how it sustains rivers, streams, and reservoir levels late into the water year is important. The snow season typically begins in October and November. Subsequent melt-out occurs between April (at lower elevations) and June and July (at higher elevations). Reservoirs depleted from the previous year's water use fill with spring snowmelt runoff. The Bureau of Reclamation monitors water levels in its larger reservoirs for agricultural use, municipal use, flood control, power generation, fish and wildlife, and recreation (*http://www.usbr.gov/gp/wyao/*). Maintaining water supplies in reservoirs becomes critical for agriculture during the late summer and fall, when precipitation levels are low and demand for water is high. Major storage reservoirs in Wyoming and storage capacities are shown in Table 1.

WATER RIGHTS

The Wyoming Constitution declares all water within its boundaries property of the state. Individuals who wish to use water must obtain an approved permit through the State Engineer's Office (SEO). The SEO approves permit applications once it has determined that other water users will not be harmed by the appropriation.

Wyoming water law operates under the prior appropriation doctrine, or "first in time, first

Table 1: Large Reservoirs in Wyoming

Major River Basin	Name	Volume*
Bear	Sulphur Creek Reservoir	19,775
	Woodruff Narrows Reservoir	57,300
Green	Big Sandy Reservoir	38,300
	Boulder Lake	22,280
	Bush Creek Reservoir	17,267
	Eden Reservoir	18,490
	Flaming Gorge Reservoir	3,749,000
	Fontenelle Reservoir	344,800
	Fremont Lake	1,370,000
	Meeks Cabin Reservoir	33,571
	Naughton Reservoir	45,465
Northeast	Keyhole Reservoir	193,000
Platte	Alcova Reservoir	184,400
	Glendo Reservoir	492,000
	Grayrocks Reservoir	104,109
	Guernsey Reservoir	45,600
	Hawk Springs Reservoir	16,735
	High Savery Reservoir	22,400
	Hog Park Reservoir	22,656
	La Prele Reservoir	20,000
	Lake Hattie Reservoir	65,260
	Pathfinder Reservoir	1,070,000
	Rob Roy Reservoir	35,434
	Seminoe Reservoir	1,017,273
	Wheatland Reservoir #2	98,900
	Wheatland Reservoir #3	71,318
Powder/Tongue	Lake De Smet	210,000
Snake/Salt	Grassy Lake Reservoir	16,200
	Jackson Lake	3,380,000
	Palisades Reservoir	1,400,000
Wind/Bighorn**	Bighorn Lake	1,312,000
	Boysen Reservoir	757,900
	Buffalo Bill Reservoir	644,500
	Bull Lake	151,951
	Pilot Butte Reservoir	34,600
	Sunshine Reservoir	52,987

* Physical capacity, measured in acre-feet.

** Numbers in Wind/Bighorn reflect the capacities as reported under the Yellowstone River Compact.

Sources: Wyoming Water Resources Data System, the Wyoming State Engineer Office ePermit System (2011), Yellowstone River Compact annual reports, and http://usbr.gov/projects

in right." Those holding an earlier priority water right are allowed to receive their full portion of water before those with junior rights during times of water regulation. The state engineer can issue permits to anyone who plans to make beneficial use of the water as long as the proposed means of diversion and construction are adequate and granting the application is not detrimental to the public interest. Once the water has been put to beneficial use, an appropriator must petition the Board of Control to perfect the water right through an administrative process called adjudication. Recognized beneficial uses include, but are not limited to: irrigation, municipal, industrial, power generation, recreational, stock, domestic, pollution control, instream flows (state-held), and miscellaneous. Water right holders may not use more water than they can put to beneficial use and are limited to the amount authorized by their permits unless sufficient surplus water is present.

The Board of Control, comprised of the state engineer and four superintendents representing each of the state's administrative water divisions (see Figure 6), is a quasi-judicial agency, established by Wyoming's Constitution, responsible for adjudicating, administering, and amending water rights. Adjudication of a water right involves a field inspection to ensure the water is being put to beneficial use as specified in the permit. The Board of Control also hears requests for water rights transfers. Water rights in Wyoming are attached to a particular parcel of land or place of use; however, water rights owners may petition the Board of Control to change the location of use, the type of use, or the point of diversion. The Board of Control must consider whether other water rights holders will be injured when it reviews a water right change petition.

Figure 6
Administrative Water Divisions of Wyoming

Source: Wyoming Water Resources Data System (2015).

Figure 7
Wyoming River Basin Compacts and Decrees

Source: Wyoming State Engineer's Office (2003).

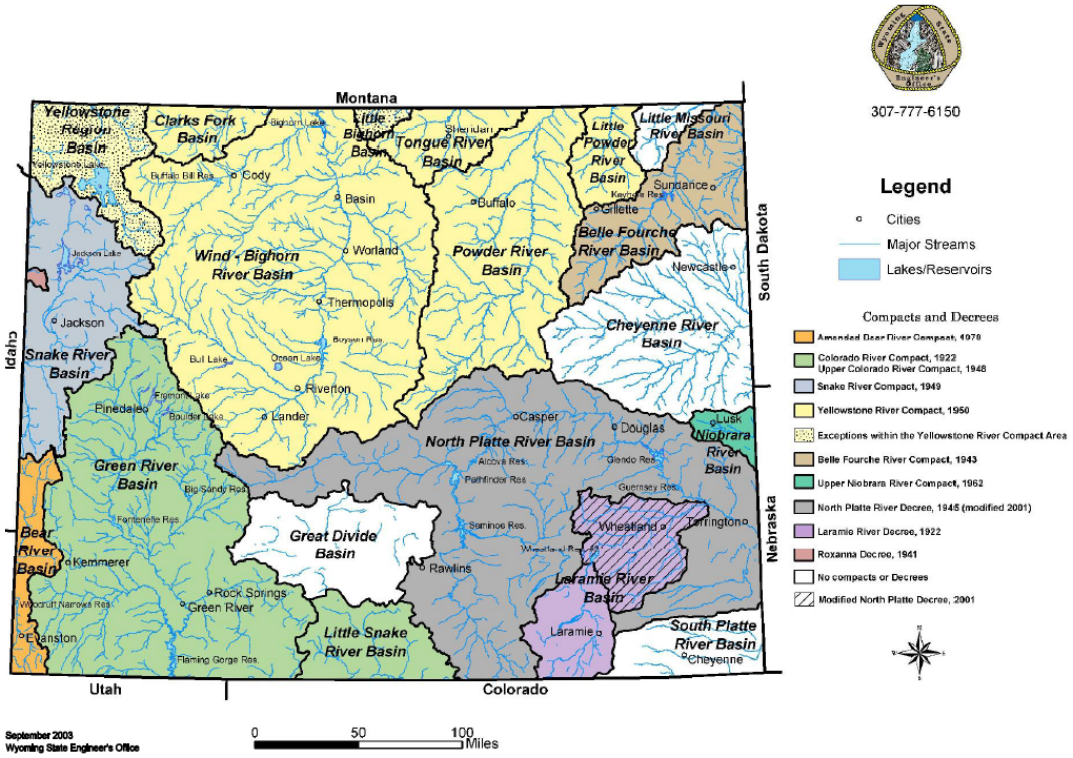


Table 2: Average Annual Streamflow* and Uses Under Normal Condition

Basin	State Line Outflow (Modeled Natural Flow)	Depleted Streamflow Leaving Wyoming	Wyoming's Remaining Share Under Compact
Bear River (2011)	388,588	291,128	9,790
Green River (2010)[1]	2,381,316	1,792,000	257,684
Northeast Wyoming (2003)[2]	240,500	148,000	9,800
Platte River (2006)[3]	1,307,400	526,700	0
Powder/Tongue River (2002)	982,600	775,000	248,100
Wind/Bighorn River (2010)	4,393,200	3,147,300	2,377,800
Yellowstone River (2010)[4]	3,205,800	3,205,800	0
Snake/Salt River (2003)[5]	3,540,000	3,345,800	155,000
Total (Includes post-2007 Updates)	16,439,404	13,231,728	3,058,174

[1] Depletions for municipal, domestic, and stock include 14,400 af diverted to the N. Platte for city of Cheyenne use.

[2] Excludes the flows for the Little Missouri and Niobrara rivers.

[3] The Platte River system is fully appropriated: a water right with a current-day priority cannot be expected to provide a reliable supply. Estimates exclude the flows and depletions from the Horse Creek and South Platte drainages.

[4] Drainage area is within Yellowstone National Park and includes estimates for the Madison, Gibbon, Firehole, and Gallatin rivers. A significant volume of water in this drainage (2.7 maf) is available for appropriation but is unlikely to be used in Wyoming because of its location in Yellowstone National Park.

[5] Excludes the flows for the Henrys Fork and Teton rivers.

*Volumes of stream flow in acre-feet.

Source : WWC (2007) with updates from subsequent basin plans (WWDC website).

INTERSTATE WATER RIGHTS

Although the Wyoming Constitution declares water to be the property of the state, Wyoming is limited in the amount that streamflows can be depleted by interstate water compacts established with other states and by court decrees. How Wyoming and its neighbors share this water is governed by interstate water compacts established with other states, court decrees and, in one instance, an international treaty. Figure 7 indicates the compacts and decrees that govern the allocation of water with neighboring states.

Interstate compacts are agreements allocating the water of an interstate stream among states and have been negotiated on most of Wyoming's streams. In instances where downstream states are developing more quickly than Wyoming, interstate compacts prevent downstream states from establishing water rights on the water reserved for Wyoming. Interstate compacts can consequently protect Wyoming's ability to develop water in the future.

Wyoming's rights to water have been apportioned by interstate compact on the Bear and Snake rivers (with Idaho and Utah), the Belle Fourche river (with South Dakota), the Green and Little Snake rivers in the Colorado River Basin (with Arizona, California, Colorado, Nevada, New Mexico, and Utah), the Niobrara (with Nebraska), and the Clarks Fork of the Yellowstone, Wind/Big Horn, and Tongue rivers in the Yellowstone River Basin (with Montana and North Dakota).

In some instances, disagreements over rights to the waters of interstate streams have been settled in U.S. federal courts. This is the case for the Laramie River (Colorado and Wyoming), the North Platte River (Colorado, Nebraska, and Wyoming), and Teton and South Leigh creeks (Idaho and Wyoming). The Yellowstone River Compact is also in litigation before the U.S. Supreme Court (Montana, North Dakota, and Wyoming).

Wyoming's use of water in the Colorado River Basin (Green and Little Snake rivers) is also indirectly affected by an international treaty between the U.S. and Mexico, as the Colorado River ultimately flows into Mexico (SEO 2006).

A key distinction between these compacts, decrees, and treaties is how waters are divided between states. In some instances, waters are divided based on diversions. For example, with regard to water rights junior to January 1, 1950, the Yellowstone River Compact specifies the percentage of available water Wyoming water users may divert on each tributary of the Yellowstone River before the water crosses the state border into Montana. Waters are divided based on consumptive use in other instances. For example, rather than specifying how much water Wyoming users may divert, the North Platte River Decree instead requires a certain percentage of available water cross the state border into Nebraska.

Table 2 (rightmost column) estimates the unappropriated waters from various streams and basins available to Wyoming for consumptive uses on an annual basis. Of the nearly 17 maf that flows out of the state on an annual basis under normal conditions, approximately 3.3 maf is available for use in Wyoming.

Montana v. Wyoming

The state of Montana sued the state of Wyoming in the U.S. Supreme Court in 2007, claiming Wyoming had violated the Yellowstone River Compact of 1951 – the agreement that governs water allocation in the Yellowstone River system (including the Clarks Fork, Big Horn, Tongue, and Powder rivers) among users in Montana, North Dakota, and Wyoming. Montana alleged that new, post-1950 appropriations in Wyoming (for irrigating new acreage, building new storage

facilities, pumping additional groundwater, and increasing consumption on existing acreage by installing more efficient irrigation systems) were interfering with Montana's pre-1950 rights.

One issue in the case is whether efficiency improvements on existing acreage by Wyoming's pre-1950 users are acceptable under the compact. Wyoming pre-1950 irrigators have installed sprinkler irrigation systems since 1950, which may have increased their consumptive use. Thus although their diversions have remained the same, their return flows to the river system may have decreased. Does the compact allow Wyoming's pre-1950 users to increase irrigation efficiency even if doing so reduces flows to Montana's pre-1950 users? The U.S. Supreme Court has said yes; increased irrigation efficiency is within the scope of the original appropriative right. Although the Supreme Court has ruled on some aspects of the case, others remain outstanding.

Further information can be found at *http://www.supremecourt.gov/SpecMastRpt/SpecMastRpt.aspx*.

Nebraska v. Wyoming

Nebraska filed suit against Colorado and Wyoming in the U.S. Supreme Court in the mid-1930s over flows from the North Platte River. The resulting 1945 Decree apportioned water between the states and, among other things, limited the number of acres in Wyoming that could be irrigated by the North Platte River. Nebraska filed another suit before the U.S. Supreme Court in 1986, alleging Wyoming had violated certain aspects of the 1945 Decree. The 2001 Modified Decree for this second suit resulted in new limits on the amount of water Wyoming could store, irrigate, divert, and consumptively use from the North Platte River.

The 2001 Modified Decree also established the North Platte River Recovery Implementation Plan, to maintain habitat of four species (the whooping crane, interior least tern, piping plover, and pallid sturgeon) protected under the Endangered Species Act. Consumptive use in Wyoming is monitored to ensure Wyoming delivers a sufficient amount of water to Nebraska at the state border. A decision is made every spring whether to place a priority call on Wyoming irrigators to ensure sufficient flows across the border into Nebraska to supply downstream water users in Nebraska. Reservoir storage levels and forecasted spring runoff inform this decision.

Big Horn Adjudication

In 1977, the state of Wyoming filed a complaint in federal district court to adjudicate all water rights in the Big Horn River Basin, including reserved water rights claims for the Wind River Indian Reservation and other federal lands. Reserved water rights are rights that have been "reserved" at the time of reservation of lands by the federal government. When the federal government establishes an Indian reservation, it reserves sufficient water to fulfill the primary purposes of the reservation, including historic and future uses. When the federal government reserves land for other purposes (national forest, national parks, etc.), it also sets aside sufficient water. The priority date of reserved rights is established as the date of the reservation. This adjudication process was to determine the nature, extent, and relative water rights of all water users in the Big Horn River Basin. The adjudication spanned 37 years and included seven Wyoming Supreme Court cases and numerous briefs, hearings, and reports by the special master, a court-appointed water law expert who assisted the judges in their deliberations.

The Big Horn Adjudication resulted in an award of federal reserved water rights to the Eastern Shoshone and Northern Arapahoe Tribes. These rights have a priority date of 1868, the year in which the Wind River

Reservation was created by treaty. The Big Horn Adjudication was concluded in September 2014 with a ruling by the court that all outstanding issues had been decided.

For more information, including a history of the Big Horn Adjudication, important court rulings, and reports of the Special Master, see the Wyoming Judicial Branch website: *http://bhrac.courts.state.wy.us/*.

WATER PLANNING AND DEVELOPMENT

State Engineer's Office

The SEO is charged with the regulation, management, and administration of water resources in Wyoming. As previously discussed, Wyoming water law is based on the doctrine of prior appropriation, meaning the first in time is first in right. The state engineer is the chief administrator of water resources in Wyoming. Procedures for obtaining a legal water right and administration of all associated water laws, including those for interstate water, are thus administered through the SEO.

Inquiries may be directed to the State Engineer's Office, 122 West 25th St., Herschler Building, 4th Floor, Cheyenne, Wyoming, 82002. 307-777-6150. *https://sites.google.com/a/wyo.gov/seo/*

Board of Control

The board is composed of the state engineer and the superintendents of the four water divisions in Wyoming. They meet four times a year: February, May, August, and November as provided for in the statutes. The board administrative office is at the SEO in Cheyenne.

The board handles all petitions including exchange petitions, any changes in adjudicated water rights, such as a change in point of diversion or change in place of use or location of irrigated lands. The board also adjudicates all water rights and all changes of use regardless of whether those rights are adjudicated. The board has exclusive original jurisdiction in water right (adjudicated or unadjudicated) abandonment proceedings. To avoid abandonment, the water must have demonstrated beneficial use within the past five years. The state engineer may provide for exchanges or changes of unadjudicated or undeveloped points of diversion points or means of conveyance. The state engineer may cancel a water right that does not provide a Notice of Completion or Notice of Beneficial Use.

Wyoming Water Development Commission

The WWDC was established in 1979 and includes ten members appointed by the governor and is administered by a director and staff (Wyoming Water Development Office). The Wyoming Water Development Commission provides grant and loan funding for water supply reconnaissance and feasibility studies and construction projects. Funding for studies and construction projects comes from mineral taxes. All planning studies and construction projects must be approved for funding by the Wyoming Legislature. Applicants must be public entities such as municipalities, irrigation districts, service and improvement districts, or joint powers boards. Projects must address water supply, transmission, conservation, or storage.

The WWDC is involved in several phases of water development including river basin planning, local project planning, project construction, a Groundwater Grant Program, and a Small Water Project Program. The intention of WWDC is to work closely with the land management agencies and the sponsoring entities in the administration of these programs. The funding available through the WWDC is designed to help develop a partnership where local, state, and federal agencies can work together for the benefit of the people of Wyoming.

Inquiries may be directed to the Wyoming Water Development Commission, 6920 Yellowtail Rd., Cheyenne, Wyoming, 82002. 307-766-7626. http://wwdc.state.wy.us/.

Department of Environmental Quality

The Department of Environmental Quality (DEQ) was created in 1973. DEQ is designated as the regulatory agency responsible for enforcing the Wyoming Environmental Quality Act, which includes water quality regulation. Administration of water quality issues are addressed by the Water Quality Division within DEQ.

DEQ operates under the guidance of an Environmental Quality Council. The council is comprised of seven private citizens appointed by the governor. Each division within DEQ, such as the Water Quality Division, has a separate advisory council.

The Clean Water Act of 1972 (PL-92-500), under Section 208, provides authority to plan and manage water quality by state and local governments. A 208 plan provides the opportunity to tie together the "point" and "nonpoint" sources of pollution through a single management scheme. The plan identifies water quality problems and alternative management practices for addressing the identified water quality problems, sets priorities and timetables for implementation of the best management practices, and identifies institutional organizations for carrying out the water quality programs in the state.

The DEQ Water Quality Division carries out the provisions of the Federal Water Pollution Act. Wyoming has developed a State Water Quality Plan, which has been certified by the governor and approved by the U.S. Environmental Protection Agency, upon which water quality planning is proceeding in the state.

Inquiries regarding water quality can be addressed to the Department of Environmental Quality, Water Quality Division, 122 West 25th St. Herschler Building, Cheyenne, Wyoming, 82002. (307) 777-7781. http://deq.wyoming.gov/wqd/.

State Water Forum

There are several local, state and federal agencies involved and interested in the state's water resources and to update each other and coordinate water programs, representatives from these agencies meet once a month at the SEO. The forum is chaired by the state engineer, or their representative, and the meetings are formatted to include agency updates and a special report on a selected water issue and/or program of current interest or concern is given at each monthly meeting.

Inquiries regarding the state water forum can be addressed to the State Engineer's Office, 122 West 25th St., Herschler Building, 4th Floor, Cheyenne, Wyoming, 82002. (307) 777-7641. https://sites.google.com/a/wyo.gov/seo/interstate-streams/water-forum.

CURRENT TOPICS IN WYOMING WATER

Groundwater Management

In some areas of Wyoming, groundwater use exceeds the natural rate at which water recharges the aquifer. Under Wyoming state law, the Board of Control may designate a control area if, among other things, the use of groundwater in the area is approaching the recharge rate, if groundwater levels are declining or have declined excessively, conflicts between users are occurring or are foreseeable, waste of water is occurring or may occur, or other conditions exist or may arise that require regulation for the protection of the public interest. All applications for new wells exceeding 25 gpm within a groundwater control area or petitions for change of existing groundwater use within

the boundaries of the designated areas must pass through an additional level of review involving public notice and recommendation from a five-member elected advisory board prior to approval. The groundwater control area advisory boards advise and assist the state engineer and Board of Control in formulating policies and recommendations on applications and petitions concerning groundwater development in the control areas.

Three groundwater control areas have been established in southeast Wyoming. They are in Laramie County, Platte County, and Prairie Center in Goshen County (Figure 8). The formation of each control area was generally precipitated by declining groundwater levels (or the perception of declining groundwater levels) associated with irrigation activities.

Ground Water/Surface Water Interactions

As in most western U.S. states, surface water and groundwater in Wyoming are managed separately; however, surface and groundwater in many areas of Wyoming are hydraulically connected. If the groundwater table is in physical contact with a stream channel, they are hydraulically connected and may constitute one source of supply. In such instances, an upstream groundwater pumper may be regulated (i.e., they may be required to limit their withdrawals below their permitted amount) if a downstream surface water user with a more senior right is being harmed. We will likely see more attention paid to these interactions in the future as our ability to monitor interactions between groundwater and surface water flows improves.

Horse Creek in Goshen County, over the LaGrange Aquifer, is one area where junior priority irrigation wells have been determined to be reducing the streamflow available to senior-priority surface water rights. On July 19, 2013, the state engineer issued an order determining that interactions between Horse Creek and the LaGrange Aquifer were

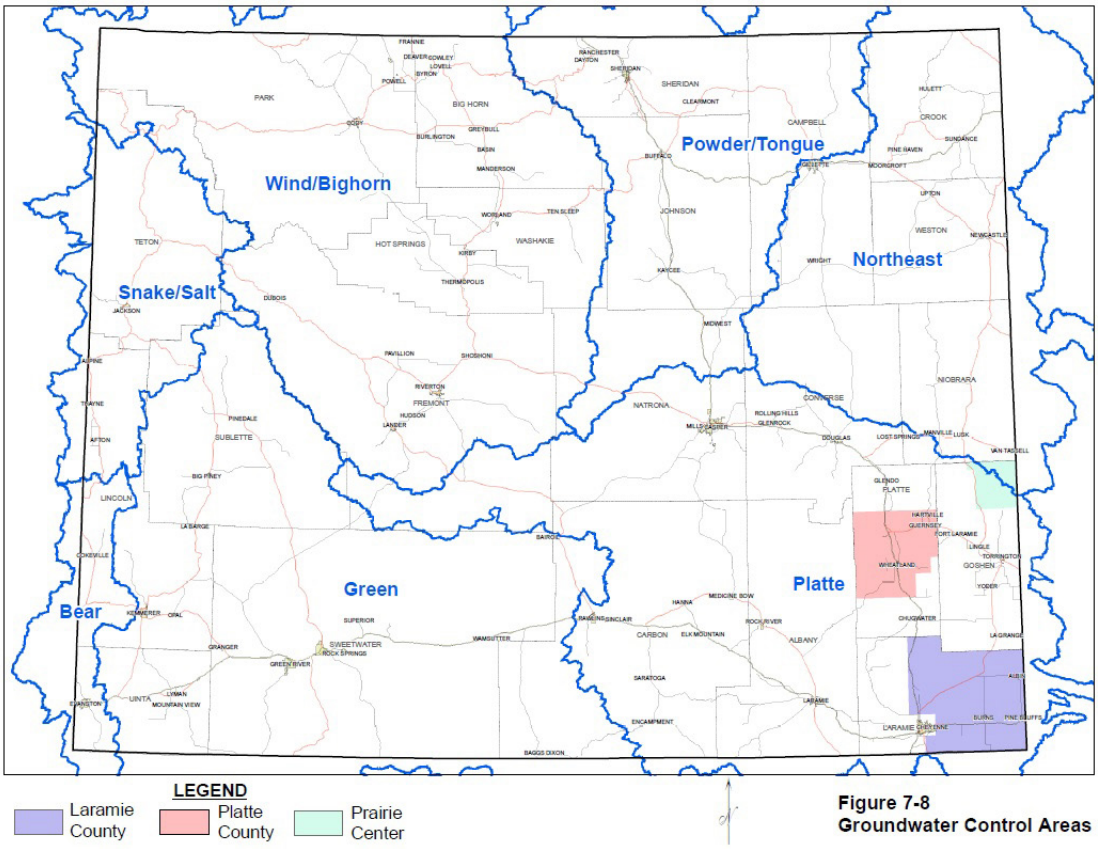


Figure 8
Groundwater Control Areas in Wyoming

Source: Figure 7-8 of WWC (2007).

significant enough that the two should be considered a single source of supply. The order placed limits on groundwater pumping and required more stream gauges for surface water monitoring and well meters be installed and measured, to improve understanding of local groundwater/surface water interactions.

Bates Creek, also in southeastern Wyoming, is another area that has seen surface water/groundwater interactions. The Nebraska v. Wyoming Supreme Court case settlement described above also recognizes the effect that groundwater pumping has on the availability of water downstream for Nebraska appropriators.

Weather Modification

The WWDC conducted a weather modification feasibility study in the Medicine Bow and Sierra Madre mountain ranges of southeast Wyoming from 2005 to 2014, to see if this technology can augment existing water supplies (NCAR 2014). The study used ground-based generators to lift silver iodide particles into clouds to encourage super-cooled water to condense and fall as snow near the mountain crests. The study's randomized statistical experiment did not show a statistically significant impact of cloud seeding but the accumulated evidence from the statistical, modeling, and physical studies did show an assessed seeding effect over a winter season of between 5 and 15 percent for seedable events. The Wyoming State Legislature appropriated funds for collaborative operations in the Wind River range, feasibility studies in the Big Horn, Laramie, and Wyoming ranges, and final design and permitting for an operational program in the Medicine Bow and Sierra Madre ranges.

Water-Energy Nexus

There are definite and specific links between energy and water in Wyoming. Water and energy are used for agricultural production and we often use water for energy production. Water resources are necessary to develop many oil and gas resources. Water used for development of conventional oil and gas varies by basin and ranges from less than 1 percent in the Green River Basin to 9 percent of available water in the Powder and Tongue River basins (Golder Associates 2014).

Although agriculture is still the primary user of the majority of water in Wyoming, there have recently been temporary changes in the use of agricultural water to meet new demands in hydraulic fracturing. Approximately 4,000 af of water was embraced in temporary water use agreements in Laramie County during 2009-11, but only 10 percent of that water was actually used. Interest in temporary use agreements for energy in Laramie County tapered off in 2012-13. Though amounts of water can vary significantly depending on the geology of the formation being fractured, hydraulic fracturing can require from 2 to 5 million gallons of water per fracturing job. This amount decreases if the waste-water is recycled.

Coalbed Methane (CBM) production relies on the extraction of groundwater. Groundwater is pumped from the coalbed to release the gas, which is held under pressure in the coal seams. At the height of CBM production in the past decade (2000-2010), wells in Wyoming were producing up to 68 million barrels (2.38 billion gallons) of water a month, according to Wyoming Oil and Gas Conservation Commission data. CBM production and hydraulic fracturing can result in product water and waste that can pose potential surface and ground water quality issues depending on the disposal methods.

Governor's Water Strategy

Governor Matt Mead recently presented a water strategy for Wyoming to address water management issues in the state (Mead 2015). Governor Mead introduced 10

strategic initiatives for Wyoming's water that centered around four major themes: water management, water development, water conservation and protection, and water and watershed restoration. These themes were developed with input from Wyoming citizens in public meetings across the state. They consequently represent some of the issues on the minds of Wyoming citizens today.

A link to the Governor's Water Strategy is available at *http://waterplan.state.wy.us/plan/statewide/govstrategy/20150115-Gov-WaterStrategy.pdf*.

SUMMARY

Water concerns cut across all lines; water is important to agriculture, municipalities, industry, recreation, and people. The physical, political, and economic aspects of water are also intertwined with one another. We know this in the western U.S. as well as anybody. Water's value is higher in places where there is less of it. A thirsty explorer in the desert is more grateful for the first glass of water than they are for the fourth, just as the first acre-foot of water applied to most crops provides more yield benefits than the third. When water is plentiful, we often take it for granted. When water is scarce, its allocation and management requires more attention from citizens and policymakers if conflict is to be avoided. Water is an important factor in the social and economic growth of any community and for the state itself. The use and management of this precious resource is essential.

Responsible development of still-available water supplies is important to the state's economy. Our efforts to develop and manage our water resources wisely can improve the resilience of Wyoming communities in the face of fluctuating water supplies and prolonged droughts. Creative approaches to resolving conflict can relieve pressure in places where we have competing demands for available water supplies. Improved understanding of hydrologic processes can enhance our ability to protect water resources as well as the ecosystems and communities that depend on them.

Note: This bulletin is an update to Jacobs, J. and D. Brosz (2000). "Wyoming's Water Resources." University of Wyoming Extension Bulletin # 969R. Laramie, WY.

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