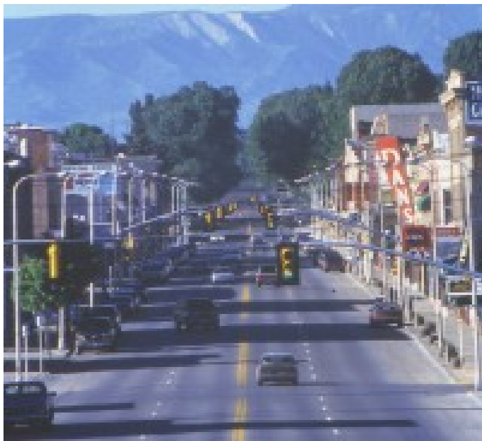
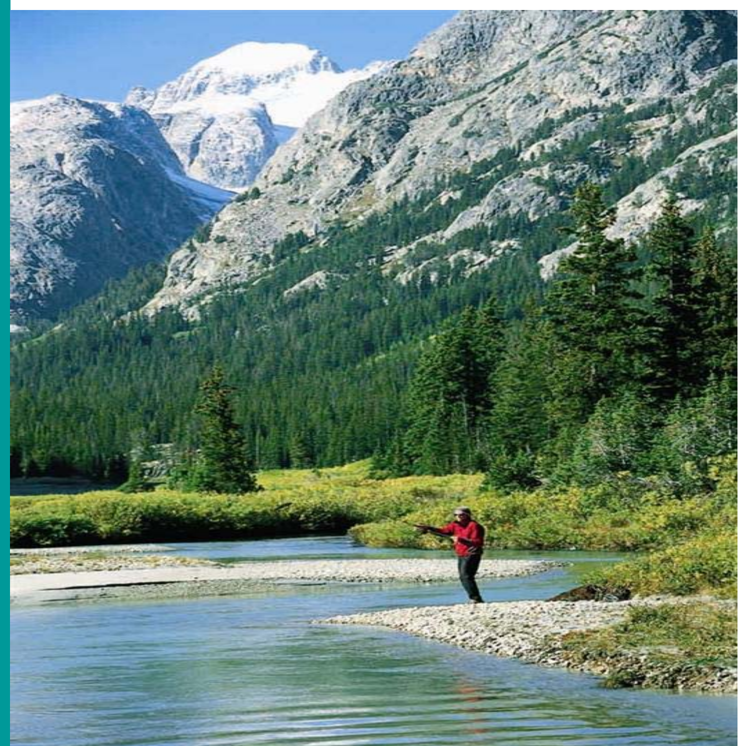
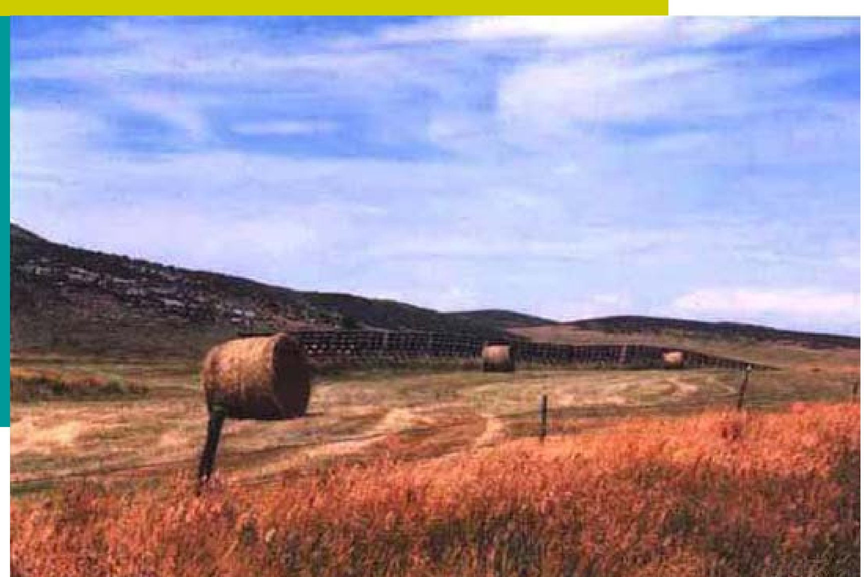


# WYOMING FRAMEWORK WATER PLAN VOLUME I





Wyoming Water Development
Commission
October 2007

This report was prepared by:

WWC Engineering
Hinckley Consulting
Collins Planning Associates
Greenwood Mapping, Inc.
States West Water Resources Corporation

# Wyoming Framework Water Plan
# Volume I

## October 2007

This report was prepared for:

Wyoming Water Development Commission
6920 Yellowtail Road
Cheyenne, WY  82002

This report was prepared by:

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States West Water Resources Corporation

I, Murray T. Schroeder, a Wyoming registered Professional Engineer, certify that this Wyoming Framework Water Plan, Volume I report was prepared by me or under my direct supervision. (The original signature and stamp are available at the Water Development Office.)


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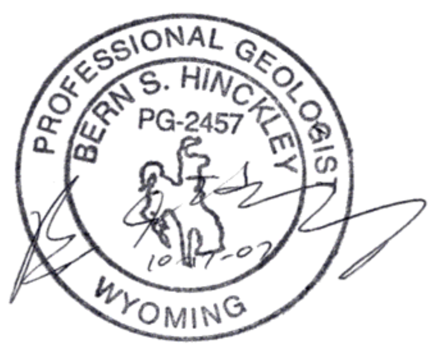
I, Bern Hinckley, a Wyoming registered Professional Geologist, certify that this Wyoming Framework Water Plan, Volume I report was prepared by me or under my direct supervision. (The original signature and stamp are available at the Water Development Office.)

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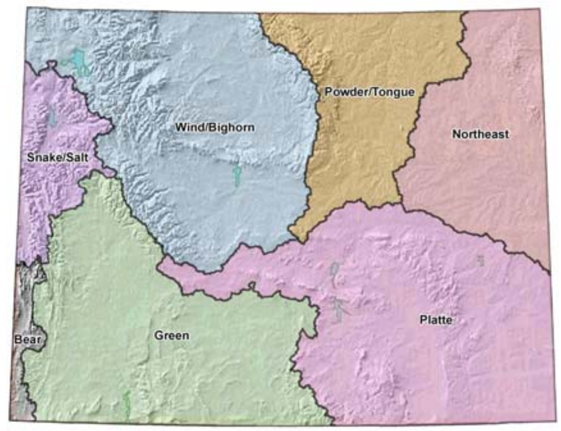
# 1.0 INTRODUCTION

## 1.1 OVERVIEW

This Wyoming Framework Water Plan presents a statewide perspective on water resources, compiled from the results of a seven-basin planning process performed by the Wyoming Water Development Commission (WWDC). This Framework Water Plan presents summary information on:




- The **Setting** chapter presents basic physical information about Wyoming, current economic and social conditions, and an outline of the institutional constraints on water use.
- The **Resources** chapter characterizes Wyoming's total water supply, including information on where the resources are located and their quality.
- The **Use** chapter quantifies how Wyoming is using its water resources in both the depleting and non-depleting water use sectors.
- The **Projections** chapter provides estimates of the future water needs of the state, for the depleting and non-depleting water use sectors.
- The **Availability** chapter presents estimates of the amounts and locations of unused water resources that are available to meet needs. Unused water resources are those that are physically and legally available over and above existing uses.
- Finally, the **Opportunities** chapter summarizes information regarding opportunities for meeting the projected water needs of Wyoming. These opportunities may provide a starting point for existing and future water users seeking to address water supply deficits.

In addition to presenting information on water resources of the state, this document covers two other important subjects:

- A **Web-based Presentation Tool** is described in Chapter 2. This tool makes the results of this Framework Water Plan available online and provides a structure that will promote efficient future planning updates.
- **Project Funding** is presented in Chapter 9. This chapter outlines opportunities for project proponents to obtain state and federal funding assistance.

## 1.2 NEED FOR BASIN PLANNING AND FRAMEWORK PLAN

The Wyoming water planning process is founded on the Prior Appropriation Doctrine and the understanding that the State of Wyoming should manage its water resources "for the benefit of the citizens of the state." The WWDC was created by the 1979 Wyoming Legislature and is charged with responsibility for "...the planning, selection, financing, construction, acquisition, and operation of projects and facilities for the conservation, storage, distribution and use of water, necessary in the public interest to develop and preserve Wyoming's water and related land resources."

The major planning goals of the Water Development Commission include:

- **Basinwide Plans** – These plans should be generated for each of the state's major drainage basins. The plans' purpose is, in part, to quantify existing uses and to project future needs. The plans should also serve to identify and prioritize water development opportunities. The plans shall document the State's plan to utilize its compact and decree allocations.
- **Project Planning** – The program should assist Wyoming municipalities, irrigation districts, and other public entities' efforts to plan for the future. This assistance will typically come through the development of reconnaissance and feasibility-level studies, which serve to identify water supply requirements and prioritize water system improvements.
- **Federal Funding** – Presently, there are federal programs which provide funding assistance for some types of water development projects. However, in order to access these funds, costly feasibility/environmental studies are often needed. The WWDC shall consider participating in these studies if a proposed project alleviates a water development, management, or rehabilitation problem, or allows the continued beneficial use of water. The amount of the WWDC's financial participation shall be based on the proponent's ability to pay.
- **Research** – The program should continue its participation in research projects which serve to clarify economic, environmental, water development, and management issues.
- **Coordination** – The WWDC should strive to keep informed on proposed state and federal rules and regulations that may affect water use, development, and management.

The last statewide water planning process was completed in 1973 with the publication of the Wyoming Framework Water Plan. As with the current planning process, the process in the 1970s was performed on a basin-by-basin basis to capture the unique water situation and needs in each basin. Since 1973, technological advances have been made in water resource planning, and political and regulatory conditions in water resource management have changed. Therefore, it was necessary that Wyoming complete an updated statewide water planning report.

## 1.3 BASIN PLANS

Most information in this Framework Water Plan was collected and presented in the development of seven individual river basin plans. These basin plans were prepared by the WWDC and its consultants between 2001 and 2006 as shown in Table 1-1. The executive summary of these individual planning efforts is included in Volume II of this report.

**Table 1-1 Basin Plan Summary**

| Basin Plan | Consultant | Date Completed |
|---|---|---|
| Green River | States West Water Resources Corporation<br>Boyle Engineering, Inc.<br>Purcell Consulting, P.C.<br>Water Rights Services, L.L.C.<br>Watts and Associates, Inc. | February 2001 |
| Bear River | Forsgren Associates Inc.<br>Anderson Consulting Engineers, Inc.<br>Leonard Rice Engineers, Inc.<br>BBC Research & Consulting | September 2001 |
| Northeast Wyoming Rivers | HKM Engineering Inc.<br>Lord Consulting<br>Watts and Associates, Inc. | February 2002 |
| Powder/Tongue Rivers | HKM Engineering Inc.<br>Lord Consulting<br>Watts and Associates, Inc. | February 2002 |
| Snake/Salt Rivers | Sunrise Engineering, Inc.<br>Boyle Engineering, Inc.<br>Hinckley Consulting<br>BBC Consulting, Inc.<br>Fassett Consulting<br>Nelson Engineering, Inc.<br>Rendezvous Engineering, Inc. | June 2003 |
| Wind/Bighorn Rivers | BRS, Inc.<br>MWH<br>Lidstone and Associates<br>Trihydro Corporation<br>Donnell and Allred Inc.<br>Water Rights Services, L.L.C. | October 2003 |
| Platte River | Trihydro Corporation<br>Lidstone and Associates<br>Harvey Economics<br>Water Rights Services, L.L.C. | May 2006 |

# 2.0 WEB TOOL

The Wyoming Water Framework Water Plan is available on the World Wide Web. A PDF version and GIS products can be downloaded at http://waterplan.state.wy.us/frameworkplan.html. An interactive Presentation Tool is available at http://waterplan.wrds.uwyo.edu/fwp/.

Figure 2-1 shows an example page from the Presentation Tool. The Presentation Tool features:

- Powerful Searching
- Database Driven Tables
- Downloadable Maps and Figures

## 2.1 Searching

Google searching is available on each page and defaults to search the Water Plan site only. After your first set of search results are presented, you will then have the option to search the entire web in addition to just the Water Plan site. Each search will return up to 8 results, with the option to select "More results" if there are more than 8 matches returned. When you select "More results", you will go into the main Google search site.

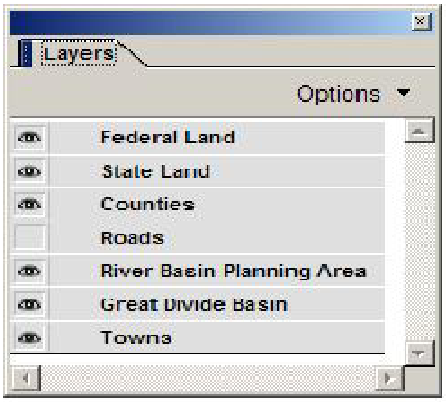
## 2.2 Database Tables

All of the data presented in tables represents values from the 2007 Framework Water Plan. Many of these tables will be updated over time. These tables have a hyperlink at the bottom: Click here to check for more recent data..

This link will open the table in a new window. The values in the table will represent the most recent data available in the database. Where data exist that are more recent than the 2007 Framework Water Plan, those data will be identified in red and the date and source of the data will be shown. The data shown in the tables in this document will always show the 2007 Framework Water Plan values. Only by clicking the hyperlink will updated values be displayed.

## 2.3 Maps and Figures

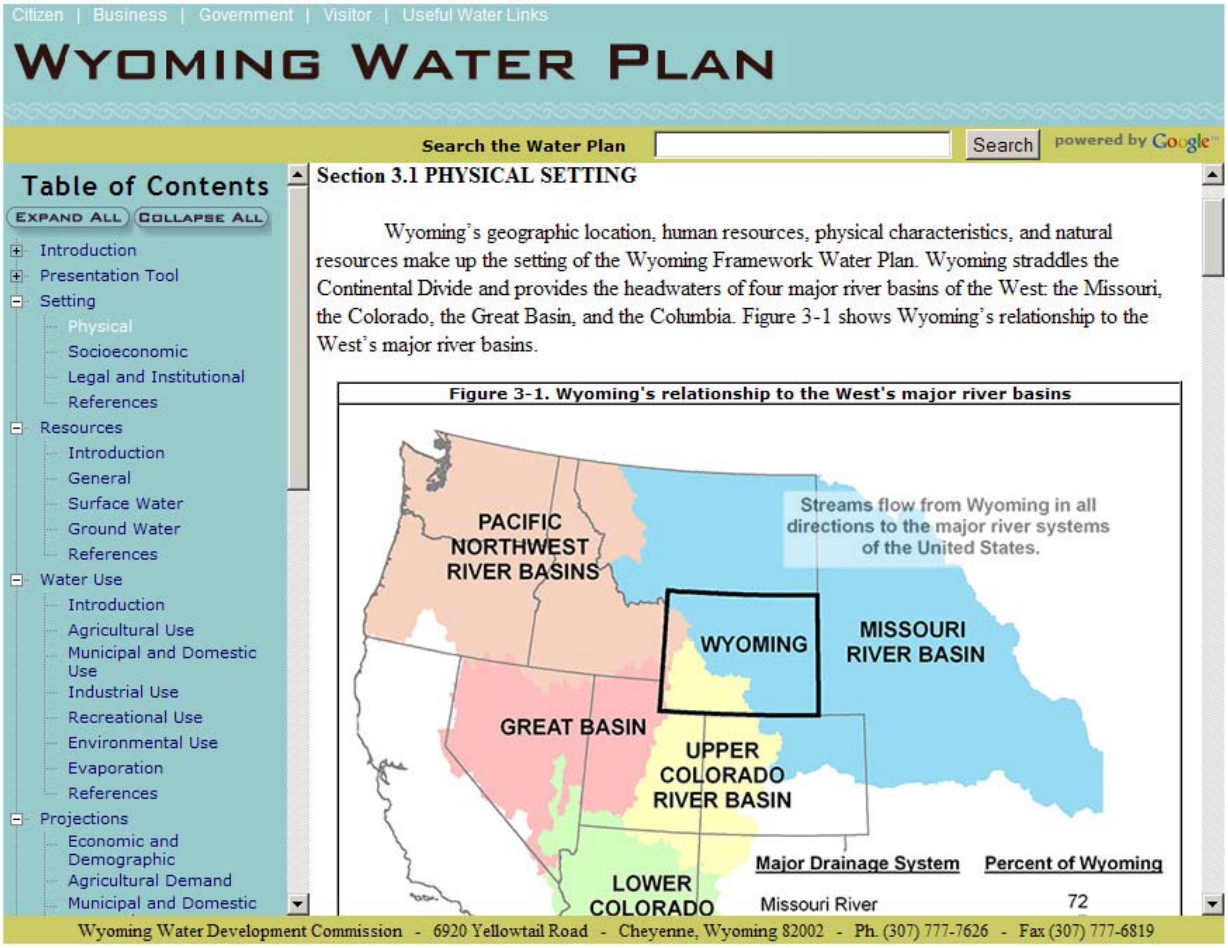
High resolution PDFs are available for all of the maps and figures. Viewing or printing the PDFs requires the Adobe Acrobat PDF viewer which is available for free download at www.adobe.com/products/acrobat/readstep2.html.




Many of the PDF maps use layers, which can be turned on and off individually. This feature aids the visualization of the information being presented. The layered PDFs will have a "Layers" tab near the upper left side of the window. Layers may be turned on or off by clicking the eye icon left of the layer name. In the example to the right, the "Roads" layer is turned off, and is not now displayed on the map.

The layer feature requires Adobe Acrobat version 6 or greater. Acrobat 4, and possibly earlier versions, will display the PDF, but without the ability to turn individual layers on and off.

Figure 2-1. Snapshot of P-Tool



# 3.0 SETTING

## 3.1 PHYSICAL SETTING

Wyoming's geographic location, human resources, physical characteristics, and natural resources make up the setting of the Wyoming Framework Water Plan. Wyoming straddles the Continental Divide and provides the headwaters of four major river basins of the West: the Missouri, the Colorado, the Great Basin, and the Columbia. Figure 3-1 shows Wyoming's relationship to the West's major river basins. The state contains 23 counties and encompasses 98,210 square miles, making it the ninth largest of the contiguous United States. Figure 3-2 shows a map of the state including the river basin planning areas and the Continental Divide. Wyoming's 493,782 people in 2000 rank the state fiftieth in population. Its abundant natural resources rank Wyoming high in the production of minerals and energy resources. Much of Wyoming's heritage stems from its agricultural and livestock industry. Transportation, important in the settlement of the state, combined with the scenic beauty of open spaces, rugged mountains, forests, and national parks, enhances an important and growing tourist industry.

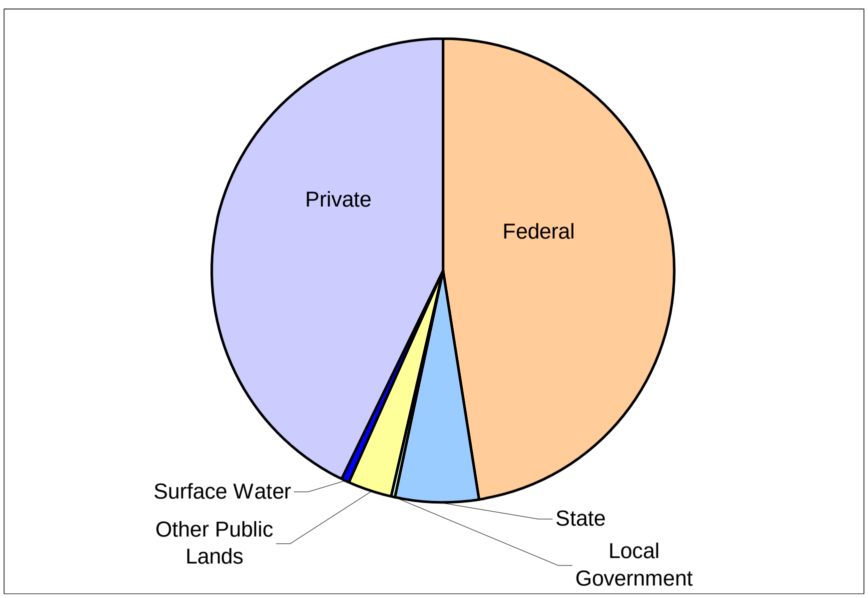
### 3.1.1 Land Area and Ownership

The land area within the boundaries of Wyoming is 62,854,000 acres, and the surface water area is 456,000 acres. Of the land acreage, about 48 percent is owned by the federal government, 43 percent is owned by private interests, 6 percent is owned by state and local government, and about 3 percent is owned by the Eastern Shoshone and Northern Arapaho Tribes. Table 3-1 summarizes the landownership on a statewide basis.

**Table 3-1 Landownership and Area**

| Landowners | Acres | Square Miles |
|---|---|---|
| **UNITED STATES GOVERNMENT** | | |
| National Park Service | 2,343,000 | 4,000 |
| Forest Service | 9,233,000 | 14,000 |
| Fish and Wildlife Service | 47,000 | 70 |
| Bureau of Land Management | 17,470,000 | 27,000 |
| Bureau of Reclamation | 955,000 | 1,000 |
| **Total Federal** | **30,048,000** | **46,070** |
| **WYOMING** | | |
| Land Commission | 3,541,000 | 6,000 |
| Recreation Commission | 8,000 | 10 |
| Game and Fish Department | 165,000 | 260 |
| **Total State** | **3,714,000** | **6,270** |
| **LOCAL GOVERNMENT** | | |
| Counties | 22,000 | 30 |
| Cities | 48,000 | 80 |
| School Districts and Colleges | 24,000 | 40 |
| **Total Local Government** | **94,000** | **150** |
| **OTHER** | | |
| Other Public Lands | 1,987,000 | 3,000 |
| Surface Water | 456,000 | 710 |
| **Total Public** | 35,843,000 | 55,000 |
| **Total Private** | 27,011,000 | 42,000 |
| **TOTAL AREA** | **62,854,000** | **98,210** |

Source: University of Wyoming, Department of Geography & Recreation



The 1973 Framework Water Plan reported that agricultural activities were using about 84 percent of Wyoming's land area. Currently agricultural activities probably use slightly less than 84 percent of Wyoming's land area due to municipal and industrial growth.

The percentage of privately owned land versus publicly owned land diminishes westward across the state. Figure 3-3 shows the landownership by river basin planning area.

### 3.1.2 Physiography

Figure 3-4 shows the varied physiography of the state. Beginning near the center of Wyoming's southern boundary, the Continental Divide extends through Wyoming in a northwesterly direction, separating the Missouri River drainage from the Columbia River and the Colorado River drainages. In southcentral Wyoming, the Continental Divide splits to encircle a closed drainage basin, the Great Divide Basin.

*Topography*

The mean elevation of Wyoming is about 6,700 feet, making the state the second highest in the United States (only Colorado has a higher mean elevation). The topographic elevations vary from a maximum of 13,804 feet above sea level at Gannett Peak in the Wind River Range to about 3,099 feet above sea level in northeastern Wyoming where the Belle Fourche River flows into South Dakota.

Wyoming's mountain ranges are generally oriented in a southeast to northwest trend. The Teton Range is probably Wyoming's most spectacular mountain range in that it rises abruptly from the floor of Jackson Hole to elevations of 9,000 to over 13,500 feet above sea level. This is a rise from 3,000 feet to over 7,000 vertical feet.

The topographic basins of the state contain a wide variety of geologic features including narrow terraces, plains, rolling hills, badlands, deserts, and uplifts with foothills and steep mountain slopes near most of the mountain ranges. Many areas of the state are dotted with sandstone buttes, hogbacks, and breaks.

*Drainage System*

Most of the streams that originate in the mountainous areas are perennial streams deriving their flow from snowmelt, rainfall runoff, and groundwater. The perennial streams provide most of the water yield in the state; however, there are numerous intermittent streams that originate in the lower elevations of the river basins.

Most of the water flowing through the state originates within the state's boundaries, with the following few exceptions. Colorado's mountains contribute to Wyoming's streamflow via the North Platte, Laramie, and Little Snake Rivers. Montana contributes streamflow in the Clarks Fork River. The headwaters of the Blacks Fork, Henrys Fork, and Bear River are in Utah.

About 72 percent of the land area of Wyoming drains northward and eastward into the Missouri River system. Tributaries of the Colorado River drain about 17 percent of Wyoming. The Bear River meanders along the western border of Wyoming and ends in Great Salt Lake in the Great Basin. The Snake River starts in Wyoming and is tributary to the Columbia River. The Bear and Snake Rivers drain about 7 percent of the state's land area. The remaining 4 percent is in the closed Great Divide Basin.

### 3.1.3 Climate

Wyoming's climate is a product of its latitude, elevation, and topography. The state is in the latitude of the prevailing westerly winds with a dominance of maritime Pacific air. This air is modified by the several mountain ranges between Wyoming and the West Coast which cause low-level moisture to be precipitated before reaching the state. Moisture in the higher mountains ranges from 20 to over 40 inches per year, most of which falls as snow. The eastern plains areas of the state normally receive from 9 to 16 inches of precipitation annually, most of which occurs between April and July. The desertic basins in the western part of the state normally receive only 6 to 9 inches of precipitation annually.

Wyoming has large seasonal and daily temperature ranges. Temperatures higher than 110° F and lower than -50° F have been recorded, and daily temperature changes of 40° F and more are not unusual.

An important climate indicator is the growing season. For some crops, the growing season is the period between the last spring frost (occurrence of 32° F or lower) and the first fall frost. For forage crops, the growing season is the period when the mean daily temperature is above 40° F. The average 32° F freeze-free periods for Wyoming are shown on Figure 3-5. In areas with long growing seasons such as the lower North Platte River area, other parts of eastern Wyoming, and the lower Bighorn River area, high-value crops such as corn, sugar beets, and potatoes can be grown if irrigation water is available. In areas with shorter growing seasons, the predominant crops are forage crops, alfalfa, and small grains. In practically all areas of the state, irrigation is necessary for dependable crop production. The average seasonal consumptive irrigation requirement (water needs minus effective precipitation) for grass is shown in Figure 3-6.

## 3.2 SOCIOECONOMIC SETTING

### 3.2.1 Historic Population Growth

Almost all demographic data are compiled on the basis of political units such as state, cities, and counties, and most of the economic data are reported on at the county, state, or national level.

According to the 2000 U.S. census, the population of Wyoming was 493,782 people, an increase from 332,416 people in 1970. The 493,782 people resided in 193,608 households within Wyoming. Roughly 45 percent of the state population lived in the Platte River Basin.

Wyoming's population has been increasing fairly steadily over time. U.S. Census Bureau data show that Wyoming's population has been increasing since the 1870 census through the 2000 census with one exception: during the 1980-1990 Energy Bust when state population actually dropped. Population has since rebounded and is once again on the rise. Table 3-2 shows the population trend of Wyoming over the past 50 years. Individual counties have experienced some fairly dramatic changes in population over the past 50 years: e.g., Campbell County went from 4,839 persons in 1950 to 33,698 in 2000 while Niobrara County went from 4,701 persons in 1950 to 2,407 in 2000.

**Table 3-2 Population 1950 to 2000**

| County | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 |
|---|---|---|---|---|---|---|
| Albany | 19,055 | 21,290 | 26,431 | 29,062 | 30,797 | 32,014 |
| Big Horn | 13,176 | 11,898 | 10,202 | 11,896 | 10,525 | 11,461 |
| Campbell | 4,839 | 5,861 | 12,957 | 24,367 | 29,370 | 33,698 |
| Carbon | 15,742 | 14,937 | 13,354 | 21,896 | 16,659 | 15,639 |
| Converse | 5,933 | 6,366 | 5,938 | 14,069 | 11,128 | 12,052 |
| Crook | 4,738 | 4,691 | 4,535 | 5,308 | 5,294 | 5,887 |
| Fremont | 19,580 | 26,168 | 28,352 | 38,992 | 33,662 | 35,804 |
| Goshen | 12,634 | 11,941 | 10,885 | 12,040 | 12,373 | 12,538 |
| Hot Springs | 5,250 | 6,365 | 4,952 | 5,710 | 4,809 | 4,882 |
| Johnson | 4,707 | 5,475 | 5,587 | 6,700 | 6,145 | 7,075 |
| Laramie | 47,662 | 60,149 | 56,360 | 68,649 | 73,142 | 81,607 |
| Lincoln | 9,023 | 9,018 | 8,640 | 12,177 | 12,625 | 14,573 |
| Natrona | 31,437 | 49,623 | 51,264 | 71,856 | 61,226 | 66,533 |
| Niobrara | 4,701 | 3,750 | 2,924 | 2,924 | 2,499 | 2,407 |
| Park | 15,182 | 16,874 | 17,752 | 21,639 | 23,178 | 25,786 |
| Platte | 7,925 | 7,195 | 6,486 | 11,975 | 8,145 | 8,807 |
| Sheridan | 20,185 | 18,989 | 17,852 | 25,048 | 23,562 | 26,560 |
| Sublette | 2,481 | 3,778 | 3,755 | 4,548 | 4,843 | 5,920 |
| Sweetwater | 22,017 | 17,920 | 18,391 | 41,723 | 38,823 | 37,613 |
| Teton | 2,593 | 3,062 | 4,823 | 9,355 | 11,172 | 18,251 |
| Unita | 7,331 | 7,484 | 7,100 | 13,021 | 18,705 | 19,742 |
| Washakie | 7,252 | 8,883 | 7,569 | 9,496 | 8,388 | 8,289 |
| Weston | 6,733 | 7,929 | 6,307 | 7,106 | 6,518 | 6,644 |
| Yellowstone Park | 353 | 420 | See Note 1 | | | |
| **WYOMING** | **290,529** | **330,066** | **332,416** | **469,557** | **453,588** | **493,782** |

[1] Yellowstone Park is included in Teton and Park Counties

Source: Equality State Almanac 2006 State of Wyoming

The 2000 census data were broken out into the river basin planning areas by the Wyoming Department of Administration and Information (WDAI) Economic Research Division. Table 3-3 presents the population estimates for each of the river basin planning areas for 2000 and 2005. The 2005 population estimates are based on U.S. Census Bureau estimates for the state of Wyoming and for each of the counties. Rapid changes in population are again evident; these changes are often associated with or tied to changes in the energy and minerals sectors.

**Table 3-3 Basin Area Populations**

| River Basin | 2000 Population | 2005 Population |
|---|---|---|
| Bear | 14,550 | 14,530 |
| Green | 54,760 | 56,229 |
| Northeast Wyoming | 45,600 | 49,034 |
| Platte | 227,330 | 232,976 |
| Powder/Tongue | 38,420 | 40,069 |
| Snake/Salt | 27,480 | 29,601 |
| Wind/Bighorn | 86,050 | 86,854 |
| **WYOMING TOTAL[1]** | **494,190** | **509,293** |

Source: Wyoming Department of Administration and Information, Economic Research Division

[1] Individual basin numbers do not total to 493,782 the 2000 census population due to differences experienced in disaggregation and assignment of census block data to the river basin areas.

### 3.2.2 Aging Population

In 2000, there was a variation in age distributions for the counties in Wyoming. Albany, Campbell, Sweetwater, Teton, and Uinta Counties had a more youthful population. Goshen, Hot Springs, Johnson, and Niobrara Counties had an older population, with a greater percentage of residents over the age of 55. Table 3-4 provides a comparison of age cohorts by percentage for the U.S., Wyoming, and the counties.

**Table 3-4 Age Groups by Percentage**

| Location | Age Group | | | | |
|---|---|---|---|---|---|
| | 0 -19 | 20 - 34 | 35 - 54 | 55 - 64 | 65 & Older |
| U.S. | 29 | 21 | 29 | 9 | 12 |
| Wyoming | 30 | 19 | 31 | 9 | 12 |
| Albany | 26 | 35 | 24 | 7 | 8 |
| Big Horn | 28 | 16 | 26 | 13 | 17 |
| Campbell | 30 | 21 | 34 | 9 | 6 |
| Carbon | 27 | 17 | 33 | 10 | 12 |
| Converse | 31 | 16 | 33 | 9 | 11 |
| Crook | 25 | 15 | 31 | 13 | 16 |
| Fremont | 31 | 16 | 30 | 10 | 13 |
| Goshen | 28 | 16 | 28 | 11 | 17 |
| Hot Springs | 22 | 13 | 29 | 15 | 21 |
| Johnson | 23 | 17 | 29 | 14 | 18 |
| Laramie | 29 | 21 | 30 | 9 | 11 |
| Lincoln | 29 | 18 | 30 | 11 | 12 |
| Natrona | 30 | 19 | 31 | 9 | 13 |
| Niobrara | 25 | 13 | 31 | 12 | 19 |
| Park | 24 | 17 | 30 | 13 | 16 |
| Platte | 28 | 14 | 31 | 12 | 17 |
| Sheridan | 24 | 17 | 30 | 13 | 16 |
| Sublette | 25 | 18 | 33 | 13 | 11 |
| Sweetwater | 29 | 20 | 32 | 11 | 9 |
| Teton | 20 | 25 | 35 | 12 | 8 |
| Uinta | 32 | 19 | 32 | 10 | 7 |
| Washakie | 27 | 14 | 30 | 13 | 17 |
| Weston | 23 | 17 | 31 | 13 | 16 |

Note: Some county percentages may not total to 100 percent due to rounding.

During the 1990s, the population of Wyoming's 24 to 44 age group declined about 12 percent while the 45 to 64 group increased by 39 percent (Foulke et al., 2000). This increasing proportion of older residents is likely due to three factors: the aging of the large baby boom generation as seen across the U.S., the in-migration of retirees seeking Wyoming's low cost of living, and the out-migration of young people looking for employment opportunities.

### 3.2.3 Employment and Labor Force Participation

Population, labor force, employment, unemployment, and average wages are summarized in Table 3-5. This information is for 2004, the most recent data. The state's unemployment rate was 3.9 percent. The average wage was $31,210. In 1970, it was estimated that 11.7 percent of the population was below the poverty level; in 2000, 11.4 percent of the population was below the poverty level.

The labor force participation rate is the percentage of residents in a given region over the age of 16 who are employed or actively seeking work. In 2000, the labor participation rate for Wyoming was 70 percent (Equality State Almanac, 2006).

As of 2000, there were over 328,000 full-time or part-time jobs in Wyoming. From about 1970 to 2000, statewide employment grew at an average rate of 2.5 percent annually. The Energy Bust is reflected in a drop in employment during the early 1980s.

The proportion of Wyoming employment by economic sector compared to the nation provides insight into which sectors are most important to the regional economic base and which economic sectors lag behind national averages. The government sector makes up 20 percent of the employment in Wyoming compared to 14 percent nationally. The federal government controls a large portion of the land in the state as discussed in Section 3.1.1. State government, F.E. Warren Air Force Base, the University of Wyoming, and local government further contribute to large employment needs in the government sector (Equality State Almanac, 2006).

Mining in Wyoming accounts for about 9 percent of all jobs compared to 0.5 percent nationally. The mining industry is a significant employer in all river basins with the exception of the Snake/Salt River Basin (Equality State Almanac, 2006).

Production agriculture also plays a larger role in Wyoming than in the nation as a whole, contributing about 4.6 percent of statewide employment compared to 3.2 percent nationally. However, Wyoming's manufacturing sector is smaller than the national average, accounting for only about 4 percent of total state employment compared to 12 percent nationally (Equality State Almanac, 2006).

**Table 3-5 2004 Population Characteristics**

| County | Population | Labor Force | Employment | Unemployment | Unemployment Rate | Average Annual Wages |
|---|---|---|---|---|---|---|
| Albany | 31,473 | 20,298 | 19,661 | 637 | 3.1 | $26,224 |
| Big Horn | 11,416 | 5,480 | 5,225 | 255 | 4.7 | $28,756 |
| Campbell | 36,721 | 22,455 | 21,755 | 700 | 3.1 | $40,857 |
| Carbon | 15,271 | 7,818 | 7,462 | 356 | 4.6 | $27,106 |
| Converse | 12,515 | 6,680 | 6,412 | 268 | 4.0 | $31,188 |
| Crook | 6,006 | 3,303 | 3,177 | 126 | 3.8 | $26,596 |
| Fremont | 36,310 | 18,204 | 17,263 | 941 | 5.2 | $26,454 |
| Goshen | 12,286 | 6,005 | 5,745 | 260 | 4.3 | $23,017 |
| Hot Springs | 4,598 | 2,416 | 2,322 | 94 | 3.9 | $22,368 |
| Johnson | 7,657 | 3,798 | 3,669 | 129 | 3.4 | $24,054 |
| Laramie | 85,296 | 42,699 | 40,764 | 1,935 | 4.5 | $31,007 |
| Lincoln | 15,626 | 8,213 | 7,893 | 320 | 3.9 | $31,099 |
| Natrona | 69,010 | 39,872 | 38,387 | 1,485 | 3.7 | $32,284 |
| Niobrara | 2,272 | 1,164 | 1,120 | 44 | 3.8 | $21,749 |
| Park | 26,516 | 14,897 | 14,290 | 607 | 4.1 | $26,124 |
| Platte | 8,666 | 4,207 | 3,993 | 214 | 5.1 | $28,777 |
| Sheridan | 27,163 | 15,441 | 14,844 | 597 | 3.9 | $28,087 |
| Sublette | 6,654 | 4,603 | 4,499 | 104 | 2.3 | $31,891 |
| Sweetwater | 37,758 | 21,846 | 21,087 | 759 | 3.5 | $38,922 |
| Teton | 18,964 | 13,972 | 13,516 | 456 | 3.3 | $31,431 |
| Unita | 19,772 | 10,906 | 10,464 | 442 | 4.1 | $29,174 |
| Washakie | 7,939 | 4,346 | 4,166 | 180 | 4.1 | $28,301 |
| Weston | 6,640 | 3,227 | 3,098 | 129 | 4.0 | $25,446 |
| **WYOMING** | **506,529** | **281,850** | **270,812** | **11,038** | **3.9** | **$31,210** |

Source: Equality State Almanac 2006 State of Wyoming

### 3.2.4 Key Economic and Water Use Sectors

Agriculture's impact on the state's land and water use is significant. Approximately 14 percent of the total employment in Wyoming is farm and farm-related employment. Table 3-6 shows the farm and farm-related employment. The energy and mineral sectors have historically added volatility to the economy, but they have also provided high-paying jobs and often require a large amount of water. While municipal water consumption is a small percentage of overall water used in the state, cities and towns have unique requirements that demand reliability. Travel, tourism, and recreation contribute to Wyoming's economy, and water plays an important, but somewhat different, role in this sector. Environmental water use is notable and indirectly affects the economy. Finally, there is an ongoing effort to attract new business and manufacturing interests to the state, which in the long run may increase the economic base and create new demand for water supplies. The future of each of the water demand sectors is integral to economic, demographic, and water demand projections for Wyoming.

**Table 3-6 Farm and Farm-Related Employment, 2002**

| Farm industries | Total[1] | | Metro | | Nonmetro | |
|---|---|---|---|---|---|---|
| | Employment | % of total | Employment | % of total | Employment | % of total |
| **Farming:** | | | | | | |
| Farm production | 12,397 | 3.66 | 1,381 | 1.35 | 11,016 | 4.64 |
| Farm proprietors | 8,870 | 2.62 | 870 | 0.85 | 8,000 | 3.37 |
| Farm Wage & Salary Workers | 3,527 | 1.04 | 511 | 0.50 | 3,016 | 1.27 |
| **Closely related:** | | | | | | |
| Agricultural services | 1,611 | 0.48 | 348 | 0.34 | 1,263 | 0.53 |
| Agricultural inputs industries | 763 | 0.22 | 88 | 0.09 | 675 | 0.28 |
| Agricultural processing and marketing | 1,191 | 0.35 | 49 | 0.05 | 1,142 | 0.48 |
| **Peripherally related:** | | | | | | |
| Agricultural wholesale & retail trade | 31,807 | 9.38 | 9,372 | 9.19 | 22,435 | 9.46 |
| Indirect agribusiness | 506 | 0.15 | 3 | 0.00 | 503 | 0.21 |
| Total farm & farm-related employment | 48,275 | 14.24 | 11,241 | 11.03 | 37,034 | 15.61 |
| All other employment | 290,846 | 85.76 | 90,705 | 88.97 | 200,141 | 84.39 |
| Total employment | 339,121 | 100.00 | 101,946 | 100.00 | 237,175 | 100.00 |

[1]Metro and nonmetro detail may not add to total because of some employment not classified by location.

Metro and nonmetro estimates are based on the June 2003 metropolitan area definitions.

Data are based on the 1997 North American Industry Classification System (NAICS).

Source: Most industry estimates were developed from an enhanced file of the County Business Patterns, U.S. Bureau of the Census. Farm proprietors and farm wage and salary workers are from the Bureau of Economic Analysis, U.S. Department of Commerce.

*Agriculture*

Wyoming's agriculture is dominated by livestock production: $798,800,000 in cash receipts came from livestock and related products in 2000 compared to cash receipts from crops of $160,600,000 (Equality State Almanac, 2006). Much of agriculture's water use is tied to production of forage and feed base for the livestock industry. Agriculture consumptively uses more water than any other economic sector. The river basin studies show total irrigated lands of about 2,070,406 acres while the 2002 Census of Agriculture, Farm and Ranch Irrigation Survey shows 1,541,688 acres. The 1997 Census of Agriculture reported 1,749,908 acres irrigated. The difference in census data may be due to the drought conditions, categories reported, non-responders, and idle lands not being reported.

*Livestock*

As of 2004, there were about 1,400,000 cattle and calves on Wyoming ranches. This is a decline from 2000 when there were about 1,580,000 head. This decline is primarily due to the severe drought that the state has been experiencing since 2000. Sheep numbers have been impacted similarly. Breeding sheep numbers declined from about 460,000 head in 2000 to about 340,000 head in 2004.

Ranchers in Wyoming depend on forage to supplement the hay they feed their animals. Therefore, during drought, they cannot afford to raise as many cattle and sheep. Although hay and alfalfa are grown across the state, many areas of the state are net importers of hay. Much of this hay comes from the more intensely farmed areas of the state.

Most of the grazing land in the eastern portion of the state is privately held minimizing reliance on public land for grazing. However, in the western portion of the state, public grazing land is very important. Therefore, federal grazing policy can significantly impact the livestock industry and the agriculture sector.

*Crops*

Cropping patterns and livestock production are closely related. Alfalfa and other hay account for over 75 percent of harvested cropland in Wyoming, and much of this hay is used to feed livestock. Other irrigated crops include corn, dry beans, sugar beets, barley, winter wheat, oats, and spring wheat. Most irrigation is by flood, but use of center pivot sprinklers is increasing in some areas. Surface water is the most common irrigation water source, though groundwater is increasingly prevalent.

*Industrial*

The chart below shows the employment and annual payroll in the industrial sector and related sectors in Wyoming. These sectors account for 28 percent of the total employment in the state but account for 41 percent of the payroll making industry a very important economic sector.

Industry can be broken out into mining, utilities, construction, manufacturing, and transportation and warehousing. Crude oil and natural gas are produced in most counties throughout Wyoming; however, the production and employment vary. The top oil-producing county is Campbell followed by Park. The top natural gas- producing county is Sublette followed by Campbell.

Coal mining is concentrated in five counties: Campbell, Carbon, Converse, Lincoln, and Sweetwater; in 2004, total coal production was 395,726,000 tons (Equality State Almanac, 2006). Other minerals produced in Wyoming include trona, bentonite, uranium, sand and gravel, stone, and other miscellaneous minerals.

Wyoming has numerous electrical generating facilities that make up the utilities subsector. Water-using electrical generating facilities can be broken out into two groups, hydropower facilities and coal-fired plants. Table 3-7 provides the number of electric power generating facilities by river basin for Wyoming.

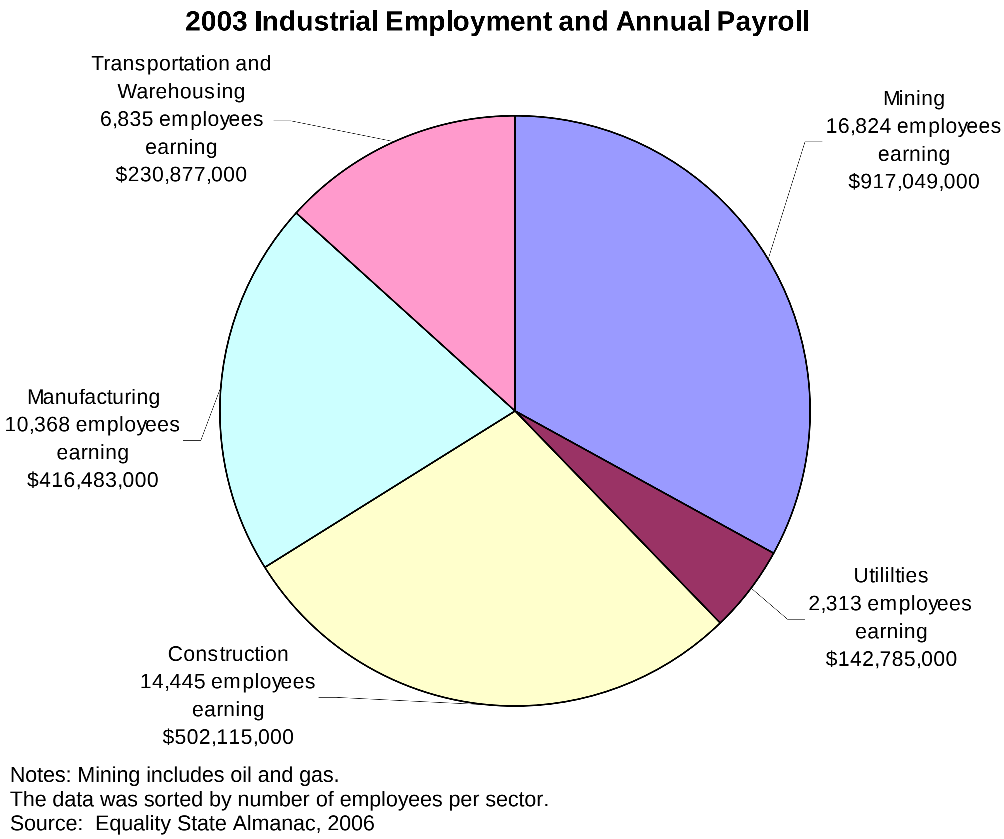



**Table 3-7 Electric Power Generating Facilities**

| River Basin | Hydropower | Coal-fired | Subtotal |
|---|---|---|---|
| Green | 1 | 2 | 3 |
| Northeast Wyoming | | 4 | 4 |
| Platte | 6 | 2 | 8 |
| Snake/Salt | 1 | | 1 |
| Wind/Bighorn | 6 | | 6 |
| **TOTAL** | **14** | **8** | **22** |

*Municipal and Domestic*

Municipal and domestic water use is a relatively small but important part of overall water use. Wyoming has 99 incorporated municipalities of which 19 are “first class cities.” A first class city is defined by Wyoming State Statute 15-3-101 as a city that has a population of at least 4,000 and has made a public proclamation. According to the 1973 Wyoming Framework Water Plan, Wyoming’s population in 1970 was 332,416, with about 60.5 percent (approximately 201,111) of the population living in cities and towns and the remaining 39.5 percent (approximately 131,305) living on ranches, on farms, and in nonfarm areas outside urban area boundaries. Between 1970 and 2000, the population increased by 49 percent (approximately 162,884 people) to 493,782. Census data for 2000 indicate that nearly 35 percent of the population resides in rural areas and the remaining 65 percent resides in urban areas (Equality State

Almanac, 2006). This indicates that the urbanization trend noted in the 1973 Wyoming Framework Water Plan is continuing.

The vast increase in population means increased water needs and use in both rural and urban sectors. Jacobs and Brosz (2000) report that 80-85 percent of water consumption is for irrigated agriculture, yet there is an increasing water demand for municipal and industrial uses.

*Recreation, Travel, and Tourism*

Wyoming's Northwest area, Wind/Bighorn River Basin, and Snake/Salt River Basin are nationally known recreation areas. The Wyoming State Parks and Recreation Areas are regionally significant recreation destinations. Water is rarely consumed in recreational use, the maintenance of golf courses being one exception. Water is an important aspect in recreation and tourism. Wyoming provides opportunities for boating, fishing, hunting, camping, golfing, and skiing. Much of this activity takes place on or near the rivers, streams, lakes, and reservoirs of Wyoming.

Each river basin has major reservoirs that were constructed for flood control, irrigation, power generation, and/or municipal water supply and do not have recreation reserve pools. As a result, recreational use at the reservoirs peaks in July and then declines as water levels are drawn down to satisfy their permitted uses.

Golfing is a growing portion of the recreation sector: e.g., the Platte River Basin has 19 golf courses, and the Snake/Salt River Basin has 5 golf courses. As population increases, demand for more courses will follow.

*Environmental*

For the purposes of water demand forecasting, environmental water use includes only water used in efforts to enhance environmental conditions, such as improving or maintaining fish and wildlife habitats. Much of the environmentally beneficial water use within the state is a by-product of other uses, such as reservoirs, and not from water rights specifically directed at environmental protection. Wyoming's instream flow law is one exception and is designed to protect and enhance fisheries.

Enhancement or creation of wetlands is an environmental use that may see more development in the future. State and federal funding sources exist to assist landowners in developing or enhancing wetlands.

## 3.3 LEGAL AND INSTITUTIONAL SETTING

The constraints or bounds that water users must operate within are defined by a mixture of state law, federal law, interstate agreements, and court decrees. Figure 3-7 depicts Wyoming river basin compacts and decrees.

### 3.3.1 Wyoming Water Rights

The Wyoming Water Development Commission (WWDC) has stated that Wyoming water law shall be respected in all aspects of the water planning process. Wyoming water law is the foundation upon which all water use, development, and protection are based. The water rights system in Wyoming is administered by the State Engineer's

Office and State Board of Control, both constitutionally based administrative and quasi-judicial entities of state government.

Wyoming's water laws have evolved from the early establishment of legal principles that were later embodied in the state's constitution and a series of statutory laws written and adopted early in Wyoming's history that have stood the test of time. One early water dispute that involved two territorial pioneers, William McCrea and Charles Moyer, is instructive regarding the history of water law in Wyoming. Moyer, whose name is associated with a now-famous spring in the coal-mining region north of Gillette, developed that spring for irrigation in 1890. Previously, McCrea developed an irrigation project along the Little Powder River downstream of, and partially supplied by, Moyer's spring. With Moyer's development, McCrea's ditch was short of water, and the resulting argument eventually reached the Wyoming Supreme Court. In one of its first rulings on water matters, the Court affirmed the "first in time, first in right" doctrine by siding with McCrea. Through this 1896 ruling, the Court recognized the concepts of the prior appropriation doctrine that Territorial Engineer Elwood Mead had been advocating in the days leading to statehood and the constitutional conventions.

Mead, who became the first State Engineer, understood that water in an arid region must be administered in a predictable and equitable fashion, and the methods he fostered were to allow the earlier developer of water to establish the senior right for its continued use. The Wyoming State Constitution adopted this priority system of appropriation and established the position of State Engineer. Through the efforts of Mead, the Constitution also embodied the basis of appropriating water on the concept of "beneficial use" to avoid the potential for exaggerated amounts of water being tied up by early settlers and developers of water diversion systems. Mead was also at the forefront of affirming a strong, active, independent state role in all aspects of appropriating and administrating the waters of the state. He also developed the process for resolving water disputes. Rather than use a water court system as in the neighboring state of Colorado, Wyoming established the State Board of Control within its Constitution. In addition to its independent authority to review matters initially decided by the State Engineer, the Board of Control is the adjudicator of all water rights and the decision-maker of all requests for changes to water rights. The Constitution declares all water in the state to be the property of the State, subject to appropriation for beneficial use through the administrative permitting of water rights. Water rights are considered property rights that attach to the land or place of use. However, the law provides that the owner of these rights may change the location of use, or the type of use, by seeking approval from the Board of Control. The final decisions of the Board of Control are subject to judicial review. The Board of Control is made up of the State Engineer and the four Water Division Superintendents.

Within this constitutional framework, the detailed statutory authority, procedures, and administration were further defined by legislation and periodic Court decisions. The State Engineer's role is defined in Title 9, Chapter 1, Article 9, along with the general authority to establish fees for certain services and some other minor activities of the agency.

The majority of Wyoming's water laws are now codified primarily in Title 41 of Wyoming Statutes, entitled "Water." Under this title, there are 14 chapters that include the authority and activities of the Water Development Commission and the laws associated with irrigation, drainage, watershed improvement, water and sewer districts, interstate compacts, and the use of watercraft. Chapters 3 and 4 contain the important laws relating to the appropriation, administration, and adjudication of water rights in Wyoming. These statutes relate to all waters of the state, whether they are from surface streams, springs, natural lakes, or underground waters.

The key elements of Wyoming's water laws were established in the Constitution and the early statutory laws before and near the turn of the century. From time to time, the legislature has modified the laws to address emerging new issues of the water users in the state. The laws addressing reservoirs were passed in the early 1900s; laws specific to groundwater sources were introduced in the 1940s and 1950s, with the last significant change adopted in 1969. Laws addressing instream flow water rights were codified in 1986. The basic framework of water right permitting actions and administration has remained the same, all the while allowing for flexibility in answering the needs of water users.

This set of laws is a part of the principles upon which the Framework Water Plan is based.

### 3.3.2 Interstate Compacts, International Treaty, Court Decrees, and Contracts and Agreements

**NOTE:** Additional information on water rights, compacts, court decrees, international treaty, and interstate agreements is available online at http://seo.state.wy.us.

*Amended Bear River Compact (1978)*

This compact provides that in the administration of the Bear River among the States of Idaho, Utah, and Wyoming, the river shall be divided into three divisions. When a water emergency exists, water administration is handled as discussed below.

Upper Division

This division is the portion of the Bear River from its source in the Uinta Mountains to and including Pixley Dam. A water emergency shall be deemed to exist when the total divertible flow is less than 1,250 cubic feet per second (cfs). Divertible flow is allocated for diversion as follows:

Upper Utah Section Diversions . . . . . . . . . . . . . . . . . . . . . . 0.6%
Upper Wyoming Section Diversions . . . . . . . . . . . . . . . . . 49.3%
Lower Utah Section Diversions . . . . . . . . . . . . . . . . . . . . . 40.5%
Lower Wyoming Section Diversions . . . . . . . . . . . . . . . . . . 9.6%

Central Division

This division is the portion of the Bear River from Pixley Dam to and including Stewart Dam. A water emergency shall be deemed to exist when the total divertible flow is less than 870 cfs or the flow of Bear River at Border gaging station is less than 350 cfs, whichever occurs first. When such a condition exists, all divertible flow in this division shall be allocated such that the portion of the river between Pixley Dam and the point where the river crosses the Wyoming-Idaho line near Border shall be limited for the benefit of the State of Idaho, 43 percent of the divertible flow. The remaining 57 percent of the divertible flow shall be available for use in Idaho in the Central Division, but if any portion of such allocation is not used therein, it shall be available for use in Idaho in the Lower Division.

Lower Division

This division is the portion of the Bear River between Stewart Dam and the Great Salt Lake, including Bear Lake and its tributary drainage. The original compact grants to Wyoming and Utah the right for each to store, above Stewart Dam, an additional 17,750 acre-feet of Bear River water in any water year and to Idaho the right to store 1,000 acre-feet of water in Idaho or Wyoming on Thomas Fork for use in Idaho. In addition, the Amended Compact (1978) allocates further storage entitlements to Utah and Wyoming for 70,000 acre-feet of Bear River water, in any water year, above Stewart Dam to be divided equally and to Idaho an additional 4,500 acre-feet of Bear River water in any water year to be stored in Idaho or Wyoming for use in Idaho. Water rights granted on water appropriated under this last entitlement, including groundwater tributary to the Bear River, which is applied to beneficial use on or after January 1, 1976, shall not result in an annual increase in depletion of the flow of the Bear River and its tributaries above Stewart Dam of more than 28,000 acre-feet in excess of the depletion as of January 1, 1976. Thirteen thousand acre-feet of the additional depletion above Stewart Dam are allocated to each of Utah and Wyoming, and 2,000 acre-feet are allocated to Idaho. Idaho, Utah, and Wyoming are also granted the right to store and use water above Stewart Dam that otherwise would be bypassed or released from Bear Lake at times when all other direct flow and storage rights are satisfied. Water availability and depletions are calculated and administered by procedures approved by the Bear River Commission.

*Belle Fourche River Compact (1943)*

The compact for the division of the waters of the Belle Fourche River between Wyoming and South Dakota was negotiated and ratified by the two states and the federal government in 1943. This compact recognizes all existing rights in Wyoming, as of the date of the compact, and permits the construction of stock water reservoirs not exceeding 20 acre-feet in capacity. As of the date of the compact, the unappropriated waters of the Belle Fourche River are allocated as follows: 10% to Wyoming and 90% to South Dakota. Another provision states that, as of the date of the compact, no reservoir built exclusively to use the water allocated to Wyoming can exceed a capacity of 1,000 acre-feet.

*Colorado River Compacts (1922 and 1948).*

A compact between the Upper Colorado River Basin states (Wyoming, Colorado, New Mexico, and Utah) and the Lower Colorado River Basin states (Arizona, Nevada, and California) was negotiated in 1922. This compact allocated 7,500,000 acre-feet of consumptive use annually to the Upper Basin. It also provided that a minimum flow of 75,000,000 acre-feet in any consecutive 10-year period should be maintained at Lee Ferry, which is the point on the river dividing the Upper Basin from the Lower Basin. In addition, provision was made for future treaties with Mexico. As a result of this clause, the 1944 Colorado, Tijuana, and Rio Grande Treaty indirectly influences the regulation of the Colorado River. In 1948, a compact among the Upper Basin states was negotiated. It was ratified by all the states and the federal government in 1949. Arizona has a small area in the Upper Basin and therefore was included in the Upper Basin negotiations. This Upper Colorado River Basin Compact apportions the use allocated to the Upper Basin by the 1922 compact as follows: 50,000 acre-feet per annum to Arizona and of *the* remaining quantity 51.75 percent to Colorado, 11.25 percent to New Mexico, 23 percent to Utah, and 14 percent to Wyoming. The 1948 compact divided the waters of Henry's Fork between Wyoming and Utah on a straight priority basis for existing development. Waters of the Little Snake River used under rights existing prior to this compact and diverted below the river's confluence with Savery Creek are administered on a straight priority basis (irrespective of the state line). Water uses developed after the Compact's signing are administered to equally share the available water supply.

*Upper Niobrara River Compact (1962)*

The compact dividing the waters of the Niobrara River between the States of Nebraska and Wyoming was negotiated by the two states in 1962 and approved by Congress in 1969. Stock water reservoirs in Wyoming not exceeding 20 acre-feet in capacity are not restricted except by Wyoming law, and no restrictions were placed on diversion or storage of water in Wyoming. The exception to this occurs on the main stem east of Range 62 West and on Van Tassel Creek south of Section 27, Township 32 North, Range 60 West. In this area, direct diversions are regulated on an interstate priority basis with lands in Nebraska west of Range 55 West. Storage reservoirs with priority dates prior to August 1, 1957, may store water only during the period of October 1 to June 1, unless water is available after meeting direct flow appropriations in Wyoming and Nebraska west of Range 55 West. Storage reservoirs with priority dates after August 1, 1957, may store a maximum of 500 acre-feet in any water year from October 1 to May 1, unless water is available after meeting direct flow appropriations in Wyoming and Nebraska west of Range 55 West. Groundwater development was recognized to be a significant factor, and the compact provides for investigation of this resource and possible apportionment at a later date.

*Snake River Compact (1949)*

The compact dividing the waters of the Snake River and Salt River between the states of Idaho and Wyoming was negotiated by the two states in 1949 and ratified by them and the federal government in 1950. The compact recognizes, without restrictions, all existing rights in Wyoming as of the date of the compact. It permits Wyoming unlimited use for domestic and stock uses provided that stock water reservoirs shall not exceed 20 acre-feet in capacity. It permits Wyoming to divert (or store) for new developments, for supplemental or original supply, 4 percent of the Wyoming-Idaho state line flow of the Snake River.

*Yellowstone River Compact (1950)*

The Yellowstone River Compact dividing the waters of the tributaries (Clarks Fork, Big Horn, Tongue, and Powder) of the Yellowstone among the states of Wyoming, Montana, and North Dakota was negotiated in 1950 and ratified by the three states and the federal government in 1951. Existing rights as of January 1, 1950, maintain their status in accordance with the laws governing the acquisition and use of water under the doctrine of prior appropriation. In addition, existing and future domestic and stock water uses including stock water reservoirs up to a capacity of 20 acre-feet are exempted from provisions of the Compact. The unappropriated *or* unused total divertible flow of each tributary, after needs for supplemental supply for existing rights are met, is allocated to Wyoming and Montana as follows:

Clarks Fork of the Yellowstone River:
Wyoming . . . . . . . . . . . . . . 60%
Montana . . . . . . . . . . . . . . . 40%

Big Horn River (exclusive of Little Big Horn River):
Wyoming . . . . . . . . . . . . . . 80%

Montana . . . . . . . . . . . . . . . 20%

Tongue River:
Wyoming . . . . . . . . . . . . . . 40%
Montana . . . . . . . . . . . . . . . 60%

Powder River (including the Little Powder River):
Wyoming . . . . . . . . . . . . . . 42%
Montana . . . . . . . . . . . . . . . 58%

*International Treaty*

The Mexican Water Treaty between the United States and Mexico dated 1944 dividing the waters of the Colorado River, which flows from the United States into Mexico, also affects Wyoming. This treaty guaranteed to Mexico the delivery of 1,500,000 acre-feet of water per annum. Under the terms of the 1922 Colorado River Compact, the burden of supplying this water to Mexico during periods of short water supplies is equally borne by the Upper Basin, of which Wyoming is a part, and the Lower Basin.

The Colorado River Basin Project Act (PL 90-537, Sec. 202) provides that the satisfaction of the requirements of the Mexican Water Treaty from the Colorado River constitutes a national obligation which shall be met by any augmentation project developed under the provisions of the Act.

*Court Decrees*

North Platte River

During the mid-1930s, the state of Nebraska filed an action against the States of Colorado and Wyoming in the Supreme Court of the United States over the flows of the North Platte River. In 1945, the Court handed down a decree equitably apportioning the waters of the North Platte among the states. The decree included the following provisions:

(a) Exclusive of the Kendrick Project and Seminoe Reservoir, the State of Wyoming is enjoined from diverting water from the North Platte River above Guernsey Reservoir and from the North Platte River and its tributaries above Pathfinder Dam for the irrigation of more than a total 168,000 acres of land during irrigation season.

(b) Exclusive of the Kendrick Project and Seminoe Reservoir, the State of Wyoming is enjoined from storing more than 18,000 acre-feet of water from the North Platte River and its tributaries above Pathfinder Reservoir for irrigation purposes during any one year.

(c) The storage rights of Pathfinder, Guernsey, Seminoe, and Alcova Reservoirs are junior to 1,165 cfs for the irrigation of land in Western Nebraska, and the State of Wyoming is enjoined from storing or permitting the storage of water in these reservoirs other than in accordance with the rule of priority.

(d) The natural flow of the North Platte River in the section of the river between the Whalen Diversion Dam, downstream of the Tri-State Dam, or approximately the Wyoming-Nebraska state line, between May 1 and September 30 of each year is apportioned 25 percent to Wyoming and 75 percent to Nebraska.

It also limits Colorado to the irrigation of 135,000 acres; the storage of 17,000-acre-feet of water in any one year; and the diversion of an average 6,000 acre-feet out of the North Platte River Basin annually.

By stipulation agreed upon by the three States and approved by the Supreme Court of the United States, the decree was amended in 1953 as follows:

Colorado was permitted to increase its irrigated acreage to 145,000 acres, and the States of Wyoming and Nebraska were permitted to store 40,000 acre-feet during any water year in Glendo Reservoir, with such storage, including holdover, never to exceed 100,000 acre-feet. The 40,000 acre-feet of storage during the year is divided 25,000 acre-feet to Nebraska and 15,000 acre-feet to Wyoming.

Nebraska filed a lawsuit in the Supreme Court of the United States on October 6, 1986, alleging that Wyoming had violated certain aspects of the 1945 Decree. The U.S. Supreme Court approved the Final Settlement Stipulation and entered the Modified Decree on November 13, 2001. The Final Settlement Stipulation and the Modified Decree include the following provisions:

(a) For the North Platte River and its tributaries, including water from hydrologically connected groundwater wells, upstream of Pathfinder Dam and between Pathfinder Dam and Guernsey Reservoir, Wyoming is enjoined from consuming more than the largest amount of water consumed for irrigation from such sources in any 10 consecutive year periods between 1952 and 1999, inclusive. Pursuant to the methodology approved by the parties, the largest amount of water during the 10-year period noted above is 1,280,000 acre-feet upstream of Pathfinder and 890,000 acre-feet between Pathfinder and Guernsey.

(b) Exclusive of the Kendrick Project, for the North Platte River and its tributaries upstream of Guernsey Reservoir including water from hydrologically connected groundwater wells, Wyoming is enjoined from intentionally irrigating more than a total of 226,000 acres of land during any one irrigation season. Ten years following the settlement date, this provision will be replaced with two injunctions: one intentionally irrigated limitation for the area above Pathfinder and one for the area between Guernsey and Pathfinder. The total of the two shall not exceed 226,000 acres.

(c) Exclusive of Wheatland Irrigation District, for the Laramie River and its tributaries including hydrologically connected groundwater wells downstream of Wheatland Irrigation District’s Tunnel No. 2, Wyoming is enjoined from intentionally irrigating more than a total of 39,000 acres of land during any one irrigation season.

(d) In accordance with an April 20, 1993 U.S. Supreme Court opinion, Inland Lakes has the priority of December 6, 1904, and the United States has the right to accrue up to 46,000 acre-feet of water during the nonirrigation season months of October, November, and April for storage in the four Inland Lakes located in Nebraska.

(e) As in the 1945 Decree, natural flow of the North Platte River in the section of the river between Whalen Diversion Dam and Tri-State Dam, between May 1 and September 30 of each year, is apportioned 25 percent to Wyoming and 75 percent to Nebraska.

(f) Within the area bounded by Whalen Diversion Dam on the west, 300 feet south of the Fort Laramie Canal on the south, one mile north of the Interstate Canal on the north, and the Wyoming-Nebraska state line on the east, diversions between May 1 and September 30 for irrigation purposes from groundwater wells with water right priorities after October 8, 1945, shall be replaced, or the pumping shall be regulated to prevent such diversions.

(g) Within the area bounded by Whalen Diversion Dam on the west, the Fort Laramie Canal on the south, the Interstate Canal on the north, and the Wyoming-Nebraska state line on the east, surface water diversions for irrigation purposes from the tributaries to the North Platte River shall be administered and accounted as diversions of natural flow in accordance with the equitable apportionment of natural flow, 25 percent to Wyoming and 75 percent to Nebraska in the section of the river between Guernsey and Tri-State Dam. For the depletions that occur when natural flow is insufficient to meet the demands of both Wyoming and Nebraska irrigators who divert from the North Platte River at or above Tri-State Dam, Wyoming must replace the depletion amount, or those irrigation rights not in priority to divert shall be regulated to prevent such diversions.

(h) By stipulation of all three States and the United States in September 1997, Wyoming shall install measuring devices at no fewer than eight of the largest irrigation reservoirs storing water from the North Platte River and its tributaries upstream of Pathfinder Reservoir, to accurately measure the annually accrued irrigation storage in each reservoir. The storage limitation injunction from the 1945 Decree is unchanged in the 2001 Modified Decree: Wyoming is enjoined from storing or permitting the storage of more than 18,000 acre-feet of water for irrigation purposes upstream of Pathfinder Reservoir exclusive of Seminoe Reservoir during any one year.

(i) By stipulation of Nebraska, Wyoming, and the United States in December 1998, referred to as the 1998 Allocation Stipulation, the parties jointly agreed to a method of allocating storage water during periods of shortage. The U.S. Bureau of Reclamation (USBR) shall follow procedures and guidelines when allocating storage water from Pathfinder and Guernsey Reservoirs and the Inland Lakes. During the first week in February, March, and April, the USBR shall advise the other parties when the current year is likely to be an "allocation year" if storage and forecasted water supplies are less than the approximate irrigation demand for the year of 1,100,000 acre-feet. With respect to water rights administration upstream of Pathfinder Reservoir before May 1, if the USBR advises that the current year is a likely allocation year, the_Reclamation shall be deemed to have placed a priority call for Pathfinder Reservoir, excluding the Pathfinder Modification Project. With respect to water rights administration along the mainstem of the North Platte River and the tributaries between Pathfinder Dam and Guernsey Reservoir before May 1, if the USBR advises that the current year is a likely allocation year, then the USBR shall be deemed to have placed a priority call for Inland Lakes (April only), Guernsey Reservoir, and Glendo Reservoir storage rights. In both situations described above, the Wyoming State Engineer shall determine whether the calls are valid and warrant regulation upstream of the calling right. Any resulting administration will cease as of May 1, the first day of the irrigation season. Between May 1 and September 30 during an allocation year, Wyoming will limit the cumulative diversions for irrigation purposes from the mainstem of the North Platte River between Pathfinder Dam and Guernsey Reservoir to 6,600 acre-feet per two-week period.

(j) By an amended stipulation of all three States and the United States in March 2001, the Pathfinder Modification Stipulation includes the following provisions:

(i) The capacity of Pathfinder Reservoir may be increased by approximately 54,000 acre-feet to recapture original storage space lost to sediment.

(ii) The recaptured space would store water under the existing 1904 storage right for Pathfinder Reservoir except that it could not place regulatory calls on existing upstream water rights other than the rights pertaining to Seminoe Reservoir.

(iii) Approximately 34,000 acre-feet of the 54,000 acre-feet of recaptured space would be accounted for in an environmental account and operated for the benefit of endangered species and their habitat in central Nebraska.

(iv) Wyoming has the exclusive right to contract with the USBR for the use of the remaining 20,000 acre-feet of the recaptured capacity. The primary use of the 9,600 acre-feet of annual estimated firm yield from this “Wyoming Account” is to supplement Wyoming municipalities’ water right needs. The account’s other uses in prioritized order are: to serve as Wyoming’s source of replacement water required by the Modified Decree, to replace Wyoming’s excess depletions from existing water-related activities under the Platte River Recovery Implementation Program (PRRIP), or to be leased to a program for endangered species recovery.

(k) The North Platte Decree Committee (NPDC) was created to assist in monitoring, administering, and implementing the Modified Decree and the Final Settlement Stipulation. The NPDC shall act in accordance with the NPDC Charter and may modify by unanimous agreement the administrative procedures attached as Exhibits 3 through 12 to the Charter.

(l) The river carriage and reservoir loss calculations established in the 1945 Decree have been replaced with the procedures defined in Exhibit 9 to the NPDC Charter.

(m) Upon occurrence of ‘negative natural flow at Orin’, as defined in Exhibit 7 of the NPDC Charter, the Wyoming State Engineer will administer water rights or take other action as necessary to eliminate the negative natural flow at Orin.

(n) Within five years of the Court-approved settlement date, pursuant to Wyoming law, Wyoming will adjudicate the following:

(i) All unadjudicated groundwater permits for irrigation wells hydrologically connected to the North Platte River or its tributaries above Guernsey Reservoir and wells hydrologically connected to the Laramie River or its tributaries downstream of Wheatland Tunnel #2, exclusive of the Wheatland Irrigation District.

(ii) All existing unadjudicated groundwater permits for irrigation wells within the area bounded by Whalen Diversion Dam on the west, 300 feet south of the Ft. Laramie Canal on the south, one mile north of the Interstate Canal on the north, and the Wyoming-Nebraska state line on the east.

(iii) All unadjudicated surface water permits for irrigation purposes that divert from tributaries and drains that lie within the area bounded by Whalen Diversion Dam on the west, the Fort Laramie Canal on the south, the Interstate Canal on the north, and the Wyoming-Nebraska state line on the east.

*Laramie River*

In 1911, Wyoming started proceedings in the Supreme Court of the United States against Colorado to limit Colorado diversions from the Laramie River. In 1922, the Supreme Court handed down its decree, which allowed Colorado to annually divert 4,250 acre-feet for the meadow lands and 33,500 acre-feet by transmountain diversion plus "the relatively small amount of water appropriated..." from the headwaters of Deadman Creek, through the Wilson Supply Ditch. In 1936, the Supreme Court stated that the record showed that the "relatively small amount of water" referred to actually amounted to 2,000 acre-feet of water per year. Therefore, the total annual diversion allowed Colorado was 39,750 acre-feet. In 1939, Wyoming secured an order from the Supreme Court restraining Colorado from diverting more than the 39,750 acre-feet annually that the State had been allotted. The Supreme Court stated that this amount should be administered according to Colorado laws. By stipulation between Colorado and Wyoming in 1957, the Supreme Court vacated all former decrees and decreed that only 19,875 acre-feet of water per year could be diverted from the Laramie River Basin and that 29,500 acre-feet per year could be diverted by the meadow land users for the irrigation of certain lands described by map in the decree.

*Teton and South Leigh Creeks*

Conflict between the water users on Teton and South Leigh Creeks in Wyoming and Idaho was settled by a decree of the United States District Court entered February 4, 1941, known as the "Roxana Decree". This decree contains a stipulation that the Wyoming users may make unlimited diversions from Teton Creek and its tributaries until the flow diminishes to 170 cfs. After that, the Wyoming water users are limited to a diversion of 1 cfs for each 50 acres of land. When the flow further reduces to 90 cfs, the flow of Teton Creek and its tributaries is divided equally between the Wyoming and Idaho water users. The Wyoming appropriators are permitted unlimited diversions from South Leigh Creek until the natural flow of the creek diminishes to a total of 16 cubic feet per second, after which time the Wyoming users are permitted to divert one-half of the streamflow and the Idaho users are permitted to divert the balance.

*Wind/Bighorn River Basin*

The two million acre Wind River Indian Reservation, located in Fremont and Hot Springs Counties, is in the Wind/Bighorn River Basin (WBHB) watershed. The Wind River and many of its tributaries originate on or run through the Reservation, making it an important factor in the WBHB's water management. In January 1977, the State of Wyoming enacted Wyoming Statute, 1-37-106 authorizing the State to commence general stream adjudications. On January 24, 1977, the State filed a complaint in Washakie County District Court seeking adjudication of the Bighorn River system and all other sources. In 1979, the Court and the parties agreed to divide the case into three main phases, Phase I addressing the Indian Reserved Water rights, Phase II covering all non-Indian federal water rights for the national forests and parks and other federally owned land, and Phase III covering all state rights evidenced by permits and certificates. During the adjudication and legal process, many important decisions were issued from the Wyoming Supreme Court and the United States Supreme Court. At the time of this writing, there exist Big Horn I through Big Horn VII court decisions. These major decisions cover awards for the Eastern Shoshone and Northern Arapahoe Tribes and Walton Awards to landowners whose land was derived from allottees lands ownership along with other significant decisions. There is also a multitude of district court decisions determining the adjudication of state water rights. Legal proceedings between the State of Wyoming and the Tribes awarded the right to use nearly 500,000 acre-feet of surface water annually on over 107,000 acres from the Wind River system to the Eastern Shoshone and Northern Arapaho Tribes, although some tribal members hold water rights individually. The tribal water rights date to July 3, 1868, the date of the treaty between the United States and the Shoshone Tribe, and are the some of oldest water rights in the WBHB. Within this award, approximately 209,000 acre-feet for 53,760 acres for irrigation use is reserved for future agricultural developments on the Reservation. The Tribes sought to use the award as instream flow for environmental/recreational purposes but failed in court to be granted such changes as the award was for use in developing irrigation projects. At the present time, the Tribes have not beneficially used this water, and downstream users, whose rights are junior to those of the Tribes, are accustomed to having this water available. Working out a management regime that will satisfy all parties is a formidable task.

The Reservation includes within its boundaries private lands not owned by the Tribes. The Reservation operates within a governmental context of tribal, federal, state, and local authority and activity. Water rights on the Reservation are managed under state law and the Wind River Water Code, jointly adopted in 1991 by the Tribes (Collins, August, 2000). A Water Resources Control Board is the Tribes' "primary enforcement and management agency responsible for controlling water resources on the Reservation" (Wind River Water Code, 1991). The Big Horn River General Stream Adjudication and the tribal water rights have a distinct impact on future water planning in the WBHB.

In addition to the tribal rights, under Phase II of the 1979 District Court case, the water rights were quantified for the United States on national park lands, in forests, and on lands of the Bureau of land Management and USBR. Several thousand rights were confirmed for use as public water reserves, instream flow, wells, reservoirs, stock reservoirs and stock driveways, firefighting uses, and discrete water uses along with other diminimus uses on federal land.

Under Phase III of the case, state water rights adjudication through the District Court has resulted in reaching final disposition of over 4,000 surface water rights and over 15,000 groundwater rights. Water rights within the entire Water Division 3 have been affected by a series of court decisions through the general stream adjudication process, both on and off the reservation. The water rights within the Wind River Indian Reservation consist of state water rights, tribal water rights, and Walton Awards. Added to this complexity is the checkerboard ownership pattern resulting in an integrated level of multiple water rights on the same ditch system which cross-jurisdictional boundaries. Water planning efforts should always take a comprehensive view of all water rights as they integrate with each other regardless of how they were derived or awarded by the courts within this complex water system.

### 3.3.3 Contracts and Agreements

Wyoming has also entered into several agreements that limit or modify water use at specific locations. A few of the most noteworthy are listed below by river basin.

*Green River Basin*

Fontenelle Reservoir Contract

Wyoming acquired the right to perpetually market 60,000 acre-feet of Fontenelle Reservoir storage from the USBR on two separate occasions. A 1958 Act of Congress authorized storage to meet anticipated future need for municipal and industrial purposes to be included in any reservoir project to be surveyed, planned, and constructed by the USBR – conditioned upon the willingness of state or local interests to pay for the cost of providing storage for the anticipated future demands. In 1959, the Wyoming legislature appropriated the funds and authorized the existing Natural Resource Board to enter into contract with the USBR for storage in an amount not to exceed 60,000 acre-feet. In 1974, Wyoming entered into a second agreement with the USBR that authorized Wyoming to market an additional 60,000 acre-feet of Fontenelle Reservoir storage water for municipal and industrial purposes. Therefore, Wyoming has a right to market 120,000 acre-feet of the 345,397 acre-feet total capacity of Fontenelle

Reservoir once the proposed sale has been reviewed pursuant to the National Environmental Policy Act (NEPA) and approved by the WWDC.

Four water sale contracts have been executed, but only one currently calls for the annual release of Fontenelle water. The three remaining contracts require remittance of a "readiness to serve fee," which reserves an amount of water specified in the contract which may be released as requested by the contractor. If all four contracts called for their associated releases, the amount of water released would total 46,550 acre-feet. Therefore, depending on water availability, Wyoming has the right to market an additional 73,450 acre-feet of Fontenelle Reservoir water.

High Savery Reservoir Contract

Construction of the High Savery Reservoir was authorized by the Wyoming legislature to provide water for recreation, agriculture, municipal and domestic water supplies, environmental enhancement, and mitigation of the Cheyenne Stage I and Stage II transbasin diversion water supply projects. The permitted capacity of the reservoir is 22,433 acre-feet. A 5,724 acre-feet minimum pool requirement was stipulated in the Clean Water Act, Section 404 permit, issued by the U.S. Army Corps of Engineers (USCOE). The USCOE 404 Permit also mandated maintenance of a 12 cfs nonirrigation season flow in Savery Creek below the dam. If actual inflows are less than 12 cfs, the flows are required to match the actual reservoir inflows. Further, the State is to maintain a flow of 10 cfs from July 15 through September 15 below the dam regardless of reservoir inflows. The State has contracted with the Little Snake River Conservancy District (District) for the sale of water residing above the elevation of the minimum pool. The District is responsible for remarketing water pursuant to the beneficial purposes described by the enabling legislation. The primary purpose of the reservoir, however, is to provide firm, reliable late-season irrigation water, eight out of 10 years, to lands within the Little Snake River Basin.

*Platte River Basin*

Cooperative Agreement

In 1997, the States of Colorado, Wyoming, and Nebraska and the U.S. Department of the Interior (DOI) signed the Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitat Along the Central Platte River, Nebraska (Agreement). The Agreement addressed recovery of four species: the whooping crane, piping plover, least tern, and pallid sturgeon. The final environmental impact statement (EIS) and the biological opinion were distributed in May and June 2006. The Record of Decision was signed by the DOI Secretary Kempthorne on September 27, 2006.

Platte River Recovery Implementation Program (PRRIP)

The federal/state basinwide PRRIP addresses recovery of the endangered species in the Central Platte River in Nebraska. The PRRIP agreement was signed by the Governors of Colorado, Nebraska, and Wyoming and the Secretary of Interior in late 2006. The PRRIP will remain in effect for the first increment, 13 years, unless terminated earlier by one of the signatory parties. The PRRIP which began on January 1, 2007 is estimated to cost $317 million, with the federal share being $157 million (2005 dollars). Wyoming's 2006 legislature approved $6 million in funding for the PRRIP and $8.5 million for the Pathfinder Modification Project, to recover 54,000 acre-feet of space in Pathfinder Reservoir. The Pathfinder Modification Project provides a municipal water supply, a water supply to help meet obligations of Wyoming under the Modified North Platte Decree, and enhancement of regulatory certainty under the federal Endangered Species Act (ESA).

In the absence of the PRRIP, each water project or activity in the Platte River Basin having a federal nexus will be required to address and comply with federal ESA regulations individually, a process that could be costly and inefficient and would severely impact the states and their water users.

Glendo Reservoir Contract

The total storage capacity of the USBR's Glendo Reservoir is 428,405 acre-feet, which includes the flood surcharge pool, a space to accommodate restoring the USBR's winter releases from Pathfinder Reservoir, temporary storage of the Inland Lake ownership, the impoundment of water for the purpose of creating head for production of hydropower and a maximum, not-to-exceed, 100,000 acre-feet conservation pool. In 1996, the parties to the *Nebraska v Wyoming* lawsuit agreed to a stipulation that amended the "1953 Order to Provide for Use of Glendo Storage Water" (1953 Order), which was incorporated as an exhibit to the "Proposed Joint Settlement" that was approved by the U.S. Supreme Court in 2001. This amendment sustained the regime of the river by adhering to the original allocation of the conservation pool. Wyoming and Nebraska contractors are limited to releases of 40,000 acre-feet on an annual basis: 15,000 acre-feet to Wyoming and 25,000 acre-feet to Nebraska. Any storage not used may be carried over as long as the total conservation pool does not exceed 100,000 acre-feet. Of the 15,000 acre-feet allocated to Wyoming, the USBR has long-term contracts for 4,400 acre-feet. Therefore, Wyoming may contract for an additional 10,600 acre-feet of water, whenever available, to maximize the beneficial use of Wyoming's allocation of the conservation pool.

The 1996 stipulation expanded the use of Glendo storage water in Wyoming by allowing use for any beneficial purpose whatsoever, rather than strictly limiting the use for irrigation purposes as mandated by the 1953 Order. Further, as stipulated in 1996, Glendo storage water can be exchanged by replacing 2 acre-feet for every acre-foot of natural flow withdrawn to support beneficial uses upstream of the reservoir. The State of Wyoming has written to the USBR seeking to enter into a long-term contract to purchase and remarket the remaining 10,600 acre-feet of Wyoming's 15,000 acre-feet allocation to maximize beneficial use. In the short term, the State of Wyoming proposes to include Wyoming's currently uncommitted 10,600 acre-feet of the state's Glendo allocation to meet the replacement obligations as described in the Modified North Platte Decree.

*Snake/Salt River Basin*

The Palisades Reservoir Contract provides Wyoming with 33,000 acre-feet or 2.75 percent of the 1,200,000 acre-feet of active storage space in Palisades Reservoir. Wyoming is entitled to the water accruing to this space in priority for a variety of purposes, including the Snake River Compact replacement storage space obligations, subcontracting the use of storage water to others, and maintaining instream flows and lake levels within Wyoming through exchange. Wyoming is treated, for the most part, like any other storage spaceholders in Palisades Reservoir under contract with the USBR, with the same general rights and obligations for the use, accounting, and administration of the storage space.

*Wind/Bighorn River Basin*

In a 1985 agreement with the United States of America, covering the Buffalo Bill Dam Modifications which raised the dam 25 feet and increased storage capacity, Wyoming acquired approximately 190,000 acre-feet of space from the 644,540 acre-feet total upsized capacity of Buffalo Bill Reservoir. Wyoming and the USBR provide winter releases, beginning in October and ending with the onset of the irrigation season, that range from a minimum of 100 cfs to a maximum of 350 cfs. During normal and wet cycles the majority of the winter releases come from the Wyoming account. A maximum winter release of 50 cfs accrues to the original reservoir before undertaking the Buffalo Bill Modifications project. The actual release is dependent upon reservoir inflows and the amount of carry-over storage remaining in Wyoming's 190,000 acre-feet storage account. During periods of drought, the winter 100 cfs releases equally debit the Wyoming account and the USBR's original storage space, which was available before the Buffalo Bill Modifications project.

After winter releases are considered, Wyoming's Buffalo Bill Reservoir account yields 20,000 acre-feet on a firm annual basis. Further, during normal and wet cycles, up to an additional 10,000 acre-feet of water, whenever available, may be marketed for irrigation, municipal, or industrial purposes. Before a water sale contract can be executed, the required NEPA review must be completed, and the potential sale must first be approved by the WWDC and the Governor. As of the date of printing this report, the State has not marketed any of its Buffalo Bill storage water.

### 3.3.4 Water Environmental Laws

The Environmental Quality Act was passed by the Wyoming Legislature in 1973. The purpose of the law was to address the concern that pollution "will imperil public health and welfare, create public and private nuisances, be harmful to wildlife, fish and aquatic life, and impair domestic, agricultural, industrial, recreational and other beneficial uses." The act authorized the state "to prevent, reduce and eliminate pollution; to preserve, and enhance the water and reclaim the land of Wyoming; to plan development, use, reclamation, preservation and enhancement of the air, land, and water resources of the state; to preserve and exercise the primary responsibilities and rights of the state of Wyoming; to secure cooperation between agencies of the state, agencies of other states, interstate agencies, and the federal government in carrying out these objectives" (Wyoming Department of Environmental Quality Act, 1973).

The State of Wyoming has designated the Water Quality Division (WQD) of the Wyoming Department of Environmental Quality (WDEQ) to oversee water quality and enforce the Environmental Quality Act. This is being done through a number of programs that have been set up to control various forms of potential pollution. Pollution can come from point and nonpoint sources and can affect surface water and groundwater.

The WQD developed water quality standards which are documented in Chapter 1, Wyoming Water Quality Rules and Regulations, and are available on the WQD website at http://soswy.state.wy.us/rules/search.htm. The surface water quality standards are divided based on four surface water classifications:

- **Class 1, Outstanding Waters**: Class 1 waters are surface waters in which no further water quality degradation by point source discharges other than from dams will be allowed. Nonpoint sources of pollution shall be controlled through implementation of appropriate best management practices. Water quality and physical and biological integrity which existed on the water at the time of designation will be maintained and protected. The designation of Class 1 waters is reflective of water quality. This includes the following characteristics:

aesthetically pleasing, scenic, recreational, ecological, agricultural, botanical, zoological, municipal, industrial, historical, geological, cultural, archaeological, fish and wildlife habitat, the presence of significant quantities of developable water, and other values of present and future benefit to the people.

- **Class 2, Fisheries and Drinking Water**: Class 2 waters are waters, other than those designated as Class 1, that are known to support fish or drinking water supplies or where those uses are attainable. Class 2 waters may be perennial, intermittent or ephemeral and are protected for the uses indicated in each subcategory.
- **Class 3, Aquatic Life Other than Fish**: Class 3 waters are waters, other than those designated as Class 1, that are intermittent, ephemeral, or isolated and because of natural habitat conditions, do not support have the potential to support fish populations or spawning; Class 3 includes certain perennial waters which lack the natural water quality to support fish (e.g., geothermal areas). Class 3 waters support invertebrates, amphibians, or other flora and fauna which inhabit waters of the state at some stage of their life cycles. Uses designated on Class 3 waters include aquatic life other than fish, recreation, wildlife, industry, agriculture, and scenic value. Generally, waters suitable for this classification have wetland characteristics, and such characteristics are a primary indicator used in identifying Class 3 waters.
- **Class 4, Agriculture, Industry, Recreation and Wildlife**: Class 4 waters are waters, other than those designated as Class 1, where it has been determined that aquatic life uses are not attainable. Uses designated on Class 4 waters include primary contact recreation, wildlife, industry, agriculture, and scenic value.

*Groundwater Quality*

The State of Wyoming has identified the following standards for different classes of groundwater (WDEQ, 2004):

- Class I groundwater is defined as groundwater suitable for domestic use.
- Class II groundwater is defined as groundwater suitable for agricultural use where soil conditions and other factors are adequate.
- Class III groundwater is defined as groundwater suitable for stock use.
- Class Special (A) groundwater is defined as groundwater suitable for fish and aquatic life.
- Class IV groundwater is defined as groundwater suitable for industry.
- Class V groundwater is defined as groundwater found closely associated with commercial deposits of hydrocarbons, or groundwater which is considered a geothermal resource.
- Class VI groundwater is defined as groundwater that may be unusable or unsuitable for use.

Table 3-8 includes additional information regarding the standards for Classes I, II, and III.

**Table 3-8 WDEQ Groundwater Quality Standards**

| Constituent | Class I (domestic) | Class II (agricultural) | Class III (livestock) |
|---|---|---|---|
| | mg/L | | |
| Chloride | 250 | 100 | 2,000 |
| Iron | 0.3 | 5 | |
| Sulfate | 250 | 200 | 3,000 |
| TDS | 500 | 2,000 | 5,000 |
| SAR[1] | | 8 | |

[1] Sodium Adsorption Ratio (SAR) has been found to be important with respect to use of coalbed methane waters for irrigation.

The U.S. Environmental Protection Agency (USEPA) regulates public drinking water supplies in Wyoming since the State has not assumed primacy for this Clean Water Act program. This program provides comprehensive regulation of both surface and groundwater supplies, including enforceable standards for organic and inorganic constituents, complex filtration and disinfection requirements for surface water or groundwater determined to be under the influence of surface water, and monitoring and reporting requirements to ensure compliance. Although these rules and regulations continue to evolve, groundwater is widely considered to be a more desirable source of drinking water if it is available, due to substantially less expensive compliance requirements. Table 3-9 provides a partial listing of the inorganic constituents for which the USEPA has promulgated Maximum Contaminant Levels (MCL). "Primary" standards are based on human health effects and are required to be met. "Secondary" standards are based on the aesthetics of drinking water and are advisory.

**Table 3-9 Drinking Water Standards**

| Constituent (unit) | USEPA Maximum Contaminent Level | |
|---|---|---|
| | **Primary** | **Secondary** |
| **MAJOR IONS (mg/L)** | | |
| Chloride | | 250 |
| Fluoride | 4 | 2 |
| Nitrogen, Nitrate+Nitrite as N | 10 | |
| Nitrogen, Nitrite as N | 1 | |
| Sulfate | | 250 |
| **NON-METALS (mg/L)** | | |
| Cyanide | 0.2 | |
| **PHYSICAL PROPERTIES** | | |
| Color (color units) | | 15 |
| Corrosivity (unitless) | | non-corrosive |
| Odor (threshold odor number) | | 3 |
| pH (standard units) | | 6.5 - 8.5 |
| Total Dissolved Solids (mg/L) | | 500 |
| Surfactants (methylene blue active substances) | | 0.5 |
| **METALS - TOTAL (mg/L)** | | |
| Aluminum | | 0.05 - 0.2 |
| Antimony | 0.006 | |
| Arsenic | 0.01 | |
| Barium | 2 | |
| Beryllium | 0.004 | |
| Cadmium | 0.005 | |
| Chromium | 0.1 | |
| Copper | 1.3 | 1 |
| Iron | 0.3 | 0.3 |
| Lead | 0.015 | |
| Manganese | | 0.05 |
| Mercury | 0.002 | |
| Nickel | 0.1 | |
| Selenium | 0.05 | |
| Silver | | 0.1 |
| Thallium | 0.002 | |
| Uranium | 0.03 | |
| Zinc | | 5 |
| **RADIONUCLIDES - TOTAL (pico Curies per liter)** | | |
| Gross Alpha | 15 | |
| Gross Beta | 50 | |
| Radium 226 + Radium 228 | 5 | |

Chapter 8 of the Wyoming Water Quality Rules and Regulations addresses groundwater quality standards and protection. These rules are enforced by the WDEQ (WDEQ, 2004). Chapter 8 describes various classifications that have been created for groundwater and outlines the rules for discharges to these waters. Additional information regarding groundwater quality can be found in the groundwater characterization portion of Chapter 4 of this Framework Water Plan.

*Surface Water Quality*

The Clean Water Act requires that a 305(b) report be created which covers statewide water quality, along with a 303(d) list, of impaired streams in the state. Impaired streams require the establishment of total maximum daily loads (TMDLs) for problem pollutants. A TMDL is the amount of a specific pollutant that a water body can receive and assimilate in a given time period and still meet water quality standards.

The classification of a stream indicates what use is being or can be supported by that stream. In general, the water quality in Wyoming is good based upon the number of water bodies supporting their designated uses. Wyoming's 305(b) State Water Quality Assessment Report produced by WDEQ includes 303(d) listings.

### 3.3.5 Federal Environmental Laws

Numerous federal legislative efforts have authorized the remediation and protection of water quality and the environment. These include the Clean Water Act, Pollution Prevention Act, Safe Drinking Water Act, Clean Air Act, NEPA, Solid Waste Disposal Act, Toxic Substance Control Act, and Federal Insecticide, Fungicide and Rodenticide Act. Most of the federal programs involved with water quality allow individual states to obtain primacy to administer the federal programs. The USEPA can step in if a state is not conducting the program to their satisfaction, even if the state has primacy.

The following is a list of water development and management actions that can initiate or trigger federal environmental laws. A discussion of applicable federal legislation is presented following the list.

- Issuance and renewal of special use and right-of-way permits on federal lands.
- Contracting for storage water from federal reservoirs.
- Discharge of dredged and/or fill material into waters of the United States, including rivers, streams, and wetlands.
- Procurement and renewal of licenses from the Federal Energy Regulatory Commission (FERC) to produce hydropower.
- Use of federal loan or grant funds to construct a new water project or rehabilitate an existing water project.

Key applicable federal legislation includes the following acts:

*Endangered Species Act*

The Endangered Species Act of 1973 (ESA) requires the Secretary of Interior, through the U.S. Fish and Wildlife Service (USFWS), to determine whether wildlife and plant species are endangered or threatened based on the best available scientific information. The ESA constrains all federal agencies from taking any action that may jeopardize the continued existence of an endangered or threatened species. If a federal agency is considering an action that may jeopardize an endangered species, Section 7 of the ESA requires that the agency must consult with the USFWS.

*National Environmental Policy Act*

The National Environmental Policy Act of 1969 (NEPA) requires that federal agencies consider all reasonable foreseeable environmental consequences of their proposed actions. A review of an action under NEPA can be in the form of a simple finding of no significant impact (FONSI), environmental assessment (EA), or an EIS and record of decision. Further, NEPA requires federal decision-makers to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources" (42 USC 4321 et seq., Sec. 102(2)E). NEPA provides federal agencies the opportunity to determine which alternative, including no action, they feel best serves the applicant's purpose and need. The alternative selected by the federal agency may differ from the one preferred by the applicant.

*Clean Water Act*

Section 404 of the Clean Water Act of 1972 prohibits discharging dredged or fill materials into waters of the United States without a permit from the USCOE. The waters of the United States include rivers and streams and, as of 1993, wetlands. USCOE policy requires applicants for 404 permits to avoid impacts to waters of the U.S. to the extent practicable, then minimize the remaining impacts, and finally take measures to mitigate unavoidable impacts. In addition to the alternative review required by NEPA, Section 404(b)(1) guidelines require an alternative review to define the least environmentally damaging practicable alternative.

Section 401 of the Clean Water act provides that the State of Wyoming certify any federally licensed or permitted facility which may result in a discharge into the waters of the state. The 401 certification provides a mechanism for Wyoming to amend, or perhaps veto, an action that the federal agency might otherwise permit. While the 401 certifications are required for several federal actions, most 401 certifications relate to Section 404 Dredge and Fill Permits required from the USCOE.

## 3.4 REFERENCES

Collins, Gary. Office of the Tribal Water Engineer. 2000. *Wind River Reservation Tour*. August.

Economic Analysis Division. 2006. *Equality State Almanac.*

Foulke, Coupal and Taylor. 2000. *Trends in Wyoming Agriculture: Agriculture Employment (1969-1997).*

Jacobs, James J., and Donald J. Brosz. 2000. *Wyoming's Water Resources.* University of Wyoming, Agricultural Experiment Station. August.

Water Resources Data System. 2004. *Wyoming Climate Atlas, Average Number of Frost Free Days.* http://www.wrds.uwyo.edu/wrds/wsc/climateatlas/title_page.html.

Wyoming Department of Environmental Quality. 1973. *Environmental Quality Act.*

Wyoming Department of Environmental Quality, Water Quality Division. 2004. *Wyoming Water Quality Rules and Regulations*, Chapter 8.

John Hopkins University, Applied Physics Laboratory. 1995. *Shaded Relief Map of Wyoming.* http://fermi.jhuapl.edu/states/maps1/wy.gif.

# WYOMING - Headwaters of the West!

**Streams flow from Wyoming in all directions to the major river systems of the United States.**

| Major Drainage System | Percent of Wyoming |
|---|---|
| Missouri River Basin | 72 |
| Upper Colorado River Basin | 21 |
| Pacific Northwest River Basins | 5 |
| Great Basin | 2 |

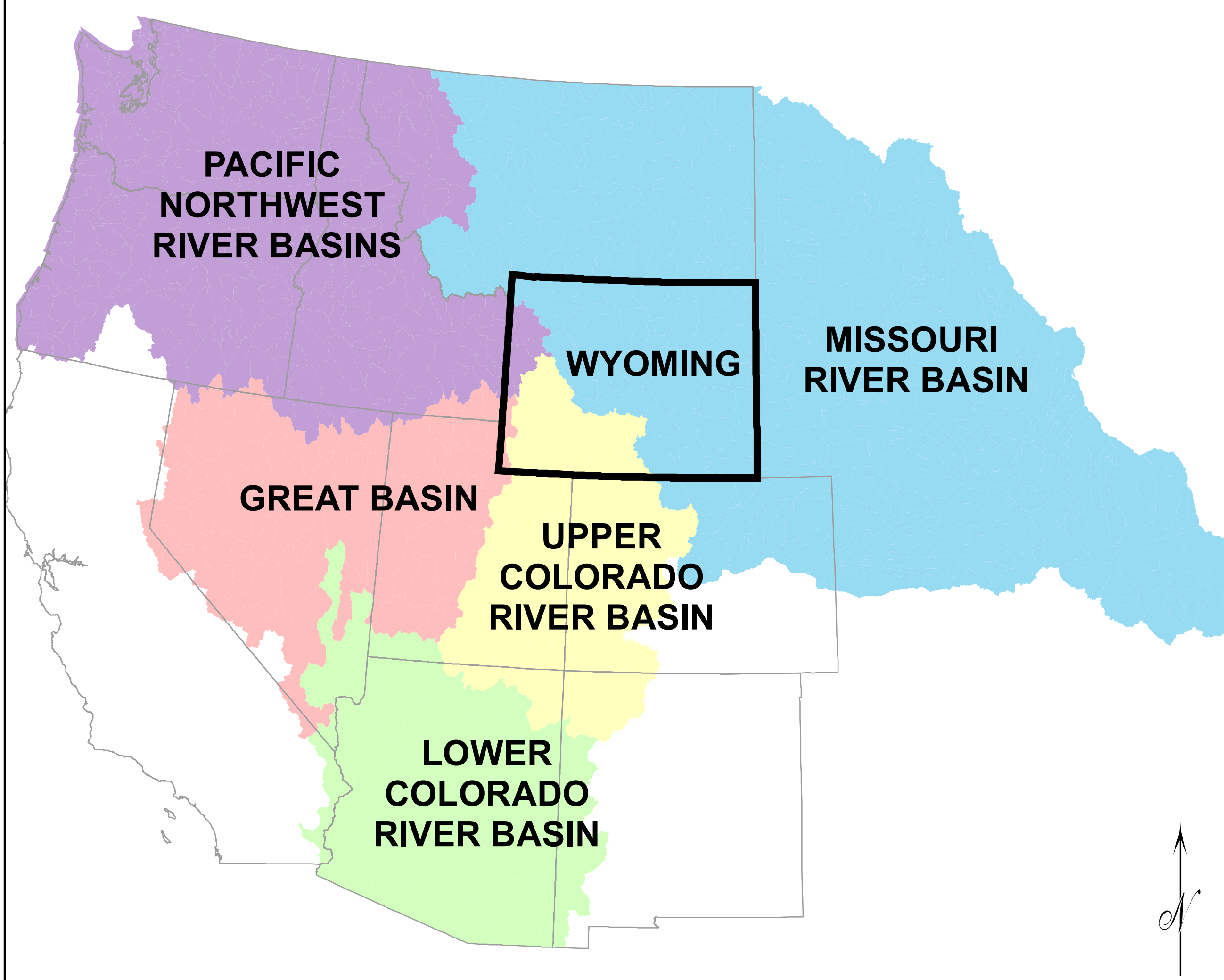
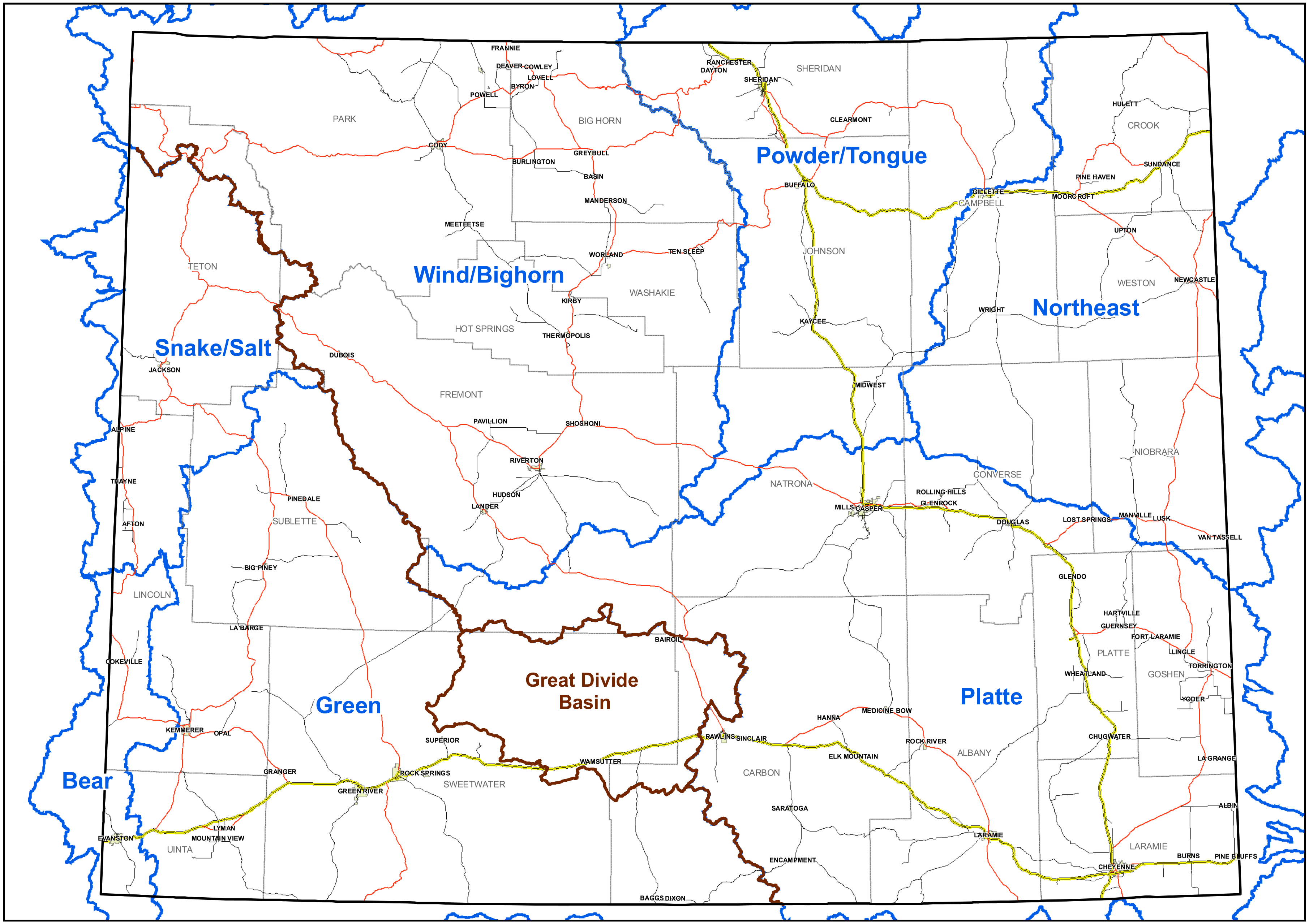



**Figure 3-1**
**Water Resource Regions**




LEGEND

River Basin Planning Area

Continental Divide

Note: The Great Divide Basin is a closed basin within the Green River Basin.

**Figure 3-2**
**River Basin Planning Area Map**

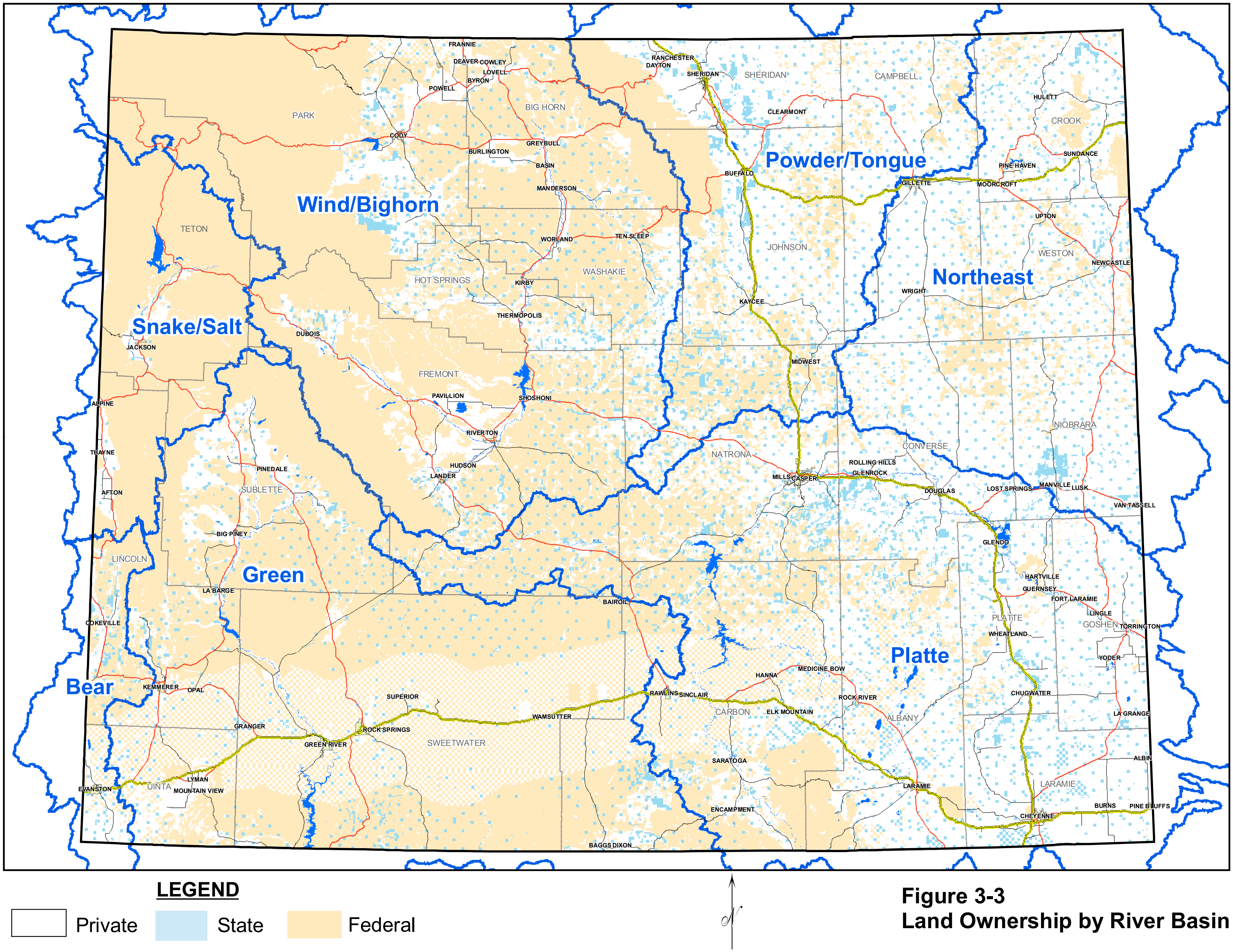
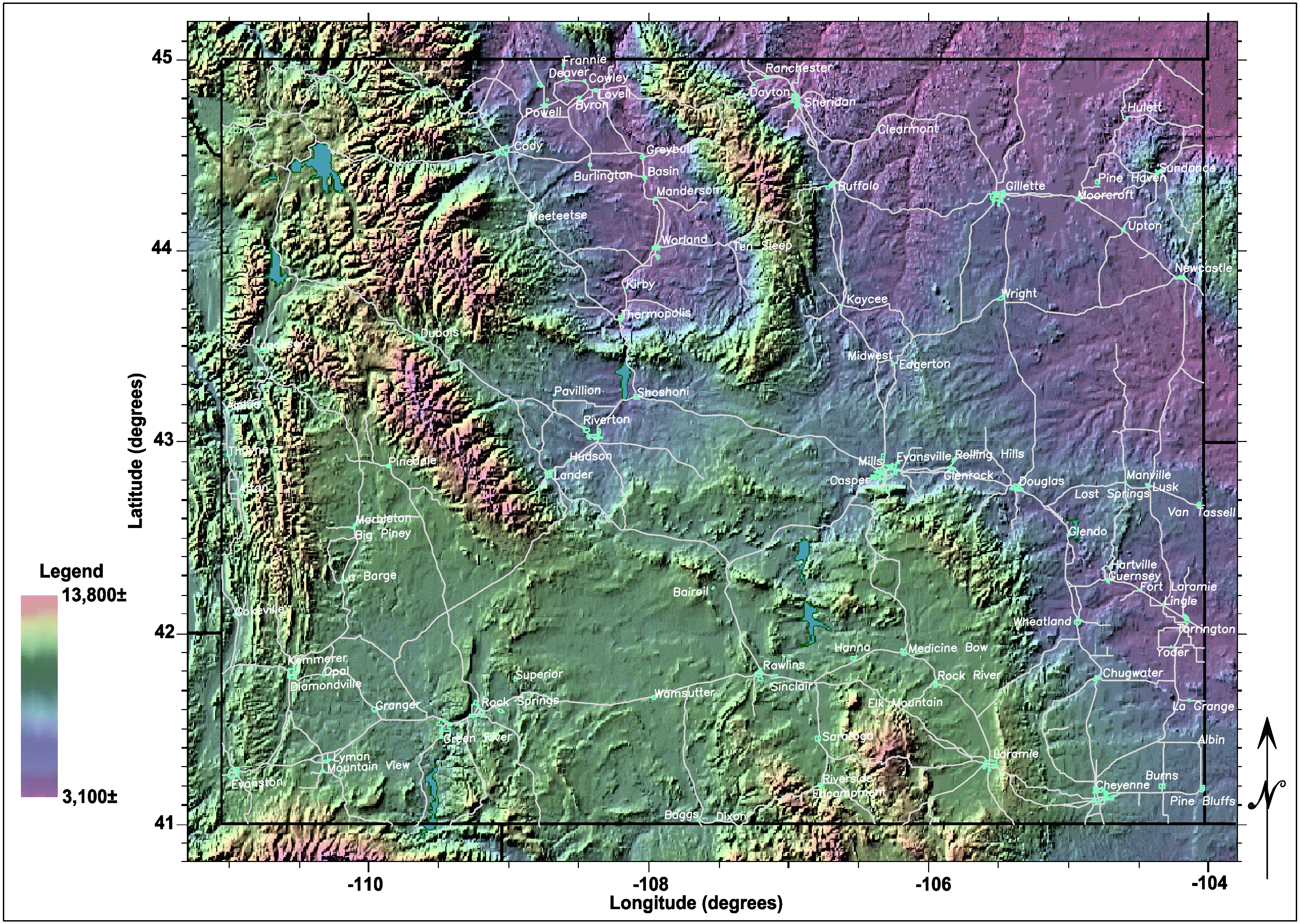



**Figure 3-3**
**Land Ownership by River Basin**




Shape corrected for lat 43.00



**Figure 3-4**
**Shaded Relief Map**

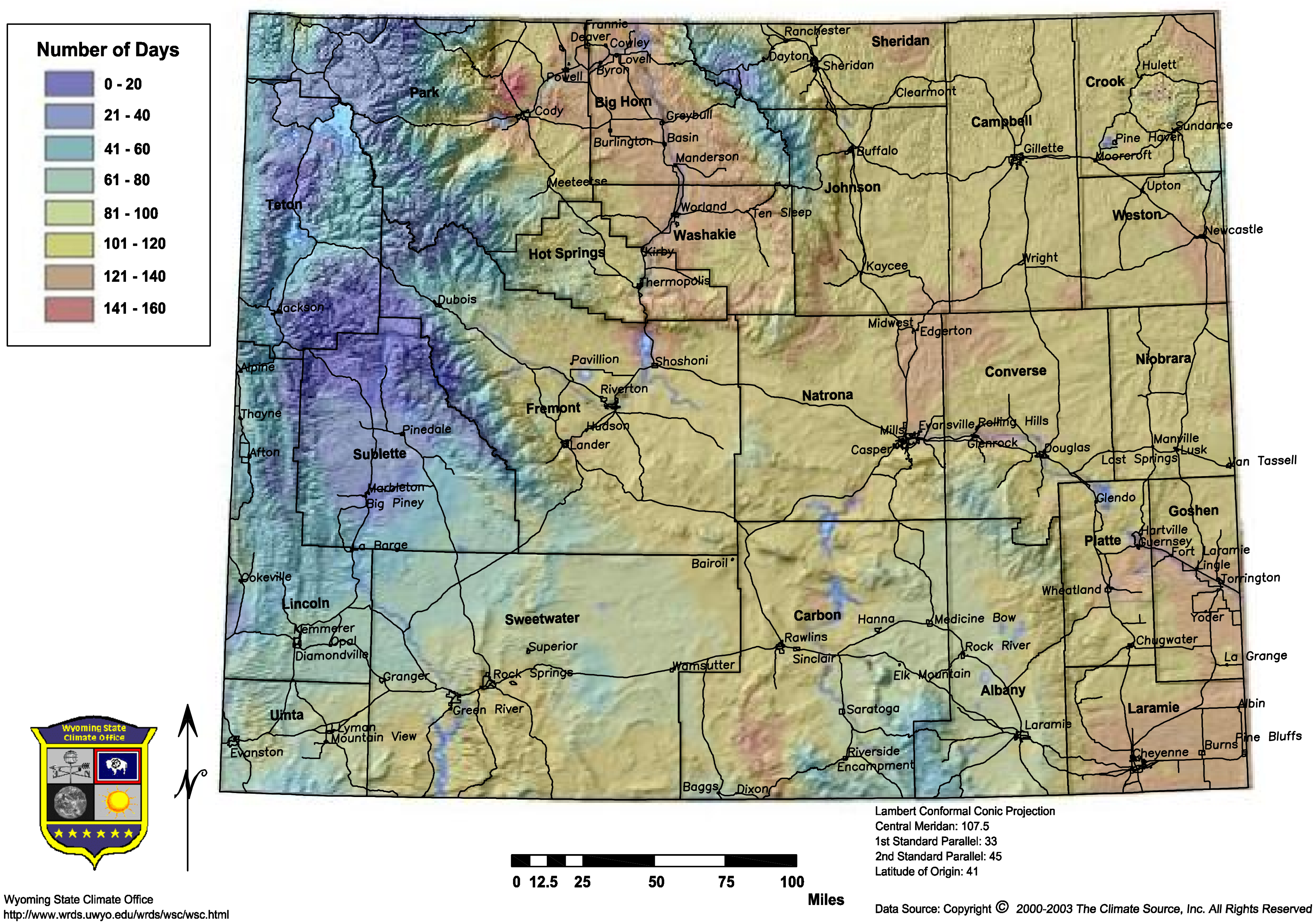
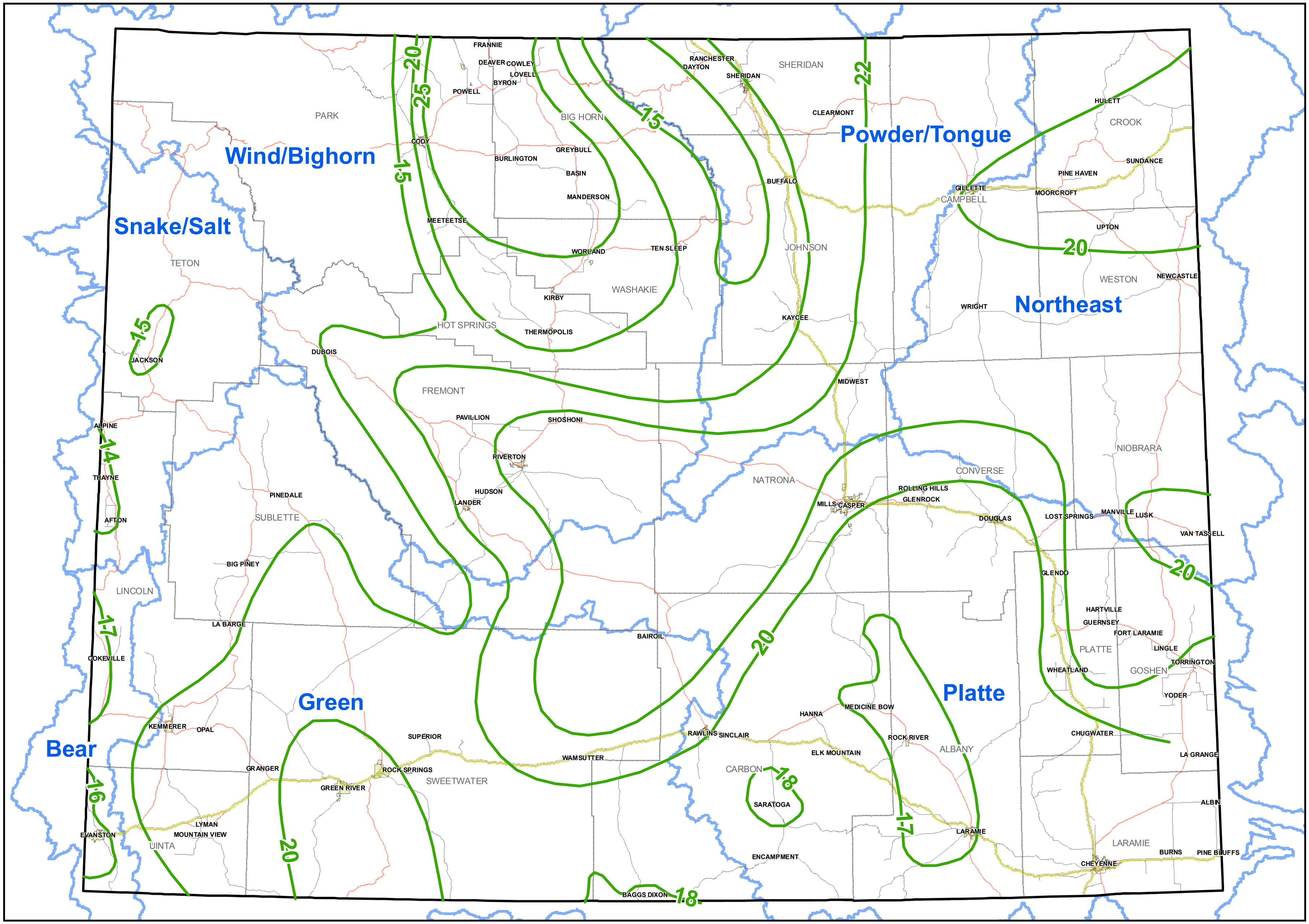




**Figure 3-5**
**Average Number of Frost-Free Days**




## LEGEND

Contour from 1973 Framework Water Plan

The values at individual Weather Bureau Stations are shown. The isolines are intended to show approximate values for the areas represented by W.B. stations. Mountainous areas are not represented on this map.

**Figure 3-6**
**Average Seasonal Consumptive Irrigation Requirements for Grass (In Inches)**

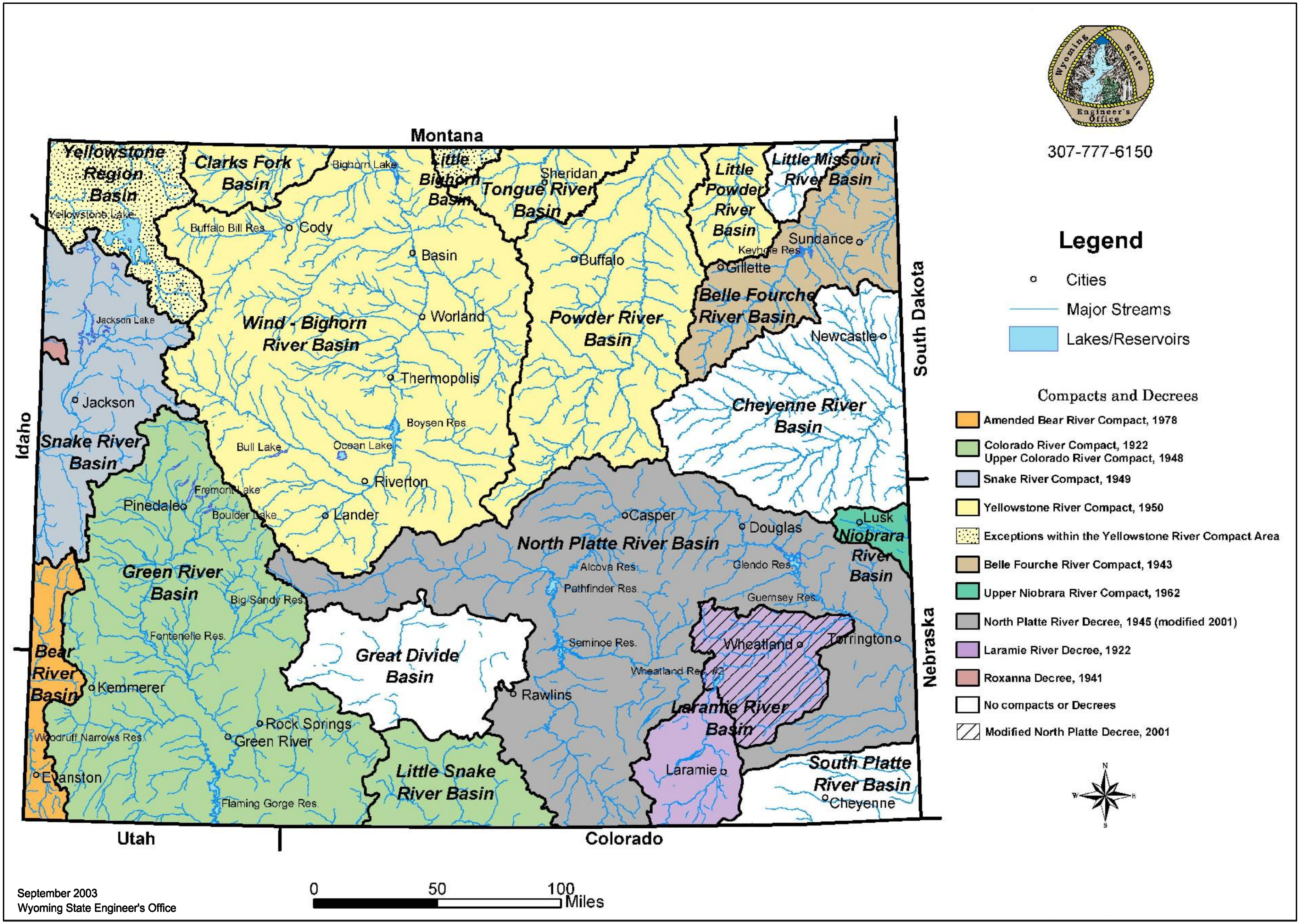



**Figure 3-7**
**Wyoming River Basin Compacts and Decrees**

# 4.0 RESOURCES

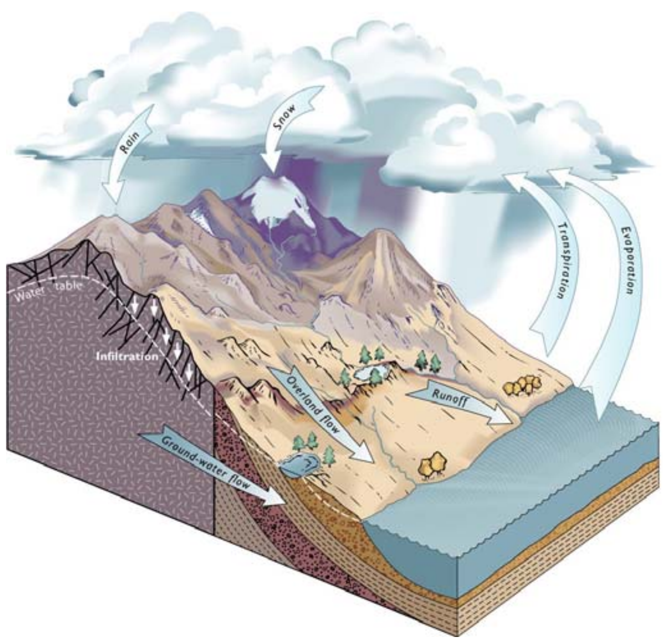
## 4.1 INTRODUCTION

This chapter presents the physical characteristics (quantity and quality) of Wyoming's surface water and groundwater. Regarding water quantity, the intent of the chapter is to characterize Wyoming's total hydrologically available water supply irrespective of existing uses, institutional constraints, and visions for how water resources might be put to future beneficial use. In other words, this chapter provides estimates for the volume of water Wyoming must draw upon to sustain itself and future generations.

The results described herein pertain to *physical availability,* which is to be distinguished from legal or permitted availability. Physical availability is important in assessing the viability of any future project, and lack of physical availability of water is an obvious fatal flaw for any water development.

## 4.2 GENERAL

Wyoming is a headwaters state, and precipitation is the source of most water in the state. Figure 4-1 presents mean precipitation rates. Approximately 68 million acre-feet per year[1] of precipitation joins 1.5 million acre-feet of surface inflows to create the total water resource. The basic hydrologic cycle is depicted in the margin graphic for a typical Wyoming river basin. Most of the precipitation will evaporate from the surface or be taken up and transpired by local vegetation. Figure 4-2 presents mean rates of potential evapotranspiration. Precipitation and snowmelt in excess of immediate demands will either run off (feeding rivers, streams, and lakes) or infiltrate to become groundwater. Approximately 15 million acre-feet per year of water become either surface or groundwater and thus available for use. This estimate is made up of the water that flows into the state plus the precipitation that runs off as streamflow or infiltrates as groundwater. Groundwater recharge will eventually return to the surface. Surface water will eventually evaporate to the atmosphere, completing the cycle. These two elements of the total water resource, surface water and groundwater, are the subject of the present report.




**Hydrologic Cycle**

[1]13.07 inches per year mean annual statewide precipitation rate (Wyoming Climate Atlas, 2004).

## 4.3 SURFACE WATER RESOURCES

### 4.3.1 Quantity

The objective of this chapter is to present basin and statewide estimates of total physically available water supply resources. A coarse estimate of those volumes can be made by simply adding the quantity of surface water leaving the state to estimates of surface water depletions. The estimates of water leaving the state come directly from gaging station records shown on Figure 4-3. The estimates for surface water depletions come from data in Chapter 5. Table 4-1 and Figure 4-4 present the estimated annual natural flows for the river basins. Table 4-1 shows the streamflow that occurs in each of the river basins. The table also shows the per-acre yield for each of the river basin planning areas. The northwest corner of the state has the largest yield per acre while the northeast corner of the state has the lowest yield per acre. Table 4-1 also shows the changes that occur due to hydrologic conditions, wet, normal, and dry. Approximately 17 million acre-feet run into Wyoming or are produced within the state under normal conditions.

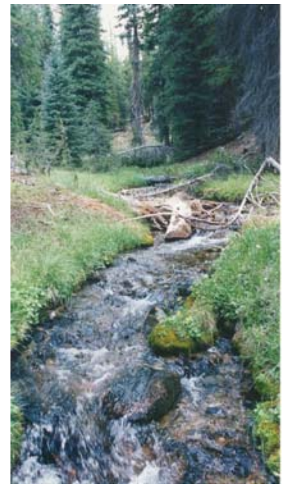


**Table 4-1 Total Annual Flow[1,2,3]**

| River Basin | Area | Yield | | | |
|---|---|---|---|---|---|
| | | Ratio Based on Normal Conditions | Wet | Normal | Dry |
| | acres[4] | ac-ft/ac | ac-ft | ac-ft | ac-ft |
| GREAT BASIN | | | | | |
| Bear River | 960,000 | 0.55 | 888,000 | 526,000 | 234,000 |
| COLORADO RIVER | | | | | |
| Green River | 13,440,000 | 0.19 | 3,746,000 | 2,617,000 | 1,543,000 |
| MISSOURI RIVER | | | | | |
| Northeast Wyoming[5] | 7,680,000 | 0.03 | 407,000 | 240,500 | 138,000 |
| Powder/Tongue River | 7,232,000 | 0.14 | 1,418,000 | 982,600 | 694,000 |
| Platte River[6] | 15,424,000 | 0.08 | 2,249,000 | 1,307,000 | 1,105,000 |
| Wind/Bighorn River | 12,928,000 | 0.36 | 5,856,000 | 4,629,000 | 3,514,000 |
| Yellowstone River[7] | 1,792,000 | 1.76 | 3,623,000 | 3,150,000 | 2,374,000 |
| COLUMBIA RIVER | | | | | |
| Snake/Salt River[8] | 3,264,000 | 1.08 | 5,047,000 | 3,540,000 | 2,179,000 |
| **Total** | **62,720,000** | **0.27** | **23,234,000** | **16,992,100** | **11,781,000** |

[1] Estimates are based on outflow plus depletions from the current river basin plans.

[2] Depletion estimates are from the current river basin plans.

[3] Depleted flows are based on outflow estimates from the current river basin plans.

[4] Basin areas do not total to the actual state area due to rounding and exclusion of small drainages in Yellowstone Park.

[5] Excludes the flows for the Little Missouri and Niobrara Rivers.

[6] The Platte River system is fully appropriated in that a water supply based on a water right with a current day priority cannot be expected to provide a reliable supply due to water rights administration. Estimates exclude the flows and depletions from the Horse Creek and South Platte Drainages.

[7] Drainage area is within Yellowstone National Park and includes estimates for the Madison, Gibbon, Firehole, and Gallatin Rivers.

[8] Excludes the flows for the Henrys Fork and Teton Rivers.

A major portion of the annual streamflows is made up of snowmelt runoff occurring during the months of April, May, June, and July. Variations in snowfall and other forms of precipitation from year to year affect average annual streamflows. Steamflow also varies considerably during the year. Figures 4-5a and 4-5b show the seasonal and annual variation in flow of 14 streamflow gages, two in each basin. These figures identify where water is available throughout the state. Three of the gages were selected to show specific points related to streamflow.

Green River at the Warren Bridge gage was selected as it represents a stream with minimal diversion and storage above the gage. The flow estimates are averages based on a 30-year period from 1970 to 2000. The average monthly flow of the Green River at Warren Bridge is 30,900 acre-feet. Average monthly flows range from less than 10,000 acre-feet during the winter to over 100,000 acre-feet in June. Figure 4-5b also shows the annual variation in flows at the Warren Bridge gage. Annual flows vary from about 200,000 acre-feet to over 500,000 acre-feet.

Another gage that shows similar conditions is the North Platte River above Seminoe Reservoir. Figure 4-5a shows the average monthly flow of 74,400 acre-feet. Monthly flows vary from under 25,000 acre-feet to over 250,000 acre-feet. Annual flow variation is from under 400,000 acre-feet per year to almost 1,600,000 acre-feet per year. These figures show the natural flow variation that is typical of Wyoming streams that are not controlled by large storage reservoirs or major diversions.

The impacts of reservoir storage and subsequent water delivery can be seen in the flows of the North Platte River below Guernsey Reservoir. The average monthly flow is 106,800 acre-feet. Monthly average flows vary throughout the year from near zero in the winter months to over 300,000 acre-feet in July, the peak irrigation water delivery month. Annual average flow of the North Platte River below Guernsey Reservoir is 1,281,000 acre-feet per year. Average annual flow varies from about 750,000 acre-feet to nearly 2,300,000 acre-feet per year. While flows here vary, the year-to-year variation is controlled due to the large amount of upstream storage.

### 4.3.2 Water Quality

Water quality refers to physical, chemical, radiological, biological and bacteriological properties. The concentration levels of various constituents dictates the uses and potential uses of a water body. In some cases, institutional constraints on water quality (Chapter 3) control the potential use of water. However, water quality also represents a basic, physical constraint on use. Table 4-2 summarizes the basic suitability of water for various uses. Quality of a water body can be impacted by natural environmental processes or by man-made actions. The success of a water development project is dependent upon the ability of the resource to meet the water quality needs of the proposed use(s), as well as the ability of the water development project to establish and maintain water quality. Where water use is sufficiently valuable, of course, desirable quality can be established and maintained by treatment.

**Table 4-2 Recommended Guidelines for TDS in Irrigation Water**

| Total Dissolved Solids (TDS) in mg/L | Guideline / Effects |
|---|---|
| <500 | No detrimental effects are usually noted |
| 500 - 1,000 | Detrimental effects on sensitive crops are possible |
| 1,000 - 2,000 | Adverse effects on many crops, requires careful management practices |
| 2,000 - 5,000 | Can be used for tolerant plants on permeable soils with careful management practices |

Source: Bear River Basin Plan

Pursuant to the Environmental Quality Act, in 1974 the Water Quality Division (WQD) of the Wyoming Department of Environmental Quality (WDEQ) developed and implemented surface water quality standards contained in Chapter 1of its Wyoming Water Quality Rules and Regulations. Chapter 1 contains numerical and narrative standards to establish effluent limitations for those discharges requiring control via permits to discharge in the case of point sources and best management practices in the case of nonpoint sources. The WQD has compiled a list of impaired streams. The streams on the 303(d) list are shown on Figure 4-6.

## 4.4 GROUNDWATER RESOURCES

### 4.4.1 Groundwater Overview

Groundwater resources are one component of the overall hydrologic cycle. “Groundwater” is not a source of water separate from “surface water”. Rather, groundwater diversions provide an alternative to surface water diversions in the use of a portion of the state’s total available water resource. Groundwater diversions differ from surface water diversions in timing, location, rate, volume, and quality.

Groundwater originates when rainfall, snowmelt, streamflow, and, in some areas, irrigation water infiltrate into geologic materials. This constitutes groundwater “recharge”. Over days, years, centuries, or even millennia where groundwater circulation is long and deep, this recharge travels through the ground and returns to the surface as discharge. Between the points of recharge and discharge, groundwater flow may be straightforward or quite complex. Because groundwater is continually returning to the surface as springs and, more importantly, as diffuse gains to most of Wyoming’s perennial streams, streamflow records include large quantities of groundwater. In the absence of storm runoff or snowmelt, most of the flow in Wyoming’s streams has been from groundwater at some point upstream.

Groundwater enters and leaves the state in the subsurface, but no estimates of rates or locations have been compiled. The total water leaving the state is more than the surface water values listed in Table 4-1. Although the area through which groundwater flow leaves the state is vastly larger than that through which surface water exits, groundwater velocities are measured in feet/day, whereas surface flows are measured in feet/second.

Like surface water, groundwater flows downhill from areas of high head to areas of lower head. Groundwater flow is from upland areas towards valley floors. Because Wyoming’s river basins are generally a reflection of regional geology, even in deep artesian aquifers groundwater flow tends to be toward and along major rivers. Figure 4-7 presents an example of groundwater head contours, from the

Tensleep Sandstone aquifer of the Bighorn Basin[2]. Groundwater flow is from the basin margins toward the center and, ultimately, to the north, like the surface drainage.

Figure 4-8 presents typical annual cycles of groundwater levels, in this example from a 110-foot deep well in an area of active irrigation. It reflects: 1) a pronounced drop in water level each spring, as irrigation pumping starts; 2) an initially rapid, then slower, recovery of water levels through the fall and winter as the aquifer is recharged from surrounding areas and the surface; and 3) overall multiyear fluctuations in the recovered water levels in response to varying irrigation management and climatic patterns.

In areas away from the influence of irrigation withdrawals, groundwater levels commonly rise in response to spring precipitation and snowmelt, and fall to annual lows in midwinter due to the absence of recharge. In aquifers remote from surface influence, there may be little or no annual fluctuation, but groundwater levels may rise and fall in response to long-term climate cycles. Individual well hydrographs vary widely, as a function of local hydrogeologic and groundwater development conditions.

### 4.4.2 Aquifer Classification

Classification of a body of geologic material as an "aquifer" depends on how much water is needed for a specific user or purpose. A hydrogeologic formation capable of adequately supplying the modest water needs of a single rural residence may be entirely inadequate to meet the needs of a large agricultural operation.

Figure 4-9 presents a hydrogeologic map of Wyoming. Approximately 210 individual geologic formations have been combined into six general groups based on the classifications and descriptions in the seven Basin Plans[3]. The figure also presents a narrative summary, including reference to the individual formations[4] within each group.

These classifications are highly generalized, because geologic materials are rarely entirely consistent over large areas. For example, the Madison Limestone (in the "Major Aquifer - Limestone" group) is famous for producing flowing wells of phenomenal productivity at certain Wyoming locations, but in the absence of fractures and solution features will produce very little. Conversely, the Cody Shale (in the "Major Aquitard" group) is universally understood to be a regional confining unit, but it can produce modest quantities of water from local sandstone beds. Regional changes in formation characteristics cause some formations to be classified differently in different basins.

Thickness, yield, and groundwater quality data in Figure 4-9 are bracketed by data from the listed basins, so may span a wider range than in any one basin. Considerable additional detail on the characteristics and variations within each aquifer is generally available in the individual basin reports.

The thickness ranges listed are for the formations themselves and do not reflect depths of occurrence. While most water wells in Wyoming are less than 200 feet deep, wells as deep as 6,000 feet have encountered useful supplies of good-quality groundwater.

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[2] Figure 4-7 is from the Wind/Bighorn Basin Plan.

[3] The individual plans did not use consistent terminology or formation grouping. The designations used here are compiled/interpreted from the plans' mapping, tabular, and narrative information.

[4] To provide a consistent, statewide formation taxonomy, Figure 4-9 uses formation symbols from the standard, USGS "Geologic Map of Wyoming" (1985), which is available either in printed form from the Wyoming Geological Survey (www.wsgs.uwyo.edu/) or electronically from http://www.wygisc.uwyo.edu/24k/bedgeol.html.

*Major Aquifers*

Alluvial

The most consistently productive aquifers in Wyoming are the alluvial sands and gravels associated with many of Wyoming's streams and rivers. The most productive area is along the Snake River west of Jackson, where the aquifer does not contain much silt or clay and is over 2,000 feet thick. Elsewhere in the state, the alluvial aquifer rarely exceeds 100 feet in thickness, but, under favorable conditions, can produce well yields on the order of 500-1,000 gallons per minute (gpm).

Alluvial deposits are unproductive where silt and clay are abundant. In some areas, although the alluvium is coarse-grained, it is relatively thin and sits above the groundwater table.

Where the alluvial aquifer is associated with an active stream, either interception of groundwater headed for the stream or induced infiltration from the stream may provide most of the available groundwater; stream depletion rates may approach pumping rates over relatively short time periods. Where closely associated with surface streams, alluvial aquifer quality tends to be good due to the low salinity of water in the stream and the filtering effect of the aquifer.

Sandstone

These aquifers are consolidated rock formations, sandstones and conglomerates, that are commonly productive for groundwater. However, most of the deposits and formations in this group include zones of poor production, due, for example, to local clay content or lack of fractures.

In the basin interiors, the sandstone aquifers tend to be widespread and horizontal or gently dipping. In some cases, individual sandstone beds are thick and widespread such as the Cloverly (Dakota) Sandstone. More commonly, however, groundwater production from these aquifers is a function of discontinuous sandstone layers and lenses, requiring penetration of a substantial number of individual beds to accumulate the desired amount of water. Examples include the Ogalalla (southeast), Wasatch (northeast), and Wind River (central) Formations. Particularly in the Powder River Basin, coal beds within these aquifers can provide substantial, widespread groundwater productivity.

Adjacent to Wyoming's mountain ranges, the older sandstone aquifers commonly dip into the basin and may provide useful water supplies for miles basinward of the outcrop areas shown in Figure 4-9. Examples include the Mesaverde, Cloverly, and Nugget Formations. The most productive formations of this group are the thick, Tertiary-age sandstones of westernmost Wyoming, where local faulting and fracturing are the key to productivity.

Groundwater quality tends to decrease with depth. High fluoride levels have been encountered in the Lance and Fox Hills Formations.

Limestone

These aquifers are consolidated rock formations: limestones and dolomites. They are the primary aquifers of the older, Paleozoic-age geologic section. Examples include the Madison Limestone, the Casper Formation, and the Bighorn Dolomite. The most productive well in Wyoming is a flowing well in the Madison Formation north of Worland, producing over 10,000 gpm of drinking-quality water. Productivity at this location is a function of fracturing and solution features at the crest of the Paintrock Anticline.

These are the most widespread Wyoming aquifers, present in all seven basins, but are generally too deeply buried to be useful away from the mountain fronts. The productivity of these aquifers is almost entirely dependent upon fractures and solution features, created by deformation and groundwater circulation, respectively, both of which processes are most well developed along the basin margins. More than with any other major aquifers, local conditions are the key to successful groundwater development.

*Minor Aquifers*

These formations are typically thinner, less extensive, and/or less productive than the "major" aquifer groups, but commonly provide useful groundwater supplies for local use. Productivity is largely a function of the thickness and texture of sandstone units, although fracture enhancement of permeability can make the difference between unacceptable and acceptable production rates. Modest yields (<50 gpm) are widely available from these formations, and higher yields are available at some locations. Examples of minor aquifers include the Arikaree (east) and Sundance (statewide) Formations.

As with productivity, groundwater quality varies widely. Permeable areas near outcrops are generally of good quality; groundwater quality commonly deteriorates with depth.

*Marginal Aquifers*

Most geologic formations can provide useful groundwater supplies under the right conditions, particularly if the demands are small such as for stock and domestic use. The formations of this group are commonly considered capable of yields on the order of 1-5 gpm, with higher production rates relatively rare. Sandstone beds are the primary source of groundwater, although zones of fractured siltstone or shale can be locally productive, and coal seams in the Hanna and Ferris Formations are locally important sources of groundwater.

The Brule Member of the White River Formation (southeast Wyoming) is a prime example of the variability of this group. It is predominantly a clayey siltstone. Extensive fracturing at the top of the formation has created pockets of high (>500 gpm) productivity around LaGrange and Pine Bluffs.

*Major Aquitards*

These formations are typically poorly productive of groundwater, and the groundwater is commonly of poor quality. These formations are mostly thick marine shales, commonly described with terms like "regional confining layer". Because of their clay content, these rocks are less brittle than sandstone or granite so are generally less subject to fracture enhancement of permeability. Examples include the Pierre and Cody Shales.

These are some of thickest and most widespread formations in Wyoming. Isolated zones produce small quantities of water at some locations-for example, the Muddy Sandstone member of the Thermopolis Formation. However, groundwater from these formations is generally scarce and of poor quality.

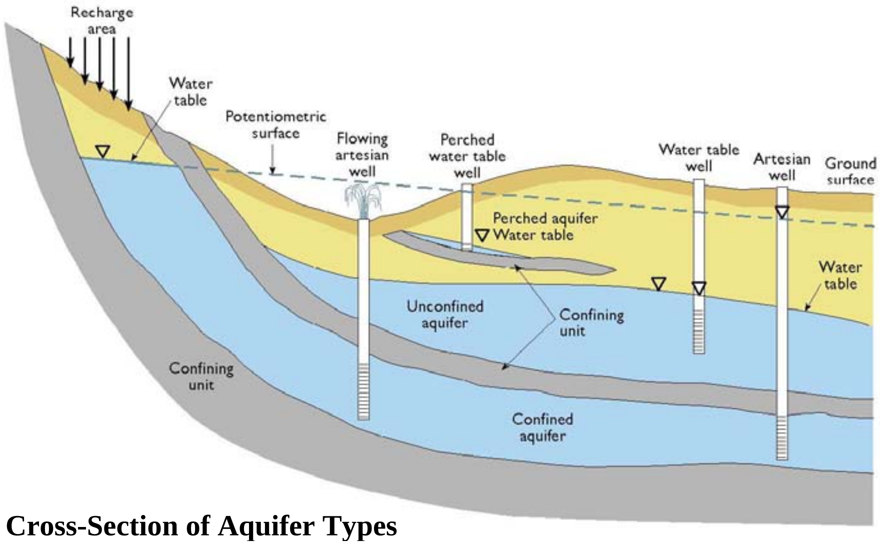
The crystalline rocks (granite, gniess, metamorphics, etc.) which underlie all of Wyoming are included in this group because in the absence of fractures they are virtually impermeable. These rocks form the lower limit to groundwater circulation in most cases. Nonetheless, these rocks may develop useful fracture permeability due to stress changes near the surface or along faults. Where groundwater can be produced, it tends to be of good quality.

*Unclassified*

These are geologic materials of limited occurrence for which insufficient data are available to suggest an aquifer grouping.

*Aquifer Location*

Figure 4-9 shows where the indicated aquifer group is present at the surface. This is where the aquifer is shallowest and has the best quality, due to the proximity to recharge. As shown schematically to the right, formations that outcrop around the basin margins commonly dip beneath younger formations present in the basin centers. Thus, groundwater is commonly available from productive basin-margin aquifers for some miles basinward of the outcrops depicted on Figure 4-9, albeit at increasing depth.

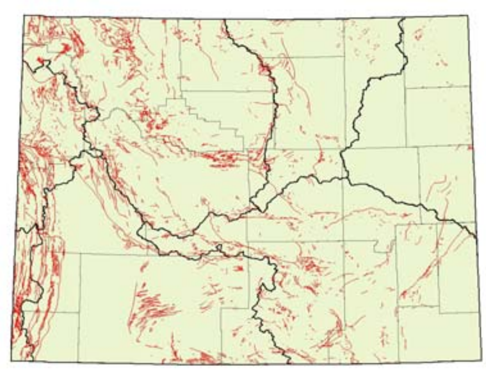



**Cross-Section of Aquifer Types**

Where a productive aquifer is overlain by less permeable strata, artesian conditions are set up which may produce flowing wells where the less permeable strata are punctured. Wyoming examples include prolific flowing wells on the flanks of the Black Hills and Bighorn Mountains. While the basin-bounding aquifers are generally present beneath the entire basin, their great depth, the absence of the basin-bounding fractures that enhance productivity, and the commonly deteriorated water quality make them poor development targets in the central basins.

For all but the alluvial aquifers, geologic structure (folds and faults) is as important as rock type in providing useful supplies of groundwater. The map to the right shows the major geologic faults in Wyoming, which provide a generalized picture of where fracturing may be an important component of groundwater productivity. In the Thrust Belt of western Wyoming and bordering the major mountain ranges, large-scale faulting is a controlling factor in nearly any bedrock aquifer. Across most of eastern Wyoming and in the basin interiors, in contrast, large-scale fracturing is much less important, and the grain size and cementing of aquifer materials play the key role.

Finally, in the carbonate aquifers (limestone and dolomite), the rocks themselves are slightly soluble, and groundwater circulation can increase the size and extent of fractures through dissolution. This is dramatically expressed in the creation of cave systems, but can vastly enhance groundwater production capacity at much finer scales. Faults, folds, and solution enhancement of permeability are most commonly associated with the basin margins, where deformation of the formations has accompanied mountain building.



**Faults**

In summary, optimum conditions for the development of groundwater reflect the conjunction of favorable formations, favorable permeability conditions within those formations – primarily coarse-grained zones and/or fractures, and recharge conditions that provide suitable groundwater quality.

### 4.4.3 Historical Aquifer Performance

Economically developable groundwater has been found across much of the Wyoming landscape. Figure 4-10 displays all water wells for which the permitted yield is greater than zero, excluding coalbed methane (CBM) wells (discussed below). Thinly populated areas of the map reflect either a lack of demand such as in the Red Desert or a lack of even small quantities of water from some of the "major aquitards" such as northwest of Casper. In some areas of Wyoming, useful groundwater is simply not present.

Highlighted on Figure 4-10 are all wells with permit yields of 500 gpm or greater. The distribution is a function of aquifer performance. Most conspicuous is the coincidence with the alluvial aquifer, reflecting both the commonly favorable conditions of permeability, depth, and quality, and the concentration of agricultural and municipal demands in Wyoming's stream valleys.

### 4.4.4 Groundwater Quality

Included on Figure 4-9 are general ranges of total dissolved solids (TDS) reported for the various formations. As with yield, the broad ranges of aquifer TDS result from widely varying conditions across basins. TDS is a generalized parameter of water quality, reflecting the total presence of dissolved minerals. For example, a TDS concentration of 500 mg/l is considered the limit of aesthetically acceptable human drinking water; 2,000 mg/l is a common maximum for irrigation water; and 5,000 mg/l is considered the limit for livestock use. Maximum groundwater TDS values of 200,000 mg/l have been reported from deep, oil field water wells.

The alluvial aquifers primarily receive recharge from an overlying stream (or irrigation applications) and/or the surrounding geologic materials. Where the former dominates, groundwater quality is generally good. The aquifer sands and gravels tend to filter sediment and bacteria from the surface source to produce water that is clean and of low salinity. Where there is substantial inflow to the alluvial aquifer from bedrock, alluvial groundwater quality will reflect that of the surrounding formations. This water will commonly be higher in salinity than the surface water and may render the alluvial aquifer of limited value for many applications.

Bedrock aquifers receive recharge through the infiltration of rainfall, snowmelt, and streamflow although discharge from groundwater to streams is more common than the other way around. Groundwater developed close to the areas of recharge may be of relatively high quality, regardless of the host formation. As water moves deeper, it generally becomes more mineralized. Near outcrops, groundwater is most commonly of a calcium bicarbonate type. Deeper, toward the basin centers, sodium commonly increases relative to calcium, and sulphate and chloride dominate over bicarbonate.

In general, groundwater quality tends to be better in the more productive aquifers because of the more active groundwater circulation and less soluble minerals. While even the "major" aquifers of Figure 4-9 may yield poor quality (particularly in deeper, central basin locations), they are more likely to provide acceptable quality than the "marginal" aquifers or aquitards. The latter group has notoriously poor quality, due to the coincident deposition of fine-grained materials (shale) and soluble minerals. An exception is the crystalline rocks (last entry of Figure 4-9) in which quality is generally good due to the very low solubilities of the constituent minerals.

Where aquifers receive recharge from the surface, they are potentially subject to contamination. In 1998, the University of Wyoming completed a statewide study of groundwater contamination potential that assessed seven factors, including depth to groundwater and recharge rates, to produce 1:100,000 scale county-by-county maps. Figure 4-11 presents a statewide version of this mapping of "Aquifer Sensitivity". Rankings are relatively-high, medium, and low and carry no specific units. The most sensitive lands are those where a contaminant at the surface such as a spill, overapplication of agricultural chemicals, or septic systems can most easily enter the aquifer. The alluvial aquifers are most sensitive. Least sensitive are bedrock aquifers where substantial thicknesses of low-permeability material lie above them.

The Snake/Salt Basin Plan extended the vulnerability concept to rural septic systems, a common source of nitrate input to groundwater. The density of rural domestic wells was mapped, looking to a general, rule-of-thumb of 2 acres/lot (20 lots per quarter-quarter section) as the threshold beyond which septic system contamination may be of concern.

### 4.4.5 Groundwater Associated with Energy Development

For many decades, groundwater has been produced along with oil and gas from Wyoming's relatively "wet" oilfields. For example, in the Wind/Bighorn Basin, annual production of 331 ac-ft of co-produced groundwater was estimated (WOGCC, 2000). This water has been discharged to the surface as a by-product of mineral production; used for oil field water flood; or, due to increasing environmental concerns, reinjected.

Starting in the 1990s, the production of groundwater in association with mineral production has vastly increased through the development of CBM wells. Unlike the groundwater produced incidentally with oil and conventional gas production, groundwater production is the driving force in CBM. Groundwater production on the order of 5-15 gpm per well is used to lower groundwater pressure to bring dissolved and adsorbed methane into the well. The produced water is typically discharged to the surface, although water quality concerns are generating increasing consideration of reinjection. Figure 4-12 presents State Engineer's Office permitted CBM wells as of December, 2006. Obviously, the Powder River Basin has been the focus of activity to date. Development is far from complete in that basin and has recently been extending to other basins. Because CBM accompanies coal seams and coal seams are present in all Wyoming basins, there is potential for CBM development throughout the state. Permitting activity beyond the Powder River Basin is just beginning and is expected to grow considerably in the near future.

Wyoming has limited potential for groundwater geothermal energy development. Various sites with low-grade geothermal resources have developed commercial applications through spa-type uses. The Snake/Salt Basin Plan discusses the potential for development of the higher-grade geothermal potential of far western Wyoming.

## 4.5 REFERENCES

Colorado Geological Society. 2003. *Ground Water Atlas of Colorado.*

Curtis, Jan, and Grimes, Kate. 2004. *Wyoming Climate Atlas.*

Love and Christiansen. 1985. *Geologic Map of Wyoming.*

Wyoming Oil and Gas Conservation Commission. 2000. *2000 Wyoming Oil and Gas Statistics.*

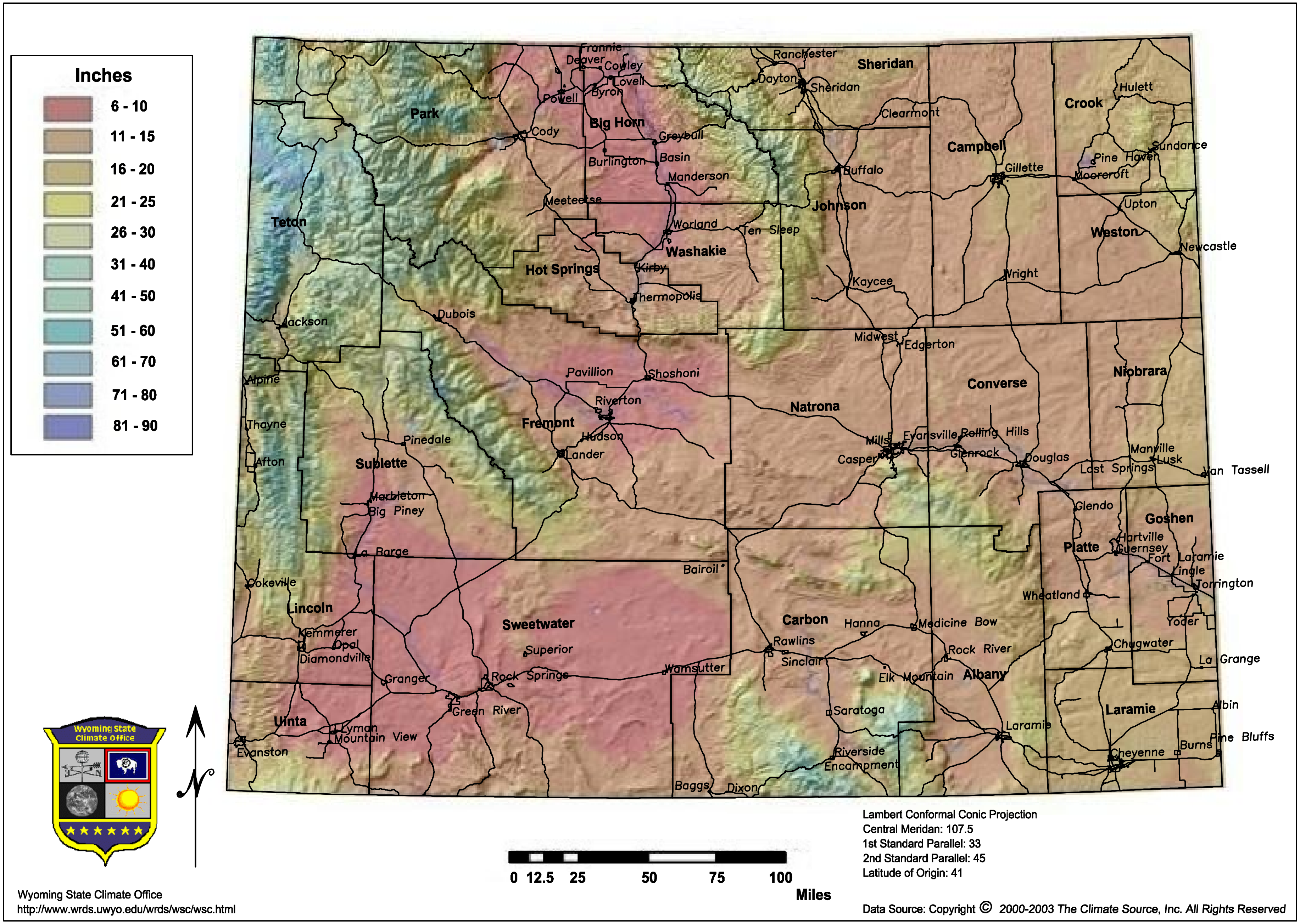
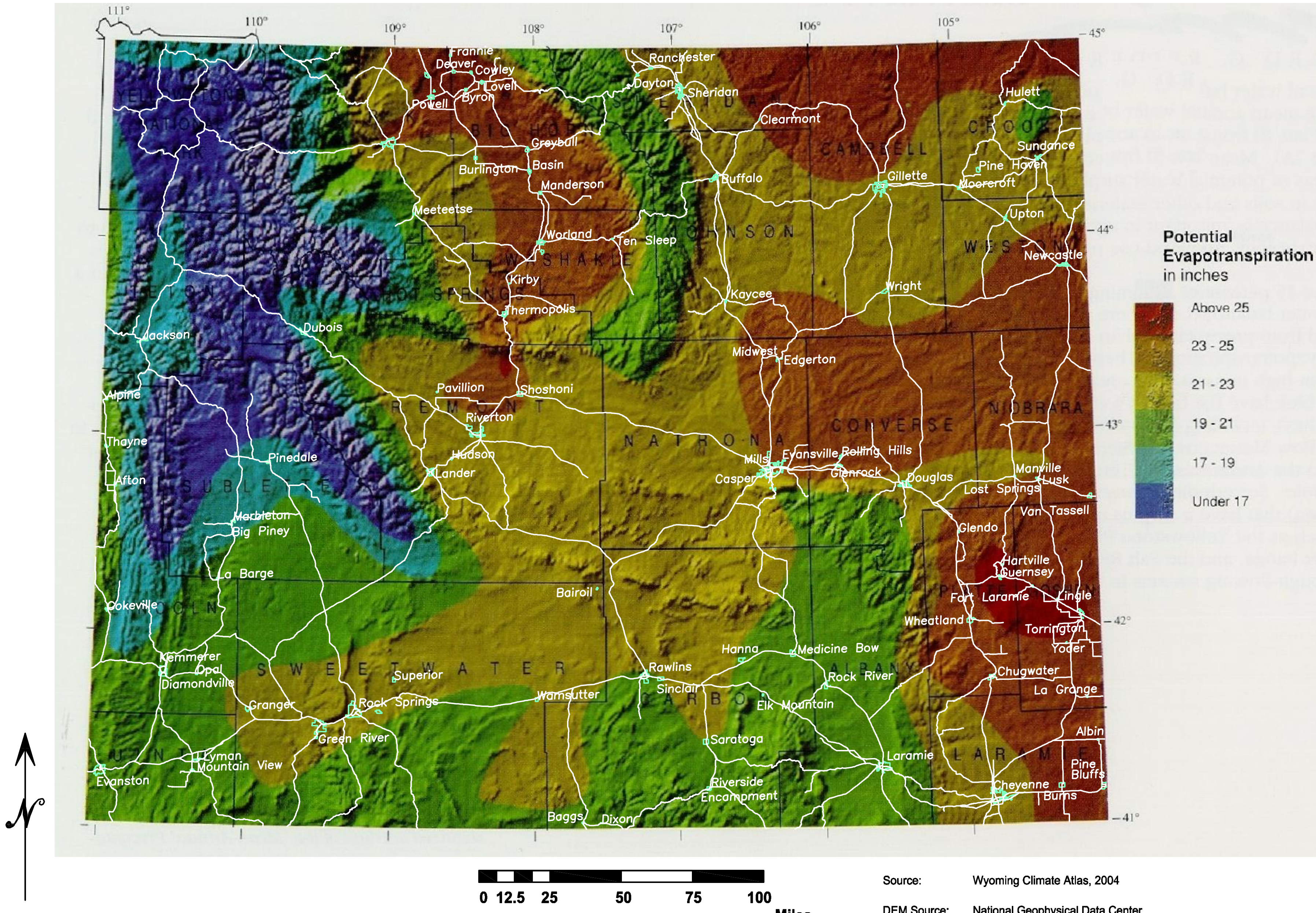


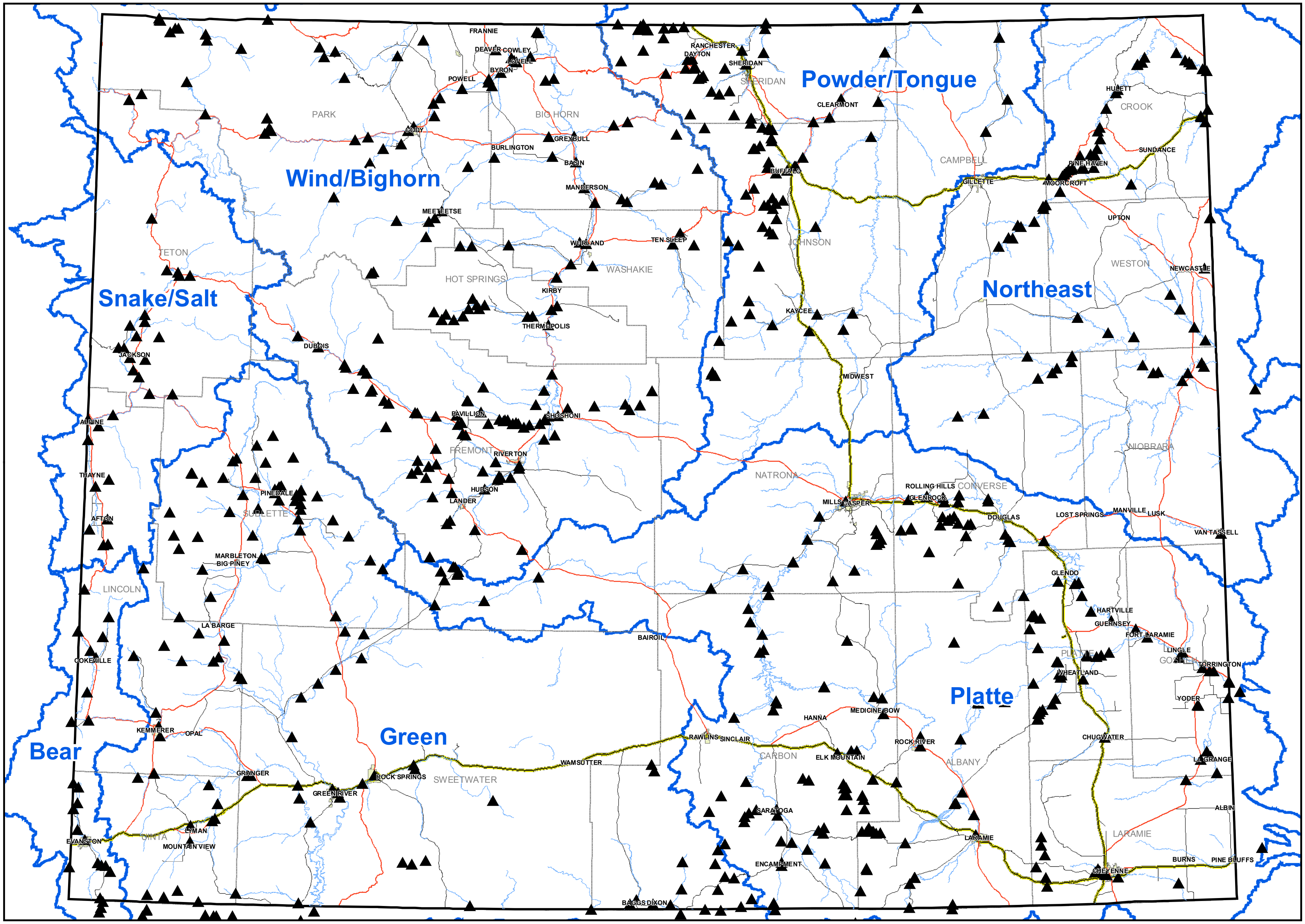

**Figure 4-1**
**Mean Annual Precipitation, 1971 - 2000**




Source: Wyoming Climate Atlas, 2004

DEM Source: National Geophysical Data Center
Alber's Equal Area Projection 1:3,000,000

**Figure 4-2**
**Mean Annual Potential Evapotranspiration**

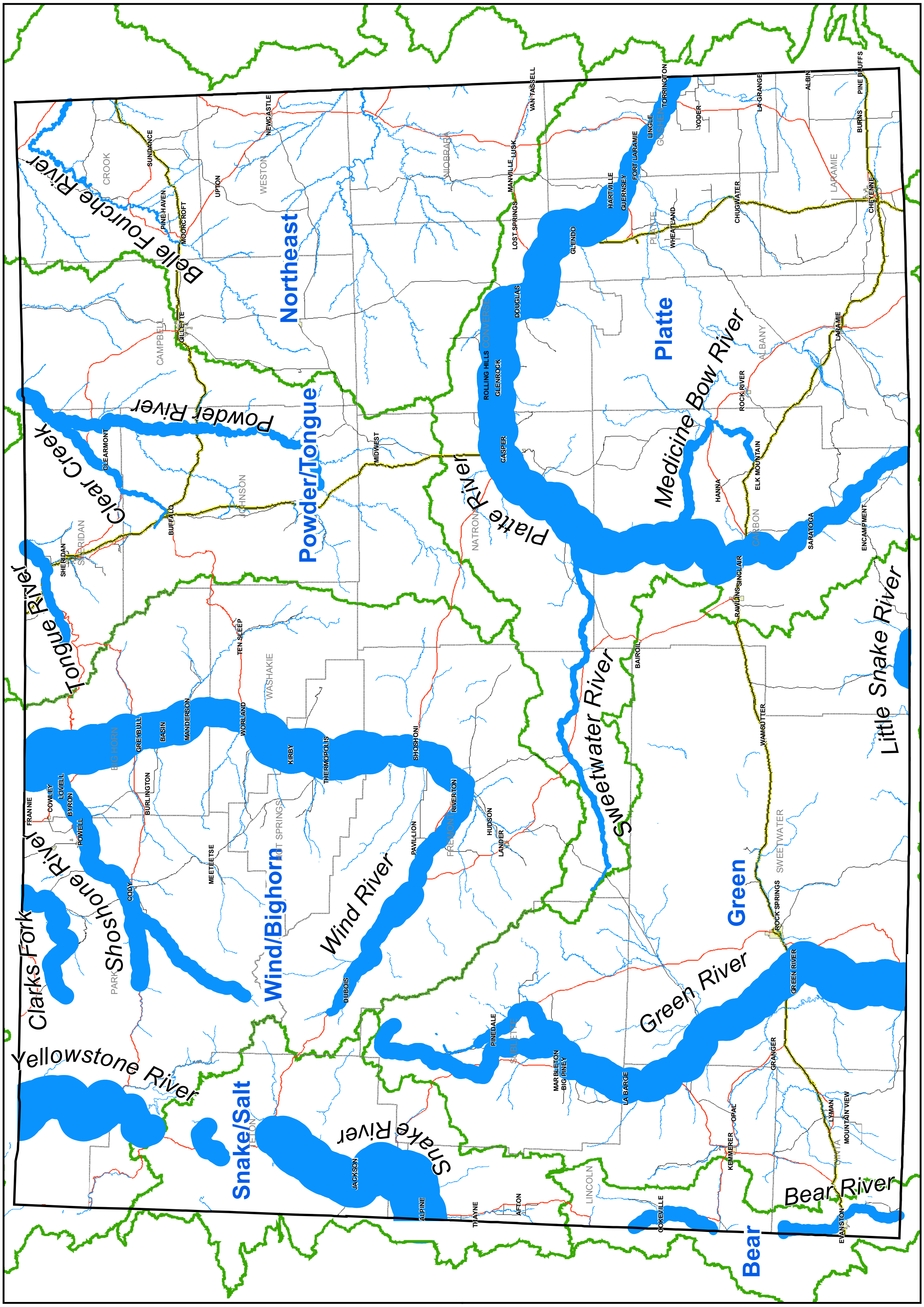



**LEGEND**

▲ USGS Streamflow Gage

All active and inactive USGS gages are shown.

**Figure 4-3**
**USGS Streamflow Gage Locations**




**LEGEND**

0.01 — 4 million ac-ft

**Figure 4-4**
**Average Annual Streamflow**

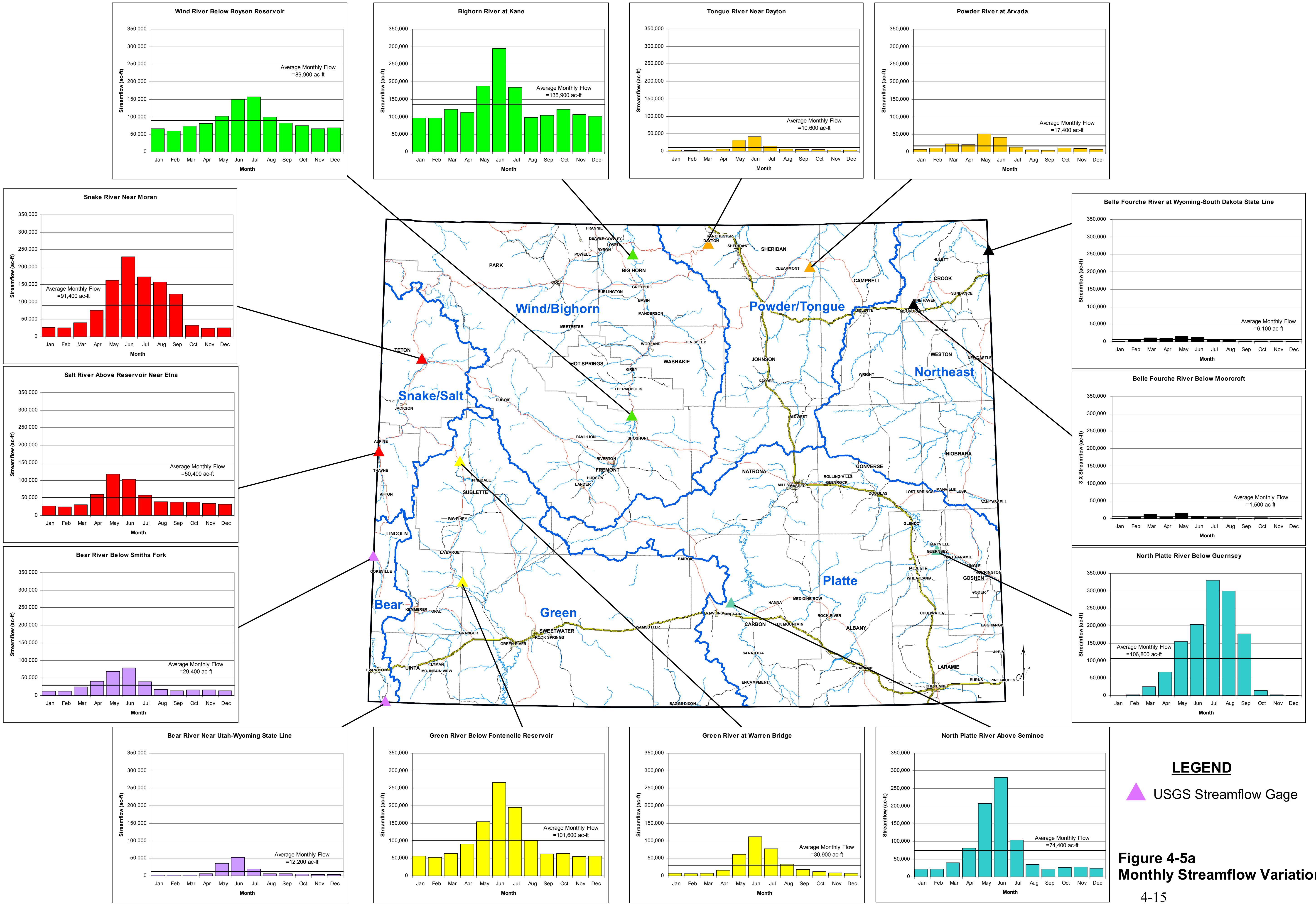



Figure 4-5a
Monthly Streamflow Variation

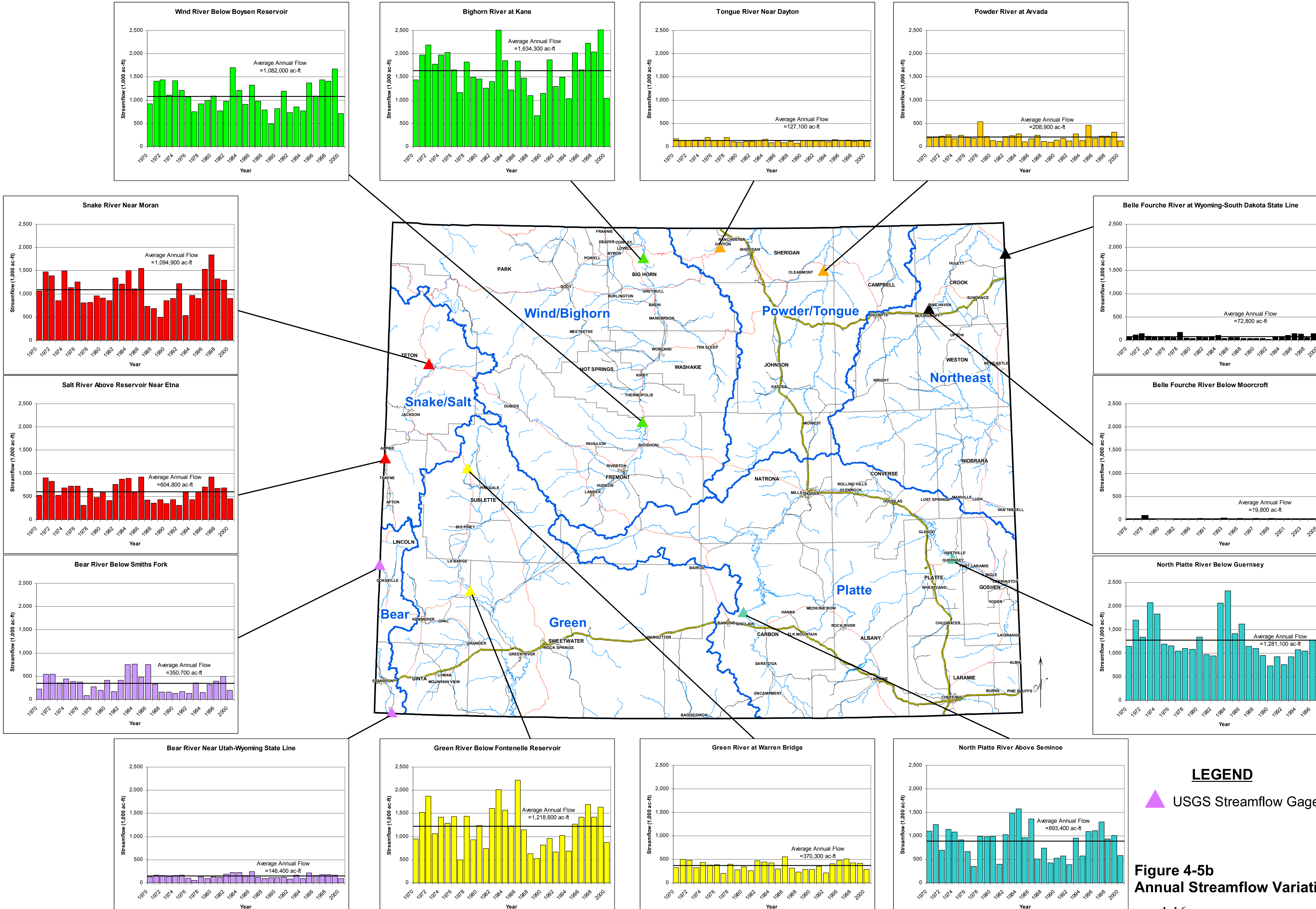
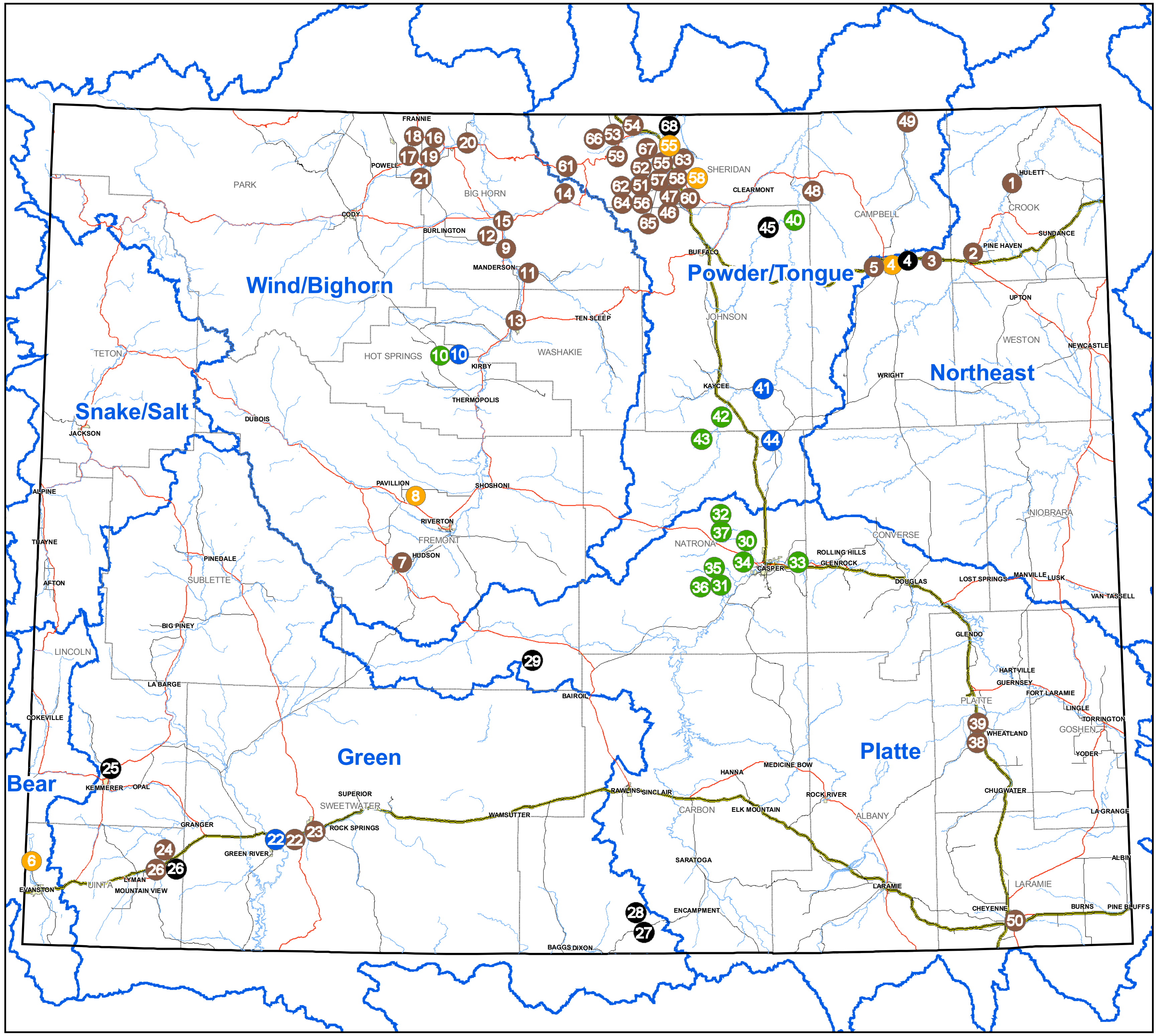



**Figure 4-5b**
**Annual Streamflow Variation**




Source: Wyoming's 2006 305(b) State Water Quality Assessment Report

## LEGEND

Fecal Coliform · Selenium · Sediment/Siltation · Chloride · Other (Phosphate, pH, Habitat, Metals, Oil, Ammonia, and Temp)

N

| Map Number | Name | Location |
|---|---|---|
| 1 | BELLE FOURCHE RIVER | Exceedences measured between Arch Ck and Hulett. |
| 2 | BELLE FOURCHE RIVER | From Keyhole Reservoir upstream an undetermined distance above Rush Ck. |
| 3 | DONKEY CREEK | From confluence with Belle Fourche R upstream to an undetermined distance above Antelope Butte Ck. |
| 4 | GILLETTE FISHING LAKE | Gillette Fishing Lake. |
| 4 | GILLETTE FISHING LAKE | Gillette Fishing Lake. |
| 5 | STONEPILE CREEK | From confluence with Donkey Creek upstream an undetermined distance. |
| 6 | BEAR RIVER | From Woodruff Narrows Reservoir up to Sulphur Creek. |
| 7 | MIDDLE FORK POPO AGIE RIVER | Undetermined distances upstream and downstream of City of Lander. |
| 8 | OCEAN LAKE | Ocean Lake. |
| 9 | BIGHORN RIVER | From Greybull R upstream to Nowood R. |
| 10 | COTTONWOOD CREEK | From Bighorn River up to Hamilton Dome Oil Field. |
| 10 | COTTONWOOD CREEK | From Bighorn River up to Hamilton Dome Oil Field. |
| 11 | NOWOOD RIVER | From confluence with Bighorn R upstream an undetermined distance. |
| 12 | GREYBULL RIVER | From confluence with Bighorn R upstream to the Sheets Flat bridge. |
| 13 | BIGHORN RIVER | From Greybull R downstream undetermined distance above Big Horn Lake. |
| 14 | GRANITE CREEK | From confluence with Shell Ck upstream approximately 4 miles to an undetermined point near Antelope Butte Ski Area. |
| 15 | SHELL CREEK | From confluence with Bighorn R upstream an undetermined distance. |
| 16 | BIG WASH | From confluence with Sage Ck upstream to Sidon Canal. |
| 17 | BITTER CREEK | From Shoshone R up an undetermined distance above Powell. |
| 18 | POLECAT CREEK | From confluence with Sage Ck upstream an undetermined distance. |
| 19 | SAGE CREEK | From confluence with Shoshone R upstream an undetermined distance above Big Wash. |
| 20 | SHOSHONE RIVER | From confluence with Bighorn Lake upstream an undetermined distance. |
| 21 | WHISTLE CREEK | From confluence with Shoshone R upstream an undetermined distance. |
| 22 | BITTER CREEK | From Green R up to Killpecker Ck. |
| 22 | BITTER CREEK | From Green R up to Killpecker Ck. |
| 23 | KILLPECKER CREEK | Near Rock Springs, tributary to Bitter Ck. |
| 24 | BLACKS FK GREEN RIVER | From confluence w/ Hams Fk upstream to an undetermined distance above Smiths Fork. |
| 25 | HAMS FORK GREEN RIVER | Exceedences measured at Diamondville. |
| 26 | SMITHS FORK GREEN RIVER | From confluence with Blacks Fork past Cottonwood Ck. |
| 26 | SMITHS FORK GREEN RIVER | From confluence with Blacks Fork an undetermined distance upstream. |
| 27 | BATTLE CREEK WEST FORK | From Battle Cr to Haggarty Ck. |
| 28 | HAGGARTY CREEK | From Ferris-Haggarty Mine to W. Fk. Battle Ck. |
| 28 | HAGGARTY CREEK | From Ferris-Haggarty Mine to W. Fk. Battle Ck. |
| 28 | HAGGARTY CREEK | From Ferris-Haggarty Mine to W. Fk. Battle Ck. |
| 29 | CROOKS CREEK | From SW NE S18 T28N R92W undetermined distance downstream. |
| 30 | CASPER CREEK | In Kendrick Reclamation Project below Casper Canal. |
| 31 | GOOSE LAKE | In Kendrick Reclamation Project. |
| 32 | ILLCO POND | S13 T35N R81W. |
| 33 | NORTH PLATTE RIVER | Exceedences measured at Casper. Impairment extends undetermined distance upstream and downstream. |
| 34 | OREGON TRAIL DRAIN | In Kendrick Reclamation Project. |
| 35 | POISON SPIDER CREEK | In and above Kendrick Reclamation Project. |
| 35 | POISON SPRING CREEK | In Kendrick Reclamation Project below Casper Canal. |
| 36 | RASMUS LEE LAKE | In Kendrick Reclamation Project. |
| 37 | THIRTYTHREE MILE RESERVOIR | On South Fork Casper Ck in Kendrick Reclamation Project. |
| 38 | ROCK CREEK | Above Town of Wheatland. |
| 39 | WHEATLAND CREEK | Impairment undetermined distance above and below Hwy 320. |
| 40 | POWDER RIVER | From S Fk Powder R downstream to the confluence with Crazy Woman Creek. |
| 41 | POWDER RIVER | From Salt Ck downstream to the confluence with Clear Creek. |
| 42 | SOUTH FORK POWDER RIVER | From confluence with Middle Fork upstream an undetermined distance above Willow Creek |
| 43 | WILLOW CREEK | From confluence with South Fork Powder R to an undetermined distance upstream. |
| 44 | SALT CREEK | From Powder R to an undetermined distance upstream. |
| 45 | CRAZY WOMAN CREEK | From Powder R to an undetermined distance upstream. |
| 46 | DALTON DITCH | Within and near Town of Story. |
| 47 | NORTH PINEY CREEK | Confluence with South Piney Creek upstream to an undetermined locationbelow SWNW S12, T53N, R84W. |
| 48 | MIDDLE PRONG WILD HORSE CREEK | Confluence with Wild Horse Creek upstream an undetermined distance. |
| 49 | LITTLE POWDER RIVER | Wyoming/Montana state line upstream an undetermined distance above Olmstead Creek |
| 50 | CROW CREEK | Impairment undetermined distance above and below Cheyenne. |
| 50 | CROW CREEK | Impairment undetermined distance above and below Cheyenne. |
| 51 | BEAVER CREEK | From Big Goose Ck to an undetermined distance upstream. |
| 52 | BIG GOOSE CREEK | From Sheridan to above Beckton. |
| 53 | COLUMBUS CREEK | From confluence with Tongue River an undetermined distance above Highway 14. |
| 54 | FIVE MILE CREEK | From confluence with Tongue River an undetermined distance above Ranchester. |
| 55 | GOOSE CREEK | From confluence of Big and Little Goose Creeks an undetermined distance downstream. |
| 55 | GOOSE CREEK | Within City of Sheridan. |
| 56 | JACKSON CREEK | From Little Goose Ck to an undetermined distance upstream. |
| 57 | KRUSE CREEK | From Little Goose Ck to an undetermined distance upstream. |
| 58 | LITTLE GOOSE CREEK | From Sheridan upstream to above Big Horn. |
| 58 | LITTLE GOOSE CREEK | Within City of Sheridan. |
| 59 | LITTLE TONGUE RIVER | From confluence with Tongue River an undetermined distance above Dayton. |
| 60 | McCORMICK CREEK | From Little Goose Ck to an undetermined distance upstream. |
| 61 | NORTH TONGUE RIVER | From confluence of Bull Creek upstream an undetermined distance above Hwy14A. |
| 62 | PARK CREEK | From Big Goose Ck to an undetermined distance upstream. |
| 63 | PRAIRIE DOG CREEK | Entire Prairie Dog Creek Drainage. |
| 63 | PRAIRIE DOG CREEK | From Tongue R to an undetermined distance upstream. |
| 64 | RAPID CREEK | From Big Goose Ck to an undetermined distance upstream. |
| 65 | SACKET CREEK | From Little Goose Ck to an undetermined distance upstream. |
| 66 | SMITH CREEK | From confluence with Tongue River an undetermined distance above Dayton. |
| 67 | SOLDIER CREEK | From Goose Ck to an undetermined distance upstream. |
| 68 | TONGUE RIVER | From Goose Ck downstream. |

**Figure 4-6**
**2006 303(d) Waters With Water Quality Impairments**

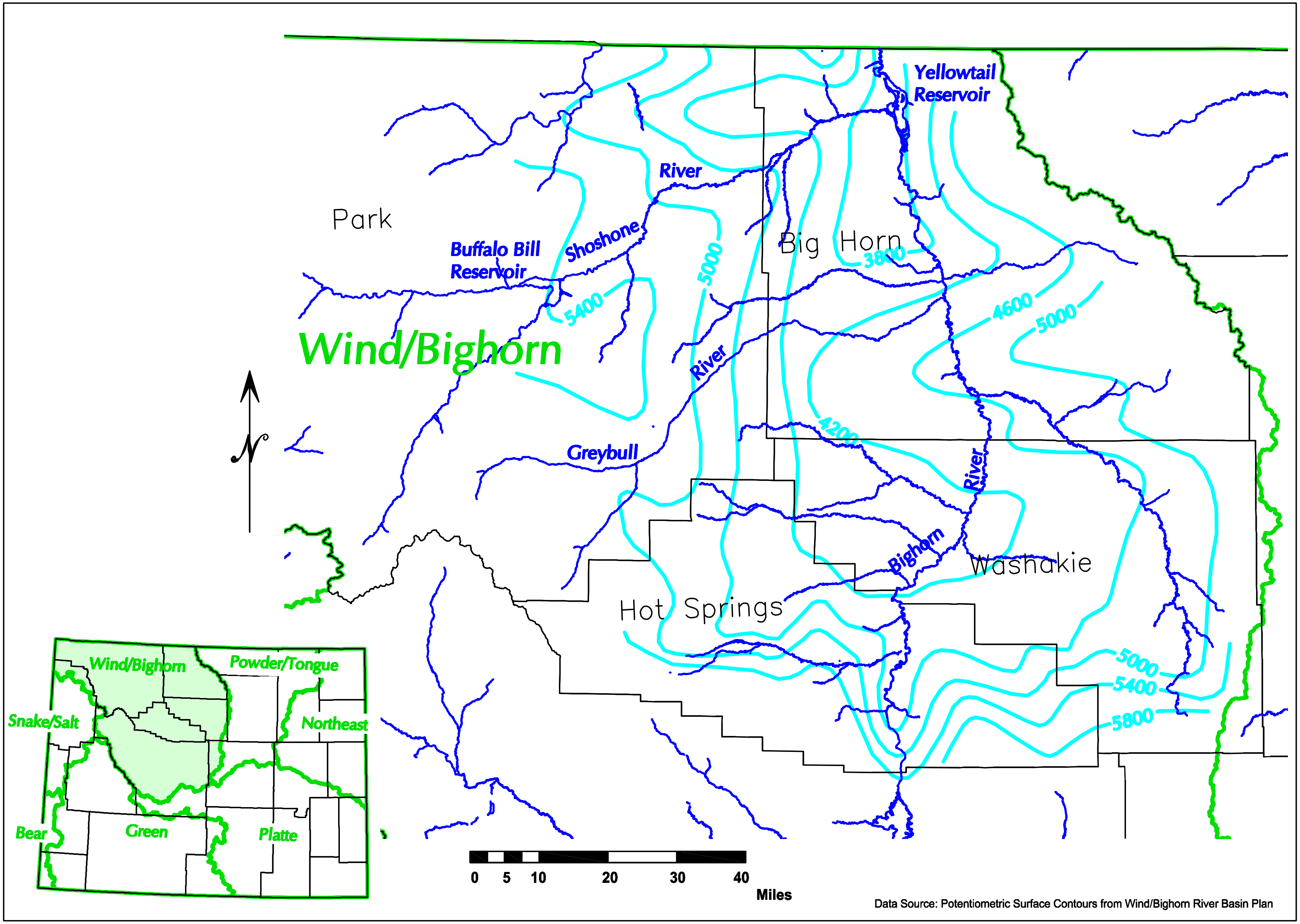



**Figure 4-7**
**Potentiometric Surface of the Tensleep Aquifer in the Bighorn Basin, Wyoming**

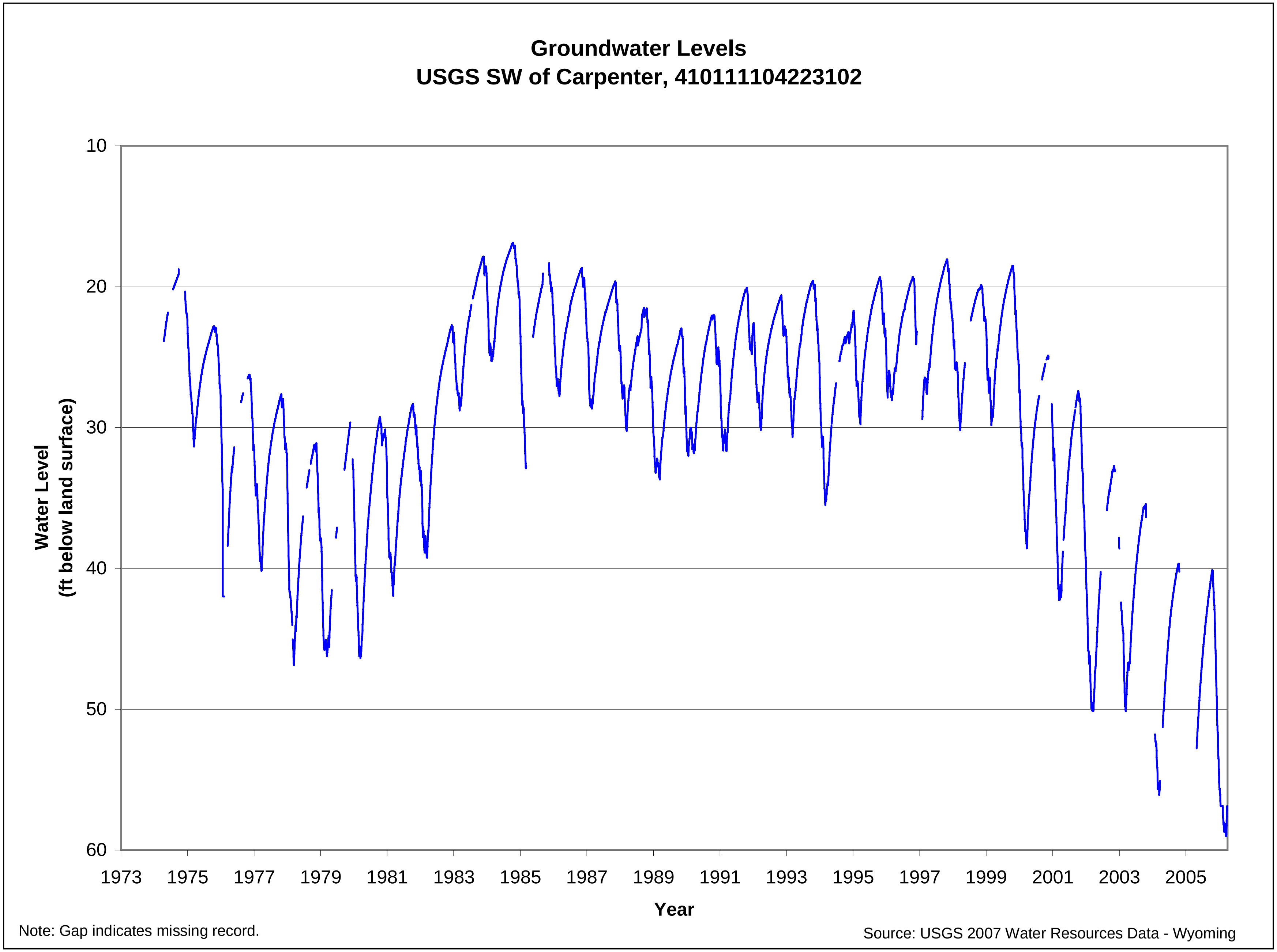



**Figure 4-8**
**Example: Groundwater Hydrograph**

| Formations | Standard Map Symbols[1] | Dominant Lithology | BE | GR | NE | PL | PT | SS | WB |
|---|---|---|---|---|---|---|---|---|---|
| Alluvium | Qa, Qt | sand, gravel, silt, clay | ● | ● | ● | ● | ● | ● | ● |
| Ogallala | Tmu | sandstone, siltstone, gravel | | | | ● | | | |
| Teewinot and Salt Lake | Tte, Tsl | tuff, limestone, claystone | | | | | | ● | |
| Arikaree, North Park, Splitrock | Tmo, Tm, Tmu | sandstone (tuffaceous) | | | ● | ● | | | |
| Bridger, Battle Springs, Fowkes | Tb, Tbs, Tf | sandstone, conglomerate | ● | ● | | | | | |
| Wasatch, Wind River | Tw, Twdr, Twk, Twm, Twmo | siltstone, sandstone, shale | ● | ● | ● | ● | ● | | ● |
| Fort Union - various members | Tfu, Tfl, Tflt, Tftr | sandstone, siltstone, coal | | ● | ● | | ● | | |
| Lance | Kl | sandstone, siltstone | | | ● | | ● | | |
| Fox Hills | Kfh, Kfl, Kfb | sandstone, shale | | | ● | | ● | | |
| Mesaverde and related rocks | Kmv, Kav, Kal, Ke, Kr, Kbl | sandstone, shale, coal | ● | ● | | | | | |
| Cloverly/Dakota | KJ, KJs, Kg | sandstone, siltstone | ● | ● | ● | | ● | | |
| Nugget | JTRn | sandstone | ● | ● | | | | ● | |
| Casper, Tensleep, Minnelusa, Hartville | P₱c, P₱cf, P₱h, P₱m, PM, P₱M | sandstone & limestone, shale | ● | ● | ● | ● | ● | ● | ● |
| Madison, Bighorn | Mm, MD, MDO, MDe, MDg, MO, OЄ, Ob, Pzr | limestone, dolomite | ● | ● | ● | ● | ● | ● | ● |
| Flathead | Єr | sandstone | ● | ● | | | | | ● |
| Non-alluvial Deposits | Ql, Qg, QTg, Qls, Qs | landslide debris, glacial deposits | ● | ● | ● | ● | ● | ● | ● |
| Arikaree | Tmo, Tmu | sandstone (tuffaceous) | | | | | ● | | |
| Willwood | Twl | sandstone, siltstone, mudstone | | | | | | | ● |
| Ft Union | Tfu | sandstone, claystone, coal | | | | ● | | | ● |
| Evanston | Tke | conglomerate, sandstone | ● | ● | | | | | |
| Lance, Fox Hills | Kl, Klm | sandstone, shale, siltstone | | ● | | ● | | | ● |
| Medicine Bow | Kmb | sandstone, shale | | | | ● | | | |
| Mesaverde | Kmv | sandstone, shale | | | | ● | ● | | ● |
| Frontier | Kf, Kft | sandstone and shale | ● | ● | | ● | ● | ● | ● |
| Cloverly (Dakota), Morrison | KJ, K , KJs, KJg | sandstone, shale | | | | ● | | | ● |
| Sundance, Nugget and related rocks | Js, Jsg, JTR, JTRn | sandstone, siltstone, gypsum | | | ● | ● | | | ● |
| Twin Creek and Thaynes | JTRnd, Jst | limestone, shale | ● | ● | | | | ● | |
| Spearfish | TRPs | shale, siltstone | | | ● | | | | |
| Phospohoria, Minnekahta | Pp, Pmo, MzPz | limestone, siltstone, sandstone | ● | ● | ● | | | ● | ● |
| Bighorn, Flathead | DO, Єr | dolomite, limestone, shale, sandstone | | | | | | | ● |
| Gallatin, Gros Ventre, Flathead | Єr | limestone, sandstone, shale | | | | ● | ● | | |
| Quaternary Deposits | Qg, Qls, Qs, Qu | sand, gravel, silt, boulders | | | | | | | ● |
| Volcanic rocks | Qb, Qr, Thr, Ti, Tii, Tcv, Tts, Twi, Ttl, Tt, Ts, Ttp, Twp, Taw, Tv | lava flows, mudflows, ash, tuff, breccia | | | | | | ● | ● |
| Camp Davis, Colter, Hoback | Tcd, Tc, Th | conglomerate, mudstone | | | | | | ● | |
| White River | Twr, Twru, Twrb, Twrc | siltstone, claystone | | | ● | ● | ● | | |
| Wagon Bed, Crandall | Twb, Teml, Tcr, TKu | sandstone, siltstone, mudstone | | | | ● | | | ● |
| Hanna | Tha | shale, sandstone, coal | | | | ● | | | |
| Ferris | TKf | sandstone, shale, conglomerate | | | | ● | | | |
| Sohare, Harebell | Kso, Ksb, Kha, Kb | sandstone, shale, siltstone | | | | | | ● | |
| Aspen, Bear River | Ka, Kbr, Kg | shale, sandstone, siltstone | | | | | | ● | |
| Sundance | Js, Jsg | shale | | | | | ● | | |
| Chugwater and related rocks | TRc, JTRgc, J TRgn, TRcd, TRPcg, TRPg | siltstone, sandstone, gypsum | | | | | | | ● |
| Woodside and Dinwoody | J TRad, TRcd | siltstone, shale | ● | ● | | | | ● | |
| Amsden | P₱Ma, P₱M | shale | | | | | | | ● |
| Indian Meadows | Tim | claystone | | | | | | | ● |
| Meetsetse and Lewis | Km, Kle, Kml | siltstone, claystone, shale | ● | ● | | | ● | | ● |
| Cody, Pierre, Steele, Niobrara, Baxter, Carlisle | Kc, Kp, Ks, Kn, Knc, Kcl, Kgb, Kgbm, Kh, Kba | shale | ● | ● | ● | ● | ● | ● | ● |
| Thermopolis, Mowry, Aspen | Kmt, KJk, Kmr, Kgb, Kgbm, Kns, Ka, Kbr | shale | ● | ● | ● | ● | ● | | ● |
| Chugwater, Goose Egg | TRc, TRcd, TRPs, TRPcg, TRPg | siltstone, sandstone, gypsum | | | | ● | ● | | |
| Precambrian rocks | | granite, gneiss, schist | ● | ● | ● | ● | ● | ● | ● |

[1] Map symbols for the Geologic Map of Wyoming (Love and Christiansen, 1985)

[2] BE - Bear; GR - Green; NE - Northeast Wyoming; PL - Platte; PT - Powder/Tongue; SS - Snake/Salt; WB - Wind/Bighorn

## LEGEND

- Major Aquifer - Alluvial
- Major Aquifer - Sandstone
- Major Aquifer - Limestone
- Unclassified
- Minor Aquifer
- Marginal Aquifer
- Major Aquitard

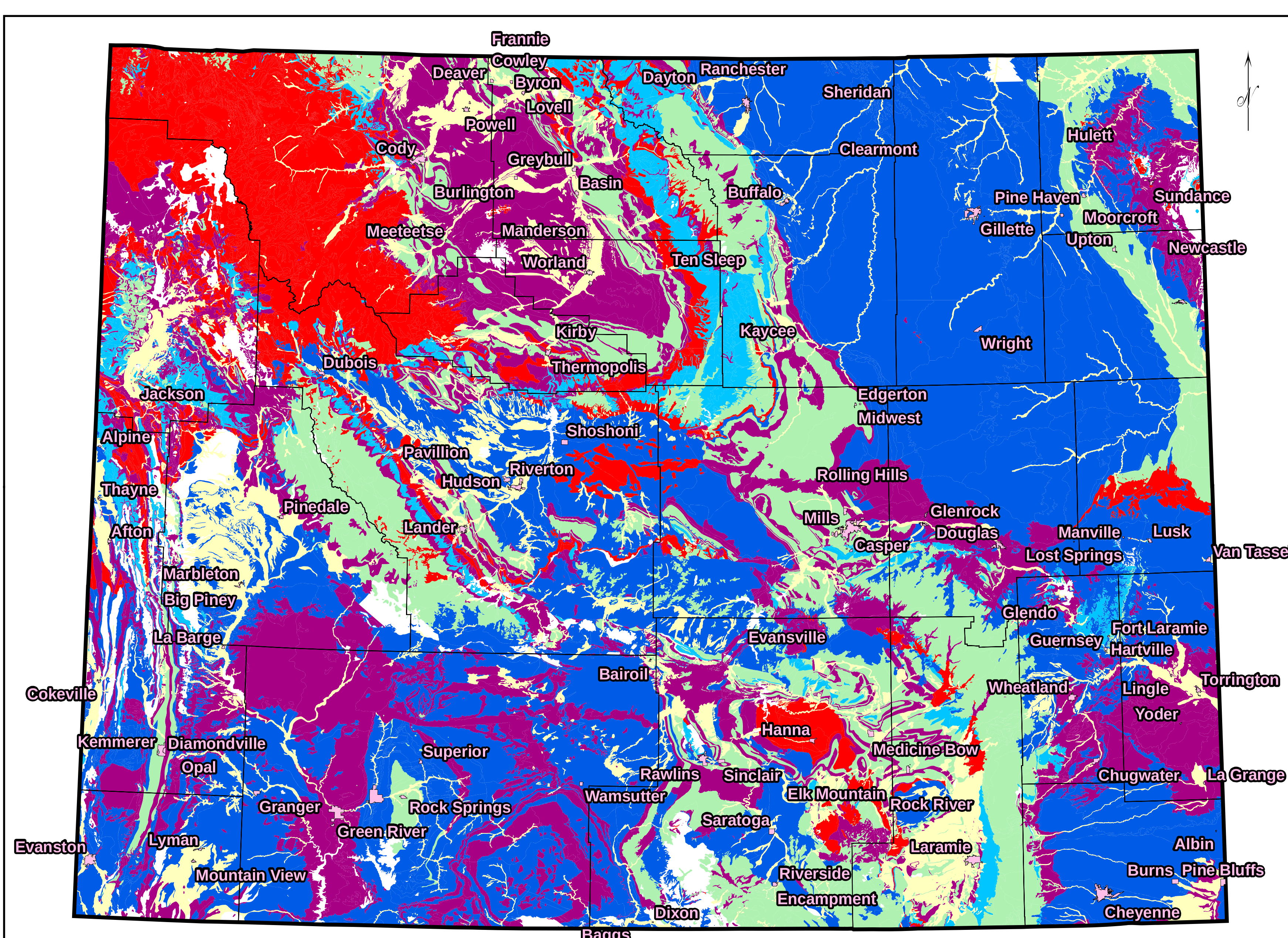
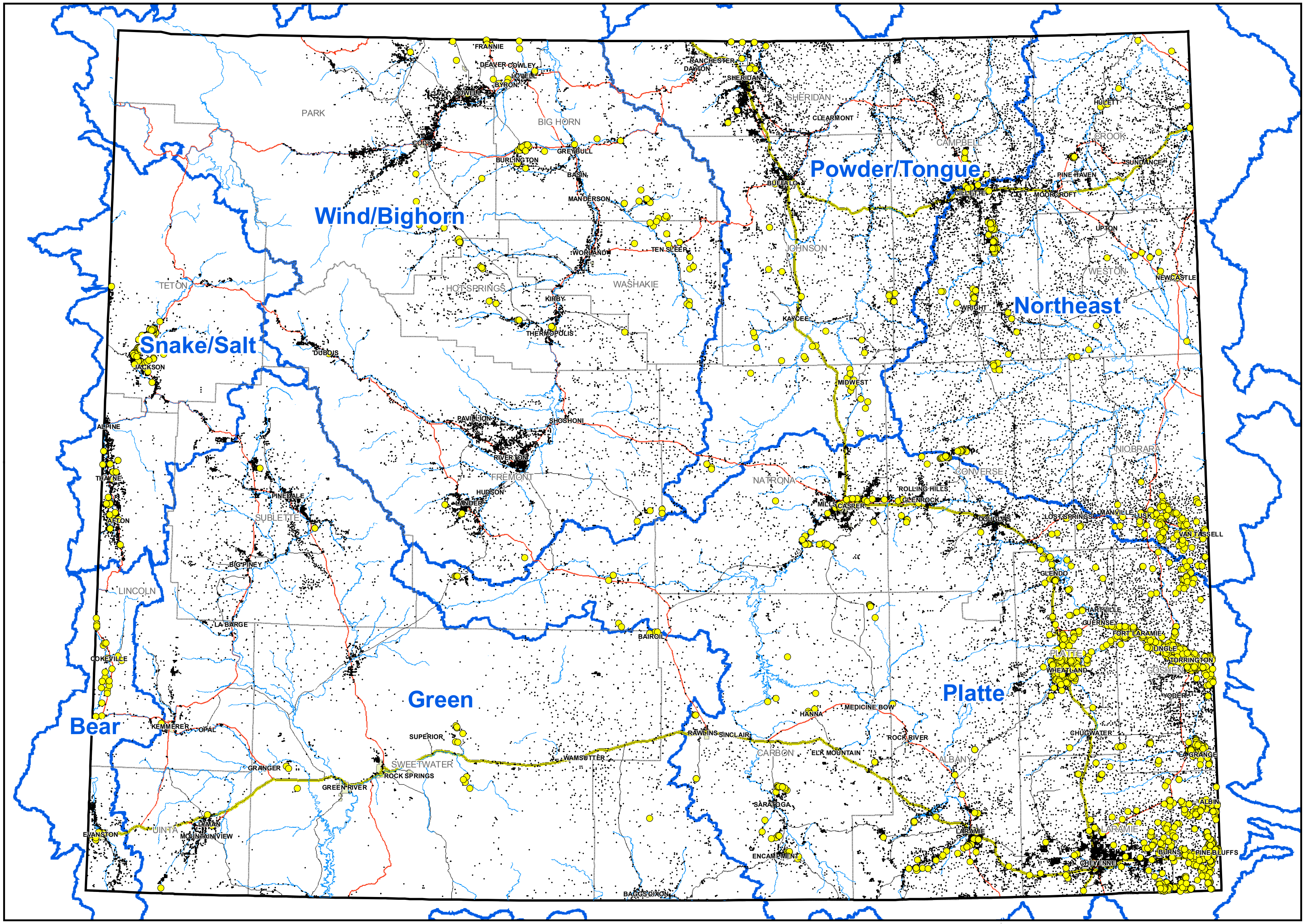



Figure 4-9
Hydrogeology Map




LEGEND
- • Active Well
- ○ Active Well, > 500 gpm

Source: Wyoming State Engineer's Office GIS files compiled June 2006

**Figure 4-10**
**Active Wells**

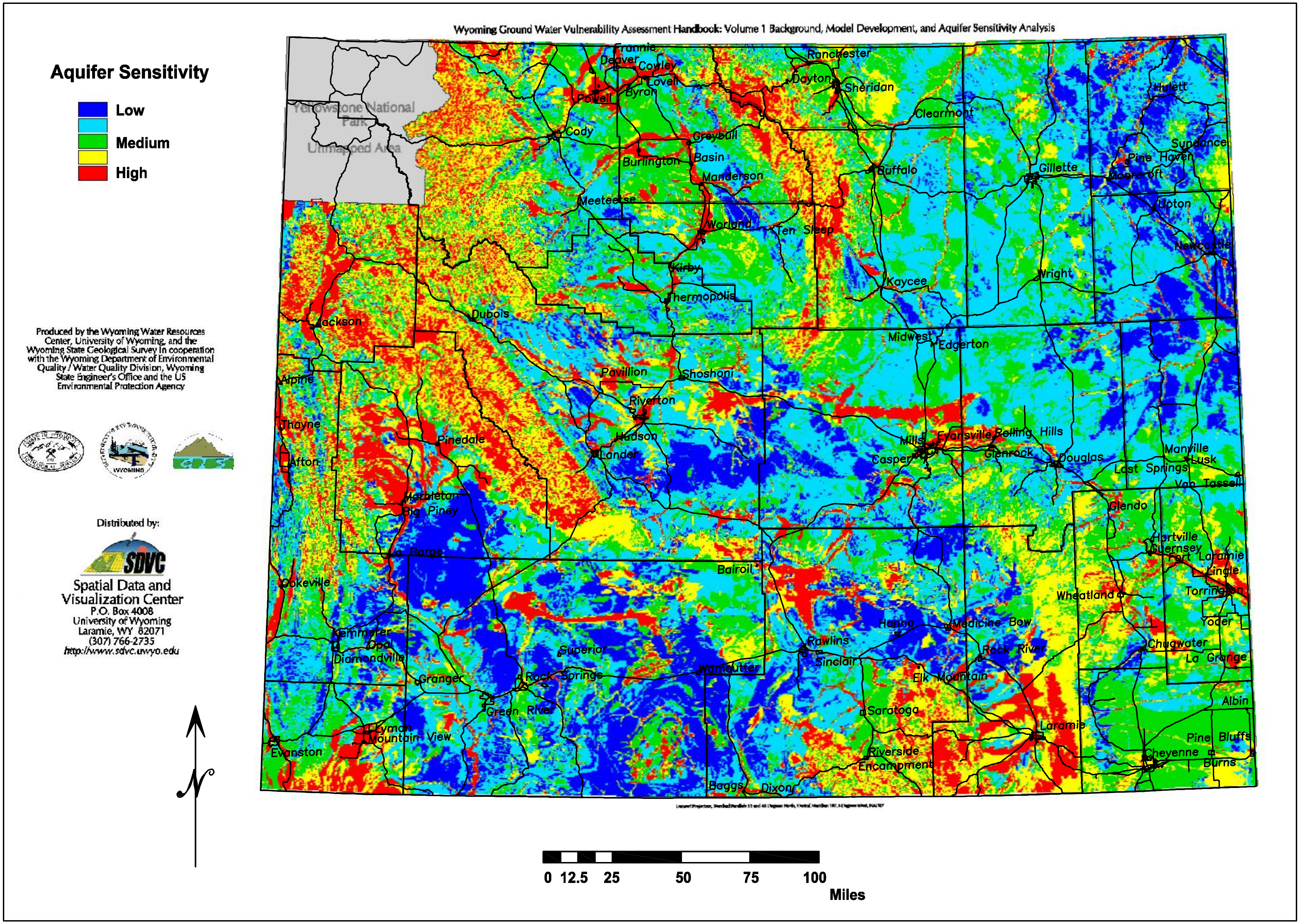
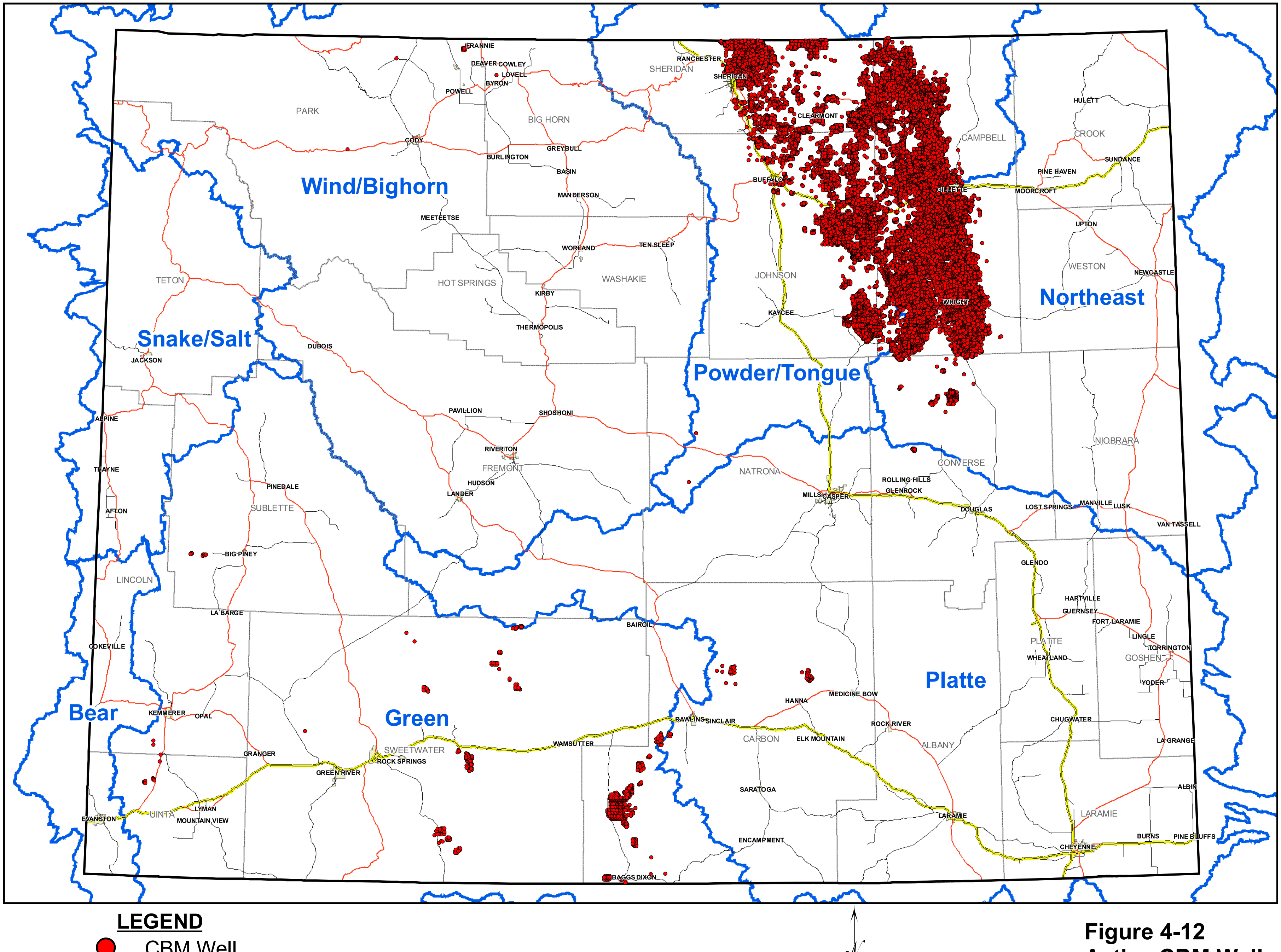



**Figure 4-11**
**Aquifer Sensitivity**




Source: Wyoming State Engineer''s Office GIS files compiled June 2006.

**Figure 4-12**
**Active CBM Wells**

# 5.0 USE

## 5.1 INTRODUCTION

This chapter presents an inventory of water use and existing water development projects in Wyoming. The purpose of this chapter is to provide the necessary understanding of the location, source, and quantity of water use. This existing water use profile is the basis for the subsequent sections in the report. State water use was determined for the following water use sectors, which combined define the total water consumed or lost due to human influence in the state:

- Agricultural use
- Municipal and domestic use
- Industrial use
- Recreational use
- Environmental use
- Evaporation

## 5.2 AGRICULTURAL WATER USE

### 5.2.1 Introduction

This section discusses agricultural water use in each of the seven basins in Wyoming. Agricultural water use, specifically crop consumptive use through irrigation, accounts for the vast majority of water consumption (depletions) in Wyoming.

### 5.2.2 Agricultural Water Use Methodology

In general, the steps listed below were followed (directly or indirectly) in the seven basin plans to estimate the agricultural consumptive use (depletion) of water (CU). More details on certain aspects of these steps are discussed in subsequent sections.

- Determine irrigated acreage (5.2.3).
- Identify and document information for key diversion structures, including crop types, irrigation practices, and general operations (5.2.4).
- Determine supply source for irrigated acreage (5.2.5).
- Calculate potential crop consumptive use (evapotranspiration) and irrigation water requirements, and determine effective precipitation (5.2.6).
- Calculate water supply: limited, or actual, crop consumptive use or depletion (5.2.7).
- Estimate livestock consumptive use (5.2.8).

Several of the above-mentioned terms have been broadly used in other studies. The definitions used in each of the basin plans are generally consistent; are consistent with *Evapotranspiration and Irrigation Water Requirements* (ASCE, 1990); and are stated as follows:

- **Evapotranspiration:** The total amount of water that would be used for crop growth if there was an ample water supply; also called potential consumptive use.
- **Effective Precipitation**: The portion of precipitation that is available to meet the evapotranspiration requirements of the crop.
- **Irrigation Water Requirement:** The amount of water exclusive of precipitation that is required from surface or groundwater diversions to fully meet crop consumptive use. Calculated as evapotranspiration less effective precipitation. Also called consumptive irrigation requirement (CIR).
- **Supply-Limited Consumptive Use:** The amount of water actually used by the crop, limited by water availability. Also called depletion.

The seven basin plans vary in their terminology regarding crop irrigation requirement, consumptive irrigation requirement, and irrigation water requirement, although the meanings are the same. For this report, we use "irrigation water requirement", which is consistent with ASCE Manual No. 70 (ASCE, 1990).

### 5.2.3 Irrigated Acreage

The majority of the appropriated water in the state's seven river basins has been appropriated for irrigation. Therefore, an estimate of the amount of water used for irrigation is central in the development of a comprehensive state water use inventory. The first step in estimating irrigation water consumption is to estimate irrigated acreage. Figure 5-1 shows irrigated lands by river basin in Wyoming.

Table 5-1 shows that 1,947,100 acres of Wyoming land are irrigated and provides a comparison to the irrigated acreage by basin determined in the 1973 Framework Plan. Generally, the current figure includes groundwater, man-induced subirrigation, idle lands, and man-made riparian acres, as described in the different basin plans. The total figure does not include Tribal Futures Projects (52,667 acres) in the Wind/Bighorn Basin awarded to the Wind River Indian Reservation. However, the Tribal Futures Projects lands have an 1868 priority and play an important role in determining potential water use in that basin (see discussion in Chapter 6).

**Table 5-1 Irrigated Acreage**

| River Basin | 1973 Total | Current Irrigated Lands[2] | | |
|---|---|---|---|---|
| | | Total | Surface Water | Groundwater |
| | acres | | | |
| Bear | 59,000 | 64,000 | --- | --- |
| Green[3] | 332,000 | 331,100 | 330,980 | 120 |
| Northeast Wyoming[3] | 161,000 | 77,600 | 59,600 | 18,000 |
| Platte | 553,000 | 613,000 | --- | --- |
| Powder/Tongue[3] | See Note 1 | 161,400 | 161,180 | 220 |
| Snake/Salt | 94,000 | 99,000 | --- | --- |
| Wind/Bighorn[4] | 539,000 | 601,000 | --- | --- |
| **Total** | **1,738,000** | **1,961,000** | **---** | **---** |

[1] In the 1973 Framework Plan, Powder/Tongue Basin is included in Northeast Wyoming Basin. Also, the 1973 Wind/Bighorn Basin included the Little Bighorn subbasin, but the Little Bighorn is in the 2002 Powder/Tongue Basin.

[2] Current irrigated acreage listed for primary source of supply. Idle lands identified in the Northeast Wyoming and Powder/Tongue basins are not included.

[3] Only Green, Northeast, and Powder/Tongue River Basin Plans distinguished between surface water and groundwater irrigated acreage.

[4] Current Wind/Bighorn figure is modeled irrigated acreage for full-supply scenario and does not include Popo Agie Basin or Tribal Futures Projects.

The nearly 2 million total irrigated acres are approximately 225,000 acres more than was estimated in 1973, a 13 percent increase. The increase came from the Northeast Wyoming, Platte, Powder/Tongue, and Wind/Bighorn River Basins, which, combined, accounted for approximately 217,000 acres of the total increase.

The large increase in irrigated acreage over the past 30 years may be due to one or more reasons, including 1) new permitted, surface water irrigated acreage (likely to be a small percentage); 2) an increase in already permitted, surface water irrigated acreage (some lands with permitted surface water rights have not been irrigated but still have valid water rights and may be irrigated); 3) a substantial increase in groundwater irrigated acreage (new lands that were irrigated with groundwater which were previously not irrigable by surface water sources); and 4) inconsistent accounting of irrigated acreage between the 1973 Framework Plan and the recent basin plans (a different accounting of recently irrigated, idle, subirrigated, etc. lands).

### 5.2.4 Irrigated Crops

Another essential part of estimating the amount of water used for irrigation is the irrigated crop distribution. Crop evapotranspiration (ET), irrigation water requirements (IWR), and irrigation methods can vary by crop type. An accurate assessment of crop distribution is important in the modeling of consumptive uses and in valuing the agricultural sector dependent on those crops.

Various combinations of data sources and methodologies were used to obtain the best estimates of crop distribution within each basin: interviews with local water users and administrators (such as extension agency); producer reports (irrigation district data); stereo aerial photography, U.S. Department of Agriculture (USDA) agencies (Service Center, Natural Resources Conservation Service [NRCS], National Agricultural Statistics Service [NASS], and Census of Agriculture); and field verification. Consistency of data sources or methodology is not essential when estimating irrigated crop types, but it is important to have the best available data. See individual basin plans for more details.

Table 5-2 shows a summation of the current estimated active crop distribution percentage and irrigated acreage. Alfalfa, hay, and pasture are the most abundant crops in the state, accounting for approximately 1,528,000 acres or 79 percent of all the crops in the state. Row crops make up about 12 percent, while small grains account for nearly 10 percent of the active crops grown in the state. Although they are not accounted for in the individual basin plans, NASS provides statistics on “Field and Misc Crops” grown in Wyoming. Between 2000 and 2006, there were between 1,400 and 1,700 acres (an insignificant amount) of these crops grown. NASS does not include names of specific crops, but this category may include crops such as sorghum, sunflowers, Christmas trees, pumpkins, and other vegetables.

**Table 5-2 1973 Versus Current Active Crop Distribution**

| River Basin | Active Irrigated Lands | Grass/ Pasture[1] | Alfalfa | Corn | Sugar Beets | Beans | Small Grains[2] |
|---|---|---|---|---|---|---|---|
| | acres[3] | | | | | | |
| Bear | 64,000 | 59,000 | 5,000 | | | | |
| Green[4] | 331,100 | 298,000 | 31,000 | 100 | | | 2,000 |
| Northeast Wyoming[5] | 77,600 | 53,000 | 21,000 | 600 | | | 3,000 |
| Platte | 613,000 | 368,000 | 137,000 | 43,000 | 21,000 | 19,000 | 25,000 |
| Powder/Tongue[5] | 161,400 | 49,000 | 93,000 | 6,000 | | | 13,400 |
| Snake/Salt[5] | 99,000 | 46,000 | 37,000 | | | | 16,000 |
| Wind/Bighorn | 601,000 | 70,000 | 261,000 | 33,000 | 78,000 | 34,000 | 125,000 |
| **Current Total** | **1,947,100** | **943,000** | **585,000** | **82,700** | **99,000** | **53,000** | **184,400** |
| **1973 Framework[6]** | **1,622,000** | **964,000** | **369,000** | **59,000** | **63,000** | **33,000** | **125,000** |

[1] Grass/Pasture category includes any kind of grass or hay (wild, native, tame, other; excluding alfalfa), mountain meadow, and pasture.

[2] Small Grains category contains winter wheat, spring wheat, barley, and oats.

[3] Above crops aggregated for comparisons; all current basin plans did not distinguish based on identical crop types.

[4] Green River Basin Plan reported irrigated crop acreage for some of the subbasins; percent distribution for most; corn and grains acreage taken from subbasins for which they were reported; other subbasins reported no corn or grain; basin distribution was estimated.

[5] Only Northeast Wyoming, Powder/Tongue, and Snake/Salt Basin Plans reported irrigated crop acreage; other acreages calculated from crop distribution percentages from individual basin plans.

[6] 1973 Framework Plan included potatoes and other categories.

Table 5-2 shows that the Bear River basin grows forage crops exclusively and the Green River basin grows forage crops nearly exclusively (99.4 percent). Northeast Wyoming, Powder/Tongue, and Snake/Salt River Basins grow 95, 88, and 84 percent forage crops, respectively, with some corn and/or small grains.

In the Platte River Basin, 82 percent of all crops are forage crops. The bulk of that is grown upstream of Guernsey Reservoir (located on the North Platte River), along the Sweetwater River, above Pathfinder Reservoir, and in the Upper Laramie subbasin. Downstream of Guernsey Reservoir, in the Lingle and Torrington area, and in the Wheatland area, is where most of the row crops of corn, sugar beets, and beans are grown. Row crops make up about 13 percent of the crop distribution in the basin. In the Wind/Bighorn River Basin, forage crops account for about 55 percent and small grains about 21 percent of the crops grown in the basin. Row crops make up a significant portion (24 percent) of the crop distribution in this basin, and are found mostly in the Cody/Powell, Worland, Thermopolis, and Riverton/Lander valleys.

Table 5-2 compares the statewide irrigated crop distribution from the 1973 Framework Plan to that from the current seven basin plans. All irrigated crop types reported in the current basin plans show increases in irrigated acreage and percent of crop distribution with the exception of grass/pasture. It appears that there has been a shift away from grass/pasture to more alfalfa, row crops, and small grains, which may be due, in large part, to the substantial increase in groundwater irrigation over the last 30 years. However, fluctuations in statewide crop distribution occur annually (even if on a small scale) and over many years, and from the snapshot data available in the basin plans, one cannot automatically detect trends in statewide crop distribution. Furthermore, changes in crop distribution, and thus any trends, tend to occur in the valleys where there are more options for various crops, such as row crops, not in the higher elevation areas where only forage crops can be grown. Crop distribution changes occur for various reasons, including 1) water supply, 2) commodity prices and expenditures, and 3) labor costs and/or intensity. Due to climatic and geographic conditions, and Wyoming's livestock production, forage crops will almost certainly continue to be the most extensive crops grown in the state in the future.

### 5.2.5 Diversions

*Surface Water*

Diversion records throughout the state of Wyoming are sparse. In none of the basins is every diversion continuously recorded. In order to quantify irrigation depletions, each stream segment or tributary where irrigation occurs would have continuous records of diversions and streamflow for a period of 10 or 20 years (including dry, low streamflow and wet, high streamflow years); local weather stations to accurately measure precipitation; and lysimeter (consumptive use) data obtained contemporaneously with the streamflow and diversion records. For obvious economic and practical reasons, such is not the case in Wyoming.

Estimates are necessarily made from incomplete records and sometimes inconsistent data. It is not uncommon in various basins to find only a small percentage of diversions with well-maintained measuring devices and/or prolonged periods of records. For instance, the Green River Basin Plan reported, "less than ten percent of the irrigation canals in the basin had diversion records of sufficient duration and detail to be of value in this analysis". The Northeast Wyoming River Basin Plan stated, "Unfortunately, there is very little available data on historical diversions in the Northeast Wyoming River Basins planning area. Diversion records are available only for the Murray Ditch on Redwater Creek and much of this irrigation is located in South Dakota, outside the limits of this planning study." The Northeast Basin Plan used the relationships between theoretical and actual water use based on diversion records from the neighboring Powder/Tongue River Basin Plan.

On the other hand, the Bear River Basin Plan reported, "The Bear River Basin, because it encompasses parts of three states and is governed by an interstate river commission, has excellent data records. Records of streamflow and diversions are well maintained and extensive." For the Bear River Basin, complete daily diversion records in Wyoming were obtained for the 36 key ditch systems from the Compact Engineer-Manager for 1971 through 1999.

Lack of diversion data is indicative of the relative lack of regulation of diversions. Examples of diversion issues that required consideration in the individual basin plans include:

- An inadequate percentage of the irrigation canals in the basin had diversion records of sufficient duration and detail to be of value in the analysis.
- Interviews regarding irrigation operations were very instructive and valuable. However, based on responses from districts and individual irrigators, a minority of the basin's irrigated acres were represented in this effort.
- Diversion records can be misleading. Some canals provide very detailed and extensive historical diversion records and show virtually uninterrupted flow throughout recent irrigation seasons. Basing irrigation supply characteristics on the records of these ditches would significantly overestimate diversions (and hence IWR) in a whole basin because they do not represent other headgates that routinely run out of water by early July. In addition, although measuring devices show flow at all times, records may not show when turnouts are closed for haying resulting in at least part of that water returning to the river. Therefore, subjective interpretation was required when reviewing the records to estimate when water diverted is actually applied to crops.
- Diversion records can also show widely varying operation that appears independent of "wet" and "dry" years. For instance, average diversions through a canal are higher in a generally "dry" year than in a "wet" year. In other words, one cannot always tell by diversion records whether a particular year was considered "wet", "dry", or "normal."
- Reservoir releases exist but are difficult to quantify. Many reservoirs permitted for irrigation are not monitored regularly for content or releases. The effect of many reservoirs, if paper evidence is sought, is in the diversion records of headgates downstream, where irrigation can occur longer with the reservoir than without. Of course, this requires that the headgate records be kept as well.

From the foregoing, assumptions were necessary regarding primarily the number of days diversions were in use. These assumptions, however, were made with the input of irrigators and State Engineer's Office (SEO) personnel for those ditches with which they were familiar. Table 5-3 shows basinwide, estimated, average, annual, historical diversions for each basin. Based on the acre-foot/acre calculations, the Wind/Bighorn River Basin enjoys the most ample water supply.

**Table 5-3 Estimated Average Annual Irrigation Surface Water Diversions**

| River Basin | Historical Diversions | | | | | | Theoretical Diversions | |
|---|---|---|---|---|---|---|---|---|
| | Wet | Normal | Dry | Overall Average[1] | Surface Irrigated | Overall Unit Average | Maximum Diversions | Unit Maximum Diversions |
| | ac-ft | | | | acres | ac-ft/ac | ac-ft | ac-ft/ac |
| Bear[2] | | | | 295,000 | 64,000 | 4.61 | 303,000 | 4.74 |
| Green[2,3] | | | | 1,011,000 | 330,000 | 3.06 | 1,394,000 | 4.22 |
| Northeast Wyoming[5] | 153,000 | 152,000 | 152,000 | 152,000 | 64,000 | 2.38 | 258,000 | 4.03 |
| Platte[4] | | | | 1,553,000 | 612,000 | 2.54 | 1,860,000 | 3.04 |
| Powder/Tongue[5] | 397,000 | 349,000 | 388,000 | 349,000 | 161,000 | 2.17 | 594,000 | 3.69 |
| Snake/Salt[2] | | | | 363,000 | 99,000 | 3.67 | 448,000 | 4.52 |
| Wind/Bighorn[5] | 3,028,000 | 3,148,000 | 2,324,000 | 3,166,000 | 600,000 | 5.28 | 3,278,000 | 5.46 |
| **Total** | | | | **6,889,000** | **1,930,000** | **3.57** | **8,135,000** | **4.21** |

[1] Overall average in the long-term average for the period of record, and is not the average of the Wet, Normal, and Dry columns.

[2] The Bear, Green, Platte, and Snake/Salt River Basin Plans did not provide normal, dry, and wet year scenarios for diversions.

[3] Green River Basin diversion data were not developed due to lack of data; data here are estimated by dividing the annual consumptive use (depletion) of irrigation water by the estimated overall irrigation efficiency. Green River Basin irrigation efficiency (39.7%) was not reported but calculated as the average of the other six basins, which were calculated by dividing the annual consumptive use by the estimated historical diversions.

[4] Platte River Basin diversions and irrigated acres represent total values, as basin plan did not distinguish between surface water and groundwater.

[5] Only Northeast, Powder/Tongue and Wind/Bighorn River Basin Plans calculated theoretical maximum diversions. Other basin theoretical maximum diversions are estimated by dividing the total irrigation water requirement by the estimated overall irrigation efficiency.

*Groundwater*

Only the Bear River Basin Plan attempted to estimate groundwater diversions (pumping). Thus, groundwater diversions by basin are not reported here. However, Figure 5-2 is provided to show the nearly 3,000 active irrigation wells in the state.

*Theoretical Maximum Diversion Requirement*

Theoretical irrigation water requirement (IWR) of crops advises irrigators on the approximate amount of irrigation water to fully meet crop needs and is, therefore, useful in determining the diversion demand necessary to meet that requirement. Not all of the water diverted for irrigation goes to meeting the IWR; in fact, the IWR oftentimes represents only a minority of the total diversion amount. A significant portion of the diverted flow is lost to seepage from the main conveyance ditch, lateral ditches, field ditches, headgate leakage, evaporative losses from sprinklers, ditch tailwater waste, field wastewater, and deep percolation past the crop root zone. The proportion of water ultimately consumed by the crop compared to the total volume of water diverted from the stream is referred to as the overall efficiency (some refer to this as the “consumptive use fraction”). Using estimated overall irrigation efficiency, one can calculate the theoretical maximum diversion requirement from the theoretical IWR.

Irrigation efficiency typically varies throughout the irrigation season but decreases as the amount of water applied relative to the crop water requirement increases (Cuenca, 1989). For example, overall efficiency would typically be at a minimum during the early irrigation season when water supply from the snowmelt runoff is abundant but crop water requirements are minimal. Conversely, overall efficiency would typically be at a maximum during the summer months (July and August) when water supply is limited, soil moisture is depleted, and crop water requirements are at a maximum.

Table 5-3 shows the estimated theoretical maximum diversion requirements by basin. The theoretical maximum diversion requirement is not the same in wet, normal, and dry hydrologic years and is based on the wetter or drier climatic conditions in a basin. The ideal conditions for maximum IWR are a high, or above average, snowfall/snowmelt producing high streamflow conditions coupled with dry, or below average, precipitation during the growing season. Statewide, average historical diversions are approximately 85 percent of theoretical maximum diversion requirements.

### 5.2.6 Theoretical Irrigation Water Requirement

In the semiarid West, an adequate crop is difficult, if not impossible, to produce by precipitation alone. Application of irrigation water is required to supplement the effective precipitation supply. This section summarizes the theoretical irrigation water requirement of crops as reported in each of the seven basins. The water intake of a crop (consumptive use) depends on crop stage, water availability, and climate factors such as temperature, humidity, solar radiation, and wind speed.

From ET, the irrigation water requirement is estimated by subtracting effective precipitation. As stated above, the IWR of crops informs irrigators how much irrigation water is needed at the field and is useful in determining the amount of water needed from surface water or groundwater sources to meet that IWR. Table 5-4 shows the estimated IWR by basin.

As crops and climate (mainly precipitation) vary across the state, so does the IWR. Alfalfa, pasture, and grass hay require the most water and thus have the highest IWRs in a given area, while small grains and beans use much less water and have a smaller IWR. Figure 3-6 shows the average seasonal IWR for grass across the state and gives the reader a sense of how IWR changes across the state.

### 5.2.7 Water Supply-Limited Consumptive Use of Crops

The IWR represents an estimate of what crops would use given a full water supply, but crops are often grown with less than a full supply. Water availability, timing, canal capacity, efficiency, and labor intensity/costs are some reasons crops receive less than a full supply. Crop yield is often a good indicator of whether a crop is well-watered or not. Table 5-5 shows the current total water supply-limited consumptive use (the amount of water actually consumed by crops) by basin and provides a comparison to the consumptive use estimated in the 1973 Framework Plan. Comparison to Table 5-4 shows that, statewide, CU is approximately 84 percent of IWR.

Current total irrigation water consumption is approximately 2.5 million acre-feet, up nearly 0.2 million acre-feet from that in 1973, but one cannot automatically assume an upward trend has developed in the data from these two time periods. Water consumption fluctuates annually with water availability, irrigated acreage, crop types, climate, etc. It comes as no surprise that the largest consumptive use of water in the state is irrigated crop land, and it will continue to be in the foreseeable future.

**Table 5-4 Estimated Average Annual Irrigation Water Requirement**

| River Basin | Total IWR | Active Irrigated Lands | Unit IWR | Total IWR | | | Unit IWR | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Wet | Normal | Dry | Wet | Normal | Dry |
| | ac-ft | acres | ac-ft/ac | ac-ft | | | ac-ft/ac | | |
| Bear[1] | 97,000 | 64,000 | 1.52 | | | | | | |
| Green | 553,000 | 331,000 | 1.67 | 465,000 | 553,000 | 576,000 | 1.41 | 1.67 | 1.74 |
| Northeast | 103,000 | 77,000 | 1.33 | 95,000 | 103,000 | 126,000 | 1.23 | 1.34 | 1.64 |
| Platte[2] | 658,000 | 612,000 | 1.08 | | | | | | |
| Powder/Tongue | 238,000 | 161,000 | 1.47 | 217,000 | 238,000 | 289,000 | 1.35 | 1.48 | 1.80 |
| Snake/Salt | 126,000 | 99,000 | 1.27 | 122,000 | 126,000 | 132,000 | 1.23 | 1.27 | 1.33 |
| Wind/Bighorn[1] | 1,165,000 | 600,000 | 1.94 | | | | | | |
| **Total** | **2,940,000** | **1,944,000** | **1.47**[3] | | | | | | |

[1] Bear and Wind/Bighorn River Basin Plans did not calculate normal, dry, and wet year scenarios but overall averages.

[2] Platte methodology does not afford calculation of irrigation water requirement; values estimated by applying average CU:IWR ratio from other basins.

[3] Average unit IWR.

**Table 5-5 Estimated Average Annual Irrigation Water Supply-Limited Consumptive Use (Depletions)**

| River Basin | 1973 Total CU | Current Total CU | Active Irrigated Lands | Unit CU | Total CU | | |
|---|---|---|---|---|---|---|---|
| | | | | | Wet | Normal | Dry |
| | ac-ft | ac-ft | acres | ac-ft/ac | ac-ft | | |
| Bear[2] | 65,000 | 94,000 | 64,000 | 1.47 | | | |
| Green | 243,000 | 401,000 | 331,000 | 1.21 | 432,000 | 401,000 | 375,000 |
| Northeast | 160,000 | 86,000 | 77,000 | 1.12 | 88,000 | 86,000 | 76,000 |
| Platte[2] | 686,000 | 550,000 | 612,000 | 0.90 | 527,000 | 566,000 | 515,000 |
| Powder/Tongue | See Note 1 | 184,000 | 161,000 | 1.14 | 194,000 | 184,000 | 178,000 |
| Snake/Salt | 84,000 | 102,000 | 99,000 | 1.03 | 105,000 | 102,000 | 94,000 |
| Wind/Bighorn[2,3] | 1,041,000 | 1,039,000 | 600,000 | 1.73 | | | |
| **Total** | **2,279,000** | **2,456,000** | **1,944,000** | **1.23**[4] | | | |

[1] In 1973 Framework Plan, Powder/Tongue Basin is included in Northeast Wyoming Basin. Also, the 1973 Wind/Bighorn Basin included the Little Bighorn subbasin, but the Little Bighorn is in the 2002 Powder/Tongue Basin.

[2] Bear, Platte, and Wind/Bighorn values are overall averages, Bear and Wind/Bighorn Basin Plans did not provide normal, dry, and wet year scenarios for consumptive use estimates. Current total CU for other basins taken from "normal" year averages.

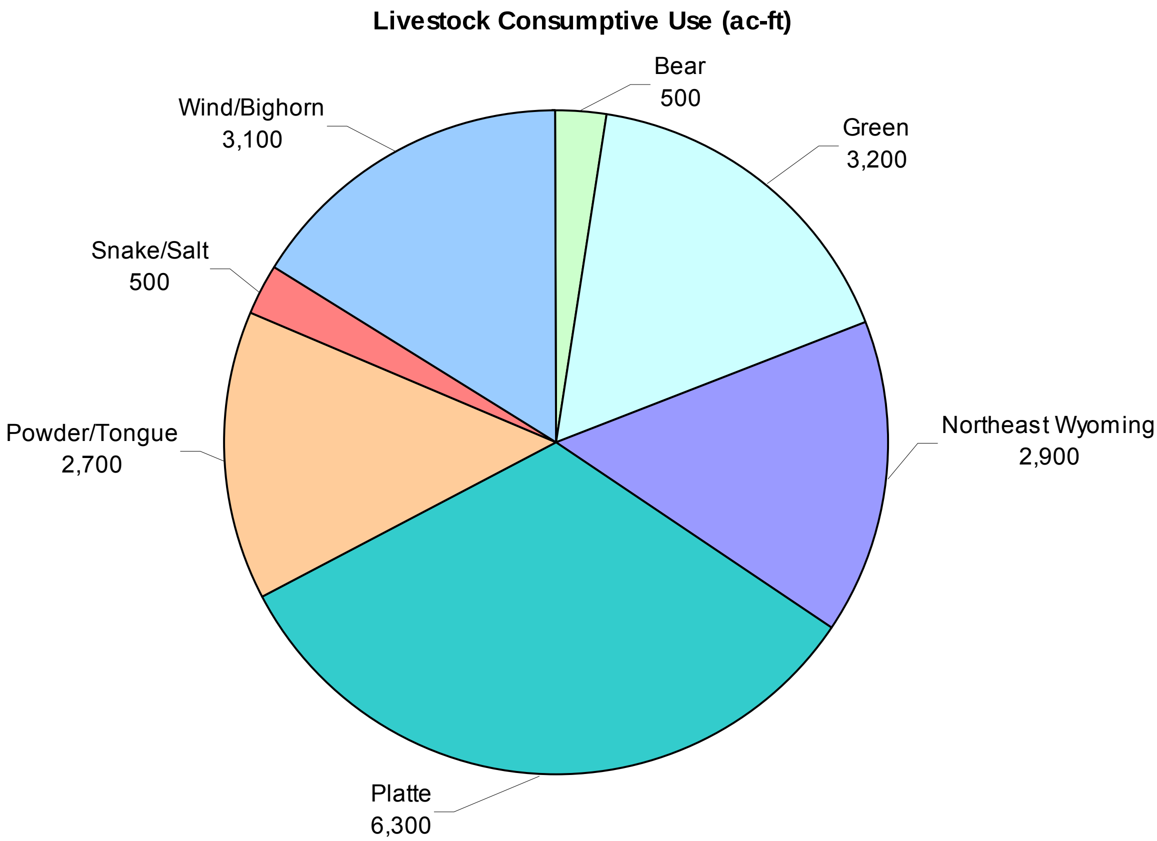
[3] Wind/Bighorn River Basin Plan provided full-supply consumptive irrigation requirement but not supply-limited consumptive use. Table value was estimated by multiplying historical diversions by overall efficiency and does not include Tribal Futures projects or Popo Agie basin.

[4] Average unit CU.

#### 5.2.8 Livestock Consumptive Use

Livestock consumption estimates are based on ten gallons of water per cow per day and four gallons of water per sheep per day. The pie chart below shows the estimated average annual livestock water consumption by basin.

## 5.3 MUNICIPAL AND DOMESTIC WATER USE




### 5.3.1 Introduction

Municipal water uses are those uses satisfied by a public water supply system. Municipal water use is a relatively small but important part of Wyoming's water use. Figure 5-3 shows the municipalities in Wyoming by river basin planning area and by primary source of supply. Municipal needs are served by surface water, groundwater, and combinations thereof.

Primarily, information was obtained from the various municipalities through direct communication or from various years of the WWDC's *"Water System Survey Report"*. Other sources included the WDEQ and various water supply reports for the areas. The detailed information compiled for each entity in each of the river basin planning areas is presented in the Municipal Use Technical Memorandum for that river basin planning area.

The river basin plans compared the existing use and the demand imposed on the municipal system to the capacity of that system. Most of the municipal systems in Wyoming have adequate capacity to meet existing needs. There are, however, a number of entities with system capacities close to or less than existing demands. Additional information on demand versus system capacity is contained in each of the river basin planning area reports.

Domestic water uses are those uses which are satisfied by individual wells and small water systems. The principal users of nonmunicipal domestic water supplies are rural homes, subdivisions, small trailer courts, commercial establishments, parks, campgrounds, rural schools, domestic uses at coal mines, and other small water uses that are not supplied from a central public water system. These uses are almost exclusively supplied from groundwater. A notable exception is limited irrigation of lawns and gardens from available surface water sources.

### 5.3.2 Current Water Use

Table 5-6 shows the current municipal and domestic water use for the state by individual river basins in gallons of use per day. The water use is split between surface water and groundwater. Large portions of the Platte River Basin population were reported as being served by conjunctive use systems (use of both surface water and groundwater). Platte River cities with conjunctive use systems include Bar Nunn, Casper, Cheyenne, Douglas, Laramie, and Rawlins. Table 5-7 presents the annual municipal and domestic use for each of the river basin planning areas. Figures in this table are shown in acre-feet used per year. In the Platte River Basin Plan, conjunctive use was estimated and reported. Figure 5-4 shows municipal wells while Figure 5-5 shows domestic wells in the state.

**Table 5-6 Municipal and Domestic Use**

| River Basin | Demand Factor[1] | Surface Water | | Groundwater | |
|---|---|---|---|---|---|
| | | Municipal | Domestic | Municipal | Domestic |
| | gpcpd | gpd | | | |
| Bear River[2] | 198 | 2,056,700 | | 897,000 | |
| Green River[3] | 133 | 18,682,000 | ≈ 0 | 646,000 | 2,598,000 |
| Northeast Wyoming | 204 | ≈ 0 | ≈ 0 | 6,957,000 | 2,540,000 |
| Platte River[4] | 197 | 5,981,000 | | 15,891,000 | |
| Powder/Tongue River | 270 | 6,446,000 | ≈ 0 | 91,000 | 2,135,000 |
| Snake/Salt River | 223 | ≈ 0 | ≈ 0 | 5,875,140 | 2,241,000 |
| Wind/Bighorn River | 207 | 8,300,000 | 1,157,000 | 3,904,000 | 5,314,000 |

[1] Demand factors are based on average use in the basin, which are reported as gallons per capita per day (gpcpd). Use is calculated in gallons per day (gpd).

[2] Combined the data for municipal and domestic uses. Number is from percentage of total water use.

[3] Surface water data are"depletions" instead of "uses" like the other basins. Also includes 12.9 mgd for City of Cheyenne, which may or may not be the same as 13 mgd in the Platte Basin total.

[4] Includes 13 mgd for City of Cheyenne, which may be duplicated in Green River Basin. Also the only basin plan to report conjunctive uses.

**Table 5-7 Municipal and Domestic Water Depletions**

| River Basin | Depletions | | |
|---|---|---|---|
| | Surface Water | Groundwater | Total |
| | ac-ft per year | | |
| Bear River | 2,300 | 1,000 | 3,300 |
| Green River[1] | 21,800 | 2,800 | 24,600 |
| Northeast Wyoming | 0 | 10,100 | 10,100 |
| Platte River[2] | 6,700 | 17,800 | 24,500 |
| Powder/Tongue River | 7,200 | 2,500 | 9,700 |
| Snake/Salt River | 0 | 9,100 | 9,100 |
| Wind/Bighorn River | 10,600 | 10,300 | 20,900 |
| **Total** | **48,600** | **53,600** | **102,200** |

[1] Municipal depletions in the Green River Basin include 14,400 ac-ft that is diverted into the Platte River Basin for Cheyenne.

[2] Platte River Basin municipal use had large amounts of conjunctive use that were not separated into surface water and groundwater. The conjunctive use was split into surface water and groundwater based on information found in the tech memos.

To estimate current or present use, water demand factors were determined for each river basin planning area. These demand factors are expressed in gallons of use per capita per day. Table 5-6 shows the average per capita daily use for each of the river basin planning areas. Individual systems will very likely exhibit different per capita use; however, the demand factors do indicate per capita use for the municipal sector across the river basin planning area.

As much of rural domestic water use is not measured, domestic water use factors were estimated based on the judgment of the individual river basin planning team. For additional information and detailed discussion, the reader should consult the specific river basin plan and its associated technical memorandum.

## 5.4 INDUSTRIAL WATER USE

### 5.4.1 Introduction

An important water-using sector in Wyoming is the industrial sector. This sector includes electric power generation, coal mining, conventional oil and gas production, uranium mining, trona mining and soda ash production, bentonite mining, gypsum mining, and coalbed methane (CBM) production.

Information was obtained during the individual river basin studies through direct communication with the various industries, the Coalbed Methane Coordination Coalition (CBMCC), Wyoming Oil & Gas Conservation Commission (OGCC), U.S. Bureau of Land Management (BLM), and SEO. Across the State some industries did not have records of their water use. Therefore, some estimates had to be gleaned from anecdotal information. These were often “rule of thumb” numbers used by industry. In other cases, SEO industrial water right permits were used to estimate water use. For example, groundwater use in the Wind/Bighorn River Basin was estimated to be 76,533 acre-feet. This number may be inflated as water rights and permitted amounts were used rather than actual use. This approach would not account for inactive or shut-in wells that are no longer in use. The methods employed in the seven river basins are described in more detail in the technical memoranda for the various study areas.

The amount of industrial water use varies from almost none in some river basin planning areas such as in the Snake/Salt River Basin to fairly large amounts of water being used such as in the Platte River Basin. Current use by the industrial sector is described in this section.

### 5.4.2 Current Water Use

Coal-fired electric power generation plants are currently located in three of the seven river basin planning areas: the Northeast Wyoming River Basin , Green River Basin, and Platte River Basin.

Four coal-fired electric power plants are now operating in Northeast Wyoming. Three of the plants, Neal Simpson #1, Neal Simpson #2, and Wyodak #1, are near the Wyodak Mine seven miles east of Gillette. All three of these plants use air rather than water for cooling steam produced during electric power generation. As a result, their water consumption is significantly lower than the more conventional water-cooled electric power plants. The only water-cooled electric generating facility in Northeast Wyoming is the Osage Station, located near Osage in Weston County. Total annual consumptive water use for power production at these plants is approximately 1,200 acre-feet.

Two coal-fired electric power plants are located in the Green River Basin: the Jim Bridger Power Plant near Point of Rocks in Sweetwater County and the Naughton Power Plant south of Kemmerer in Lincoln County. The Naughton Plant has a production capacity of 710 megawatts (MW) and consumptively uses approximately 13,500 acre-feet of water annually from the Hams Fork River. The Jim Bridger Plant has a production capacity of 2,000 MW and consumptively uses approximately 34,300 acre-feet of water annually from the Green River. Much of the power from the Naughton Plant is exported via transmission lines to Utah, while much of the power from the Jim Bridger Plant is exported to PacifiCorp customers in the Pacific Northwest.

In the Platte River Basin, the Laramie River Station in Platte County is operated by Basin Electric Power Cooperative and has a generating capacity of 1,670 MW. This plant uses about 23,250 acre-feet of water annually. The Dave Johnston Power Plant located in Converse County is owned and operated by Rocky Mountain Power and has a generating capacity of 817 MW. This plant uses about 8,600 acre-feet of water annually.

For surface water, the Green River Basin leads in industrial water use with an estimated 66,280 acre-feet. The Northeast Wyoming River Basin, Powder/Tongue River Basin, and Platte River Basin also use fairly large quantities of groundwater for industrial purposes. Table 5-8 shows the estimated present use of surface water and groundwater for industrial purposes. Some of the river basin plans did not estimate use for the minor sectors such as aggregate mining, concrete production, manufacturing, road and bridge construction, and miscellaneous industrial use. Many of these minor uses exist in all of the river basin planning areas; however, the Platte River Basin plan had the most all inclusive list of industrial use. Due to the differences in methods used in the seven river basin planning area studies, the totals shown in Table 5-8 may not accurately reflect industrial use.

Figure 5-6 shows the locations of industrial and miscellaneous wells. Miscellaneous use is a beneficial use category used by the SEO to categorize small yield wells where there is no defined major use. Total current industrial surface water use for Wyoming is estimated to be 124,490 acre-feet per year. Total current industrial groundwater use is estimated to be 246,130 acre-feet per year.

More extensive discussion of the individual river basin industrial water uses can be found in the individual river basin plans and associated technical memoranda.

**Table 5-8 Annual Industrial Water Use**

| River Basin | Coal-Fired Electric Power | Conventional Oil and Gas | Mining and Mine Reclamation[1] | Trona Mining/ Soda Ash | Coal Bed Methane[4] | Manufacturing | Misc[2] | Aggregate, Cement, Concrete[2] | Road and Bridge Construction[2] | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| | Surface Water Use (ac-ft) | | | | | | | | | |
| Bear | 0 | 300 | 0 | 0 | 0 | | | | | 300 |
| Green | 47,800 | | | 17,900 | | 560 | | | | 66,260 |
| Northeast | 0 | | | 0 | | | | | | |
| Platte | 31,900 | 2,700 | 450 | 0 | | | 4,600 | 580 | 2,000 | 42,230 |
| Powder/Tongue | 0 | | | 0 | | | | | | |
| Snake/Salt | 0 | | 0 | 0 | 0 | | | | | |
| Wind/Bighorn | 0 | | | 0 | 0 | 15,700 | | | | 15,700 |
| **Total Surface Water** | **79,700** | **3,000** | **450** | **17,900** | **0** | **16,260** | **4,600** | **580** | **2,000** | **124,490** |
| | Groundwater Use (ac-ft) | | | | | | | | | |
| Bear | 0 | 90 | | 0 | 0 | | | | | 90 |
| Green | 0 | 1,600 | | 0 | 0 | | | | | 1,600 |
| Northeast | 1,200 | 10,400 | 2,700 | 0 | 35,600 | | | | | 49,900 |
| Platte | 0 | 17,600 | 17,500 | 0 | 0 | | 9,300 | 11,200 | 0 | 55,600 |
| Powder/Tongue | 0 | 38,000 | | 0 | 24,300 | | | | | 62,300 |
| Snake/Salt | 0 | 0 | 0 | 0 | 0 | 140 | | | | 140 |
| Wind/Bighorn[3] | 0 | 73,800 | 2,700 | 0 | 0 | 0 | | | | 76,500 |
| **Total Groundwater** | **1,200** | **141,490** | **22,900** | **0** | **59,900** | **140** | **9,300** | **11,200** | | **246,130** |

[1] Green River Basin coal mining water use is included in power generation.

[2] Estimates for these sectors were made only for the Platte River Basin.

[3] Wind/Bighorn Basin conventional oil and gas use is water righted use.

[4] CBM is water extracted during the gas production phase.

Note: Blank spaces for water use in a particular basin indicate no estimate was made, not that there was no use.

## 5.5 RECREATIONAL WATER USE

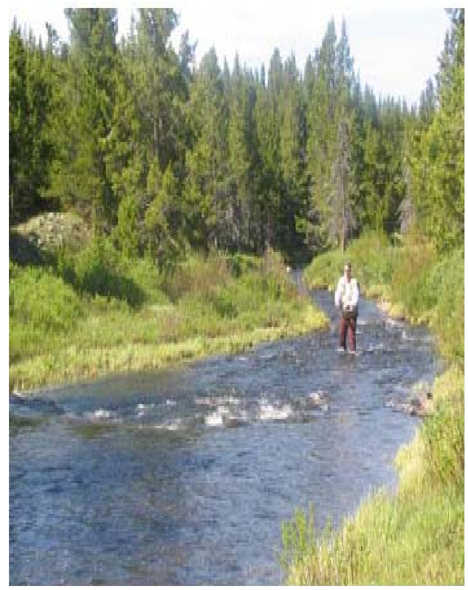
### 5.5.1 Introduction

Recreational uses of water are important and generally nonconsumptive. Uses include boating, fishing, swimming, and waterfowl hunting among others. While consumption of water is usually not involved, the existence of a sufficient water supply for a quality experience is important. The quality and quantity of good recreational opportunities are highly dependent on water quality and quantity. Recreation, including tourism, is one of Wyoming's major industries. Hunters and anglers alone spent $700,588,360 in the state in the year 2000.

Data for this section of the report were obtained for the seven basin plans from the regulatory agencies assigned the task of managing recreation in basin waterways. Those agencies include the Wyoming Game and Fish Department (WGFD), Wyoming Department of State Parks and Cultural Resources, USFWS, BLM, and USBR.

### 5.5.2 Current Water Use

Tourism and recreational use consist of two sectors, resident use and nonresident (tourism) use. Due to a lack of water-based recreational opportunities, some areas of Wyoming are not tourist destinations. The northwest portion of the state, on the other hand, is a popular recreation destination and experiences large visitation. This area includes the Snake/Salt River Basin, part of the Green River Basin, and part of the Wind/Bighorn River Basin.



The following sections describe the major types of recreation in the State that require water:

- Fishing
- Boating
- Waterfowl hunting
- Skiing and winter sports
- Golfing

*Fishing*

Fishing is a major water-based recreational activity pursued in the state. It is the most popular water-based recreational activity for residents in many areas of the state. As with boating, fishing is a nonconsumptive use of water, and in most cases is dependent on water devoted to other uses such as irrigation or municipal. A notable exception to this dependency is the instream flow water right program administered by the State of Wyoming. Instream flows are discussed later in this chapter.

The State of Wyoming classifies trout streams under the five designations listed below:

- **Class 1** – Premium trout waters – fisheries of national importance
- **Class 2** – Very good trout waters – fisheries of statewide importance
- **Class 3** – Important trout waters – fisheries of regional importance

- **Class 4** – Low production trout waters – fisheries frequently of local importance, but generally incapable of sustaining substantial fishing pressure
- **Class 5** – Very low production waters – often incapable of sustaining a trout fishery

The WGFD estimates the number of annual activity days of angling and waterfowl hunting in the state. Still water fishing on lakes and reservoirs accounts for the largest percentage of fishing activity days annually. Most of this fishing activity occurs at lowland reservoirs. In some parts of the state, still water fishing on alpine lakes and reservoirs contributes to the total still water fishing.

Stream fishing in Wyoming accounts for a large number of activity days annually in some river basin planning areas, such as in the Green River Basin where it was estimated 300,000 angler activity days annually are experienced. Stream fishing opportunities are limited in other river basin planning areas. Northeast Wyoming is a good example of a river basin with limited stream fishing opportunities, although there are some good streams, such as Sand Creek, which arise in the Black Hills.

Table 5-9 illustrates the angler days for the state by basin. The days are split between stream and still water fishing.

**Table 5-9 Angler Days**

| River Basin | Angler Days | |
|---|---|---|
| | Stream | Still Water |
| Bear River | 9,400 | 7,400 |
| Green River | 256,300 | 485,600 |
| Northeast Wyoming | 13,400 | 38,300 |
| Platte River[1] | 385,400 | |
| Powder/Tongue River | 140,200 | 131,700 |
| Snake/Salt River[1] | 116,000 | |
| Wind/Bighorn River[2] | 51,300 | |
| **Total** | **1,635,000** | |

[1] No data were presented to separate stream angler days from still water angler days.

[2] The data are the number of fishing licenses sold in the five counties of the basin.

*Boating*

Many of the streams and lakes in Wyoming support boating activities, including whitewater, scenic, fishing, and water-skiing. Power boating, rafting, canoeing, and sailing are all popular water-based activities among Wyoming residents. Boating is a nonconsumptive use because it depends on waters being maintained for other purposes.

Little quantitative data exist on the numbers of watercraft using the streams and lakes and whether numbers approach or exceed the carrying capacity of the water body used. The USBR's default figure of one boat per 10 surface acres of water is used to estimate capacities elsewhere, but until use numbers are generated in the state to support this estimate, that guideline cannot be used.

A quality boating experience requires a water level (in lakes) or flow rate (in rivers) sufficient to support the reason for boating, whether it be fishing, water-skiing, or some other sport. In this context, future water development projects should be evaluated for their effect on such levels.

*Waterfowl Hunting*

Waterfowl hunting is another popular activity among Wyoming residents. The harvest of migratory waterfowl is a recreational pursuit affected by the presence or absence of water. Wetlands and open water are needed for breeding, nesting, rearing, feeding, and isolation from land-based predators. In the state of Wyoming, waterfowl hunting is pursued where sufficient local or migratory populations are available.

Harvest objectives have not been used since 1993. In effect, the desired harvest is a prospective number using past hunter success, population effects, and regulations in concert with current-year populations.

With current duck populations and hunting pressure, it appears there is a sufficient resource to provide a quality duck hunting experience now and in the near future, with the existing water resources of the State. Goose hunting seasons and bag limits are set under guidelines from the USFWS, although states have more flexibility in setting bag and possession limits. Like duck populations, goose populations are strong and increasing. With approval from the USFWS, states can set special seasons to allow depredation harvest from growing local flocks. With current goose populations, it appears there is a sufficient resource to provide a quality goose hunting experience now and in the near future, with the existing water resources of the state.

*Skiing and Winter Sports*

Downhill skiing is another recreational water consumer. The major consumption is through evaporation during the snowmaking process. It has been estimated that snowmaking is about 20 percent consumptive. Snowmaking is practiced at many of the ski areas, particularly the larger ones. While downhill skiing is a consumptive user, the water use is a minor one.

The major ski areas in the state are located in the Snake/Salt River Basin. They include Snow King Resort, Grand Targhee Resort, and Jackson Hole Mountain Resort. Ski areas of local and regional importance exist in all of the river basin planning areas except Northeast Wyoming. Most of the ski areas have incorporated snowmaking facilities into their resorts. Figure 5-7 shows the ski areas of Wyoming.

Other winter sports in the state include cross-country skiing, snowshoeing, and snowmobiling. These activities are prevalent across Wyoming.

*Golfing*

Golfing and golf courses are scattered across all the river basin planning areas. In the Platte River Basin, there are 19 golf courses with nearly 300 holes covering about 2,000 acres. There are five courses in the Snake/Salt River Basin with three new ones planned for Teton County and one new course planned for Lincoln County. These are just a portion of the total number of courses in the state.

Figure 5-7 shows the location of many of the golf courses in the state, and the website http://www.thegolfcourses.net indicates there are 34 municipalities with at least one course listed plus the course at Warren Air Force Base.

The major water use is for irrigation of the greens and fairways. This use is often included in municipal use similar to park and cemetery use. While golfing is a consumptive user, the water use is a minor one.

*Wyoming State Parks and Historical Sites*

Wyoming is home to several state parks and historic sites which offer many recreational water activities for visitors. Figure 5-8 shows the location of the various parks and historic sites administered by the State Parks Division.

The 1997 *Wyoming State Parks and Historic Sites Visitor Survey*, compiled by the University of Wyoming, Survey Research Center, provides additional information. About 86 percent of all visitation (to all parks and historic sites) occurs in the months of June, July, and August, with attendance in each of those months almost equal. Slightly over half the visitors are first-time visitors. Approximately one in four visitors is traveling with a boat or canoe, indicating some water-based recreation is intended, either at that location or elsewhere on that particular trip. Approximately 58 percent of the visitors are from out of state.

*Wind River Indian Reservation*

The Wind River Indian Reservation (WRIR) is home of the Eastern Shoshone and Northern Arapaho Tribes. Natural resources on the WRIR are in general jointly owned by the two Tribes. (Additional information on the tribal lands is provided in Chapter 3, Section 3.3.2.)

Within the WRIR are more than 200 lakes and over 1,000 miles of streams. Fishing on the WRIR requires a tribal license. The Tribes reported selling 2,472 permits in 1998 and 3,577 in 1999. About 60 percent of these sales were to nonresidents (University of Wyoming, Cooperative Extension Service, 1999). There is significant potential for further development of recreational opportunities, including water-based activities, in the WRIR.

*National Parks and Monuments*

There are two national parks in Wyoming, Grand Teton National Park and Yellowstone National Park. Grand Teton National Park is located entirely within the Snake/Salt River Basin. Yellowstone National Park is split between the Snake/Salt River Basin and the Wind/Bighorn River Basin. Both of these parks have extensive recreational water activities.

Visitors to Yellowstone National Park provide a significant portion of the tourism in northwest Wyoming. From 1996 through 2005, recreational visitors to Yellowstone National Park averaged nearly three million people per year (Table 5-10). The East Entrance, west of Cody, averaged fewer than 400,000 per year during the 1992-1998 period (Yellowstone National Park, Visitation Statistics). The South Entrance, reached through Fremont and Teton Counties (as well as from the west and south), averaged more than 800,000 per year during the same period. These numbers suggest that fairly large numbers of people bound for Yellowstone Park pass through the Wind/Bighorn River Basin and Snake/Salt River Basin each year.

There are also two national monuments in the State: Devil's Tower and Fossil Butte National Monument. Devil's Tower was the first national monument to be declared and is located in the Northeast Wyoming River Basin. Fossil Butte has some of the world's best preserved fossils, including fish, plants, insects, reptiles, birds and mammals. Fossil Butte is located in the Bear River Basin.

Figure 5-9 shows the location of the national parks and monuments.

**Table 5 -10 Visitation to National Parks and National Monuments**

| Park or Monument | Visitation 2005 | Average Visitation 1996 to 2005 |
|---|---|---|
| Yellowstone NP | 2,836,000 | 2,945,000 |
| Grand Teton NP | 2,463,000 | 2,575,000 |
| Devils Tower NM | 370,000 | 394,000 |
| Fossil Butte NM | 18,000 | 21,000 |
| **Total** | **5,687,000** | **5,935,000** |

Source: National Park Service Annual Visitation Reports - 2006

*National Forests*

Wyoming is also home to eight national forests and one national grassland. The national forests are: Ashley, Bighorn, Black Hills, Bridger-Teton, Medicine Bow, Shoshone, Targhee, and Wasatch. The national grassland is Thunder Basin. Figure 5-9 shows the national forests and national grassland in Wyoming.

*Summary of Recreational Use*

In general, the recreational uses of water around the state are nonconsumptive. These uses do, however, require an adequate supply of water. Golf course irrigation is an exception to the nonconsumptive claim. However, this use was not accounted for in most of the river basin plans.

## 5.6 ENVIRONMENTAL WATER USE

### 5.6.1 Introduction

Previous studies conducted by the WWDC, SEO, and Game and Fish Department have estimated the amount of water designated for or consumed by various environmental uses. These include, but are not necessarily limited to, instream flow water rights permitted by the Wyoming State Engineer, minimum reservoir pools, instream flow bypasses designated to enhance fisheries and wildlife habitat, wetlands, direct wildlife consumption, evaporation from conservation pools, and maintenance of riparian areas.

### 5.6.2 Current Water Use

Environmental water uses are generally considered nonconsumptive and therefore do not have a specific use assigned to them. The following environmental factors need to be considered when discussing water use.

*Instream Flows*

In 1986, the State of Wyoming enacted legislation defining “instream flow” as a beneficial use of water and stipulated how instream flow water rights would be filed, evaluated, granted or denied, and ultimately regulated (Wyoming Statutes at Section 41-3-1001 to 1014). The law allows for instream flow water rights to be filed and granted on unappropriated water originating as natural flow or from storage in existing or new reservoirs. For natural flow sources, the flow amount is defined as the minimum needed to “maintain or improve existing fisheries”. The language relating to stored water is slightly different, defining the minimum needed to “establish or maintain new or existing fisheries”. Instream flow is generally considered a nonconsumptive beneficial use.

The WGFD first selects the stream segment on which to file for a right. This is done using biological reports, knowledge of the fisheries, and stream flow models, along with determination of how much flow will be required. The WWDC then applies for the appropriation. The WWDC must also conduct a hydrologic study to determine whether the instream flow can be provided from the unappropriated natural flow of the stream or whether storage water from an existing or new reservoir will be needed for part or all of the instream use. The WWDC study is then supplied to the State Engineer for his consideration.

After receiving reports from the WGFD and WWDC, the State Engineer may conduct his own evaluation of the proposed appropriations for instream use. Before granting or denying a permit for instream flow in the specified stream segment, the State Engineer must conduct a public hearing and consider all available reports and information. In the past, public involvement has ranged from very little to quite significant. Following the public input period, the State Engineer decides whether or not to approve, approve with modifications, or reject the application. If granted, an instream flow permit can contain a condition for review of continuation of the permit at a future time. Also, the WWDC is named as holder of the permit.

The instream flow appropriation goes into effect the date the State Engineer approves the permit. The water right cannot be adjudicated by the Board of Control for three years thereafter. An instream water right has a priority date as of the date the application was received and recorded by the SEO, and all senior priority water rights must be recognized in administration of the stream.

Only municipalities can condemn an instream flow right. However, within one mile of the state border, the water for an instream flow right is still open to appropriation. This allows for additional utilization of water prior to the flow leaving the state. Existing water rights cannot be condemned for instream flow; however, they can be gifted to the State for instream use. This has not yet happened. Regulation of water rights on a stream must be called for by the WGFD with the request proceeding through the WWDC. Instream flow rights do not ensure ingress and egress rights to the stream for public use; however, the WGFD has tried to ensure that the segments with instream rights have public access as well. Also, these rights cannot be issued if they will limit Wyoming’s use of water with respect to interstate compacts.

The first filings in Wyoming for instream flow rights were for protection of various species of cutthroat trout. There are currently 100 instream flow applications filed with the State, with 66 having been permitted as of December 2006. Instream flow filings for rivers and streams in the state are shown in Figure 5-10.

*Reservoir Minimum Pools*

Several reservoirs in the state have storage permitted for a variety of environmental uses. These uses, as they appear on the water rights, include fish or fish and wildlife. Recreational uses defined on permits can be considered environmental to the extent that water in storage for recreational purposes, and not released for other consumptive or nonconsumptive uses, can be beneficial, in an environmental sense, for fish habitat and wildlife consumption. Reservoirs with permitted capacity for stock water similarly serve a dual environmental function.

"Conservation storage" describes all of the storage capacity allocated for beneficial purposes and is usually divided into active and inactive areas or pools. "Active storage" or “Active conservation pool” refers to the reservoir space that can actually be used to store water for beneficial purposes. Each reservoir has an allocation for an active conservation pool, which holds reservoir inflow for such uses as irrigation, power, municipal and industrial, fish and wildlife, navigation, recreation, and water quality. Inactive storage refers to water beneath the lowest outlet structures where water cannot be released by gravity and to areas expected to fill up with sediments. This storage is often needed to increase the efficiency of hydroelectric power production.

*Direct Wildlife Consumption*

There are no current estimates of consumptive water use by wildlife for six of the river basin planning areas. An estimate developed for the Green River Basin puts consumptive use by big game and wild horses at about 500 acre-feet of water annually. It was assumed in the Powder/Tongue River Basin and in the Northeast Wyoming River Basin studies that a similar figure would be roughly correct for those basins. If all river basin planning areas are assumed to be similar to the Green River Basin, use would be about 3,500 acre-feet annually. This level of consumptive use is relatively small and is not expected to change significantly over the planning horizon.

*Threatened and Endangered Species*

The presence of threatened or endangered species of plants and animals, or of species that might be considered for such listing, can make water management and development more complex. A number of species in Wyoming are so listed by the U.S. Fish and Wildlife Service. Section 2(c)(2) of the Endangered Species Act requires state and local agencies to cooperate with federal agencies in issues involving such species. Particularly in cases in which federal land is involved, such cooperation means conducting wildlife and plant studies of the targeted area. Some examples of animal species include the grizzly bear, whooping crane, Kendall Warm Springs dace, bald eagle, black-footed ferret, lynx, Preble’s meadow mouse, pike minnow (squawfish), razorback sucker, Wyoming toad, and gray wolf. Some listed plant species are Colorado butterfly plant, blowout penstemon, Ute ladies’ tress, and desert yellowhead. There are also other species that have been proposed for addition to the threatened list, and a long list of candidates (258 species) for endangered or threatened status.

In regard to threatened and endangered species, however, the USFWS states that "while it is prudent to take candidate taxa into account during environmental planning, neither the substantive nor procedural provisions of the Act apply to a taxon that is designated as a candidate." Nonetheless, as a practical matter, the presence or possible presence of threatened, endangered, proposed, or candidate species in locales that could be affected by water projects must be considered by developers. Wildlife and plant (and cultural) studies are routinely done early on in most projects, particularly if public lands are involved.

*Wetlands*

The National Wetlands Inventory (NWI) of the USFWS produces information on the characteristics, extent, and status of the nation's wetlands and deepwater habitats. Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes:

- At least periodically, the land supports predominantly hydrophytes.
- The substrate is predominantly undrained hydric soil.
- The substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

The wetland classification system is hierarchical, with wetlands and deepwater habitats divided among five major systems at the broadest level. The five systems are as follows.

- Marine
  - Open ocean and associated coastline
- Estuarine
  - Salt marshes and brackish tidal water
- Riverine
  - Rivers, creeks, and streams
- Lacustrine
  - Lakes and deep ponds
- Palustrine
  - Shallow ponds, marshes, swamps, sloughs

Systems are further subdivided into subsystems which reflect hydrologic conditions. Below the subsystem is the class which describes the appearance of the wetland in terms of vegetation or substrate. Each class is further subdivided into subclasses; vegetated subclasses are described in terms of life form and substrate subclasses in terms of composition. The classification system also includes modifiers to describe hydrology (water regime), soils, water chemistry (pH, salinity), and special modifiers relating to human activities (e.g., impounded, partly drained). The three major wetland systems mapped within the Snake/Salt River Basin are Riverine, Lacustrine, and Palustrine.

Wetlands in the state provide food, shelter, and breeding habitat for waterfowl and other wildlife. Wetlands may also improve water quality by contributing to the removal of nutrients, sediment, and other impurities in water, in turn protecting rivers and lakes. Also, wetlands can help control erosion and flooding during high water events.

## 5.7 EVAPORATION

Evaporative loss from reservoirs is a loss or use that is not typically thought of as a consumptive use. The increased surface area of a reservoir provides an ideal condition for evaporation to take place. A similar situation occurs for natural lakes and streams. The seven river basin planning area studies addressed evaporative loss in varying ways. From the reports and technical memoranda, estimates of evaporative loss were compiled. For the average or normal condition, it was estimated that reservoir evaporative loss amounts to about 586,000 acre-feet per year for the state. A more detailed discussion and breakdown by basin is provided in Chapter 7, Table 7-1. Figure 5–11 shows the locations of selected reservoirs over 1,000 acre-feet in capacity.

## 5.8 REFERENCES

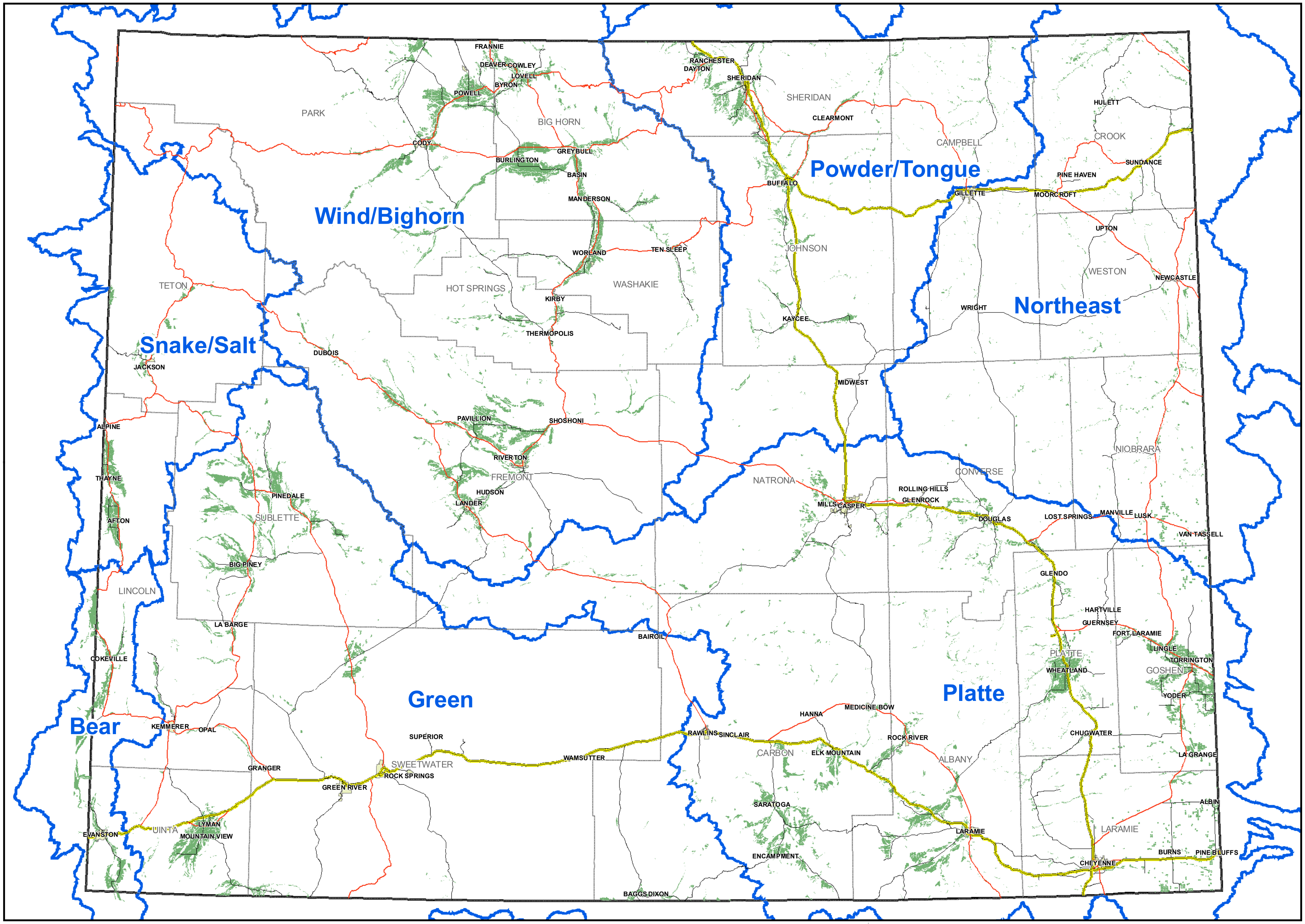

American Society of Civil Engineers (ASCE). 1990. *Evapotranspiration and Irrigation Water Requirement.* ASCE Manuals and Reports on Engineering Practice No. 70.

Cuenca, Richard H. 1989. *Irrigation System Design – An Engineering Approach.* Prentice-Hall, Inc. Englewood Cliffs, New Jersey.

University of Wyoming, Cooperative Extension Service, College of Agriculture. 1999. *Resident Outdoor Recreation for Fremont County, WY.* July.

University of Wyoming, Survey Research Center. 1997. *Wyoming State Parks and Historic Sites Survey.*

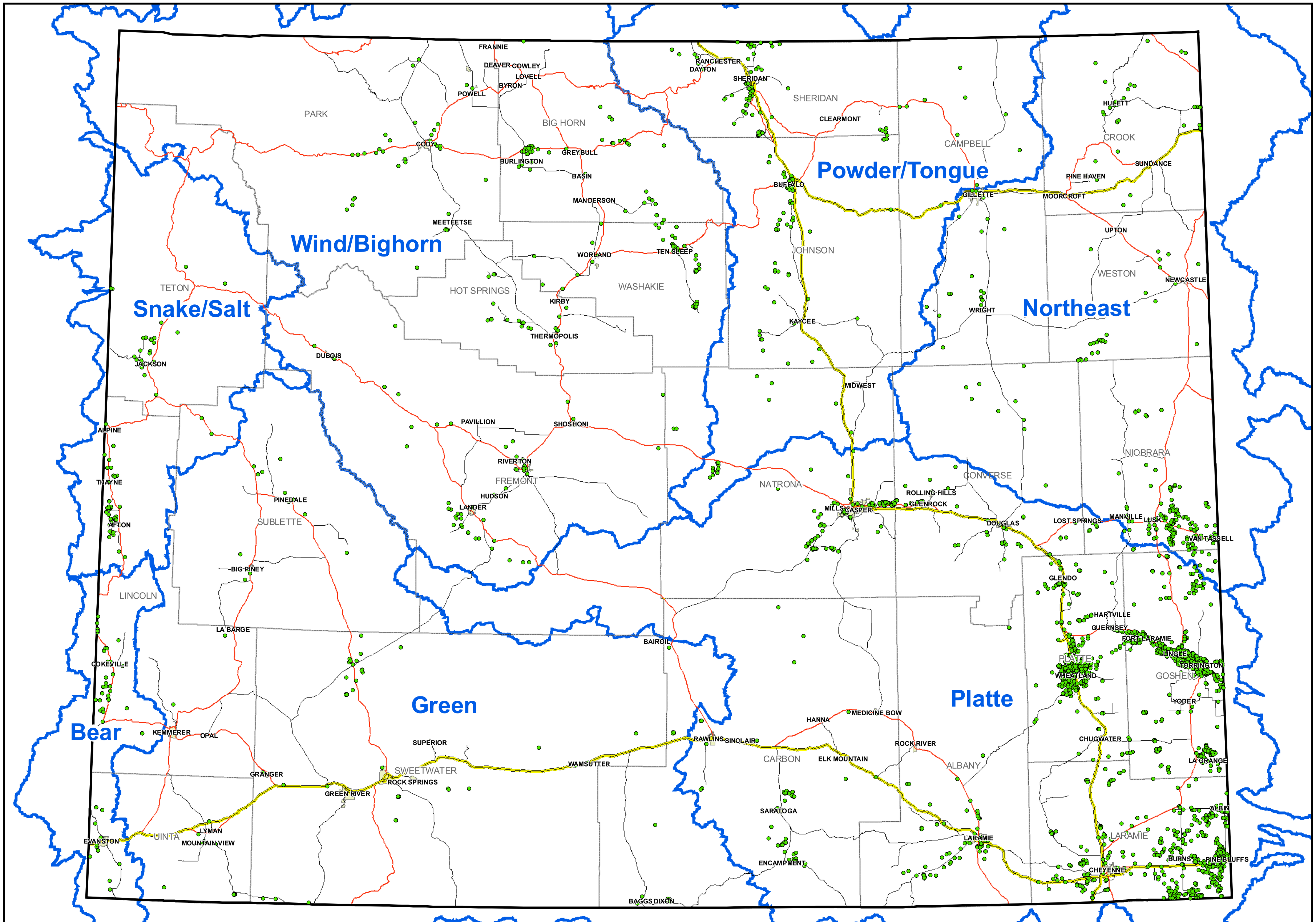
Yellowstone National Park, Visitation Statistics. http://www.nps.gov/yell/parkmgmt/historicstats.htm




**LEGEND**

Irrigated Lands

**Figure 5-1**
**Irrigated Lands**

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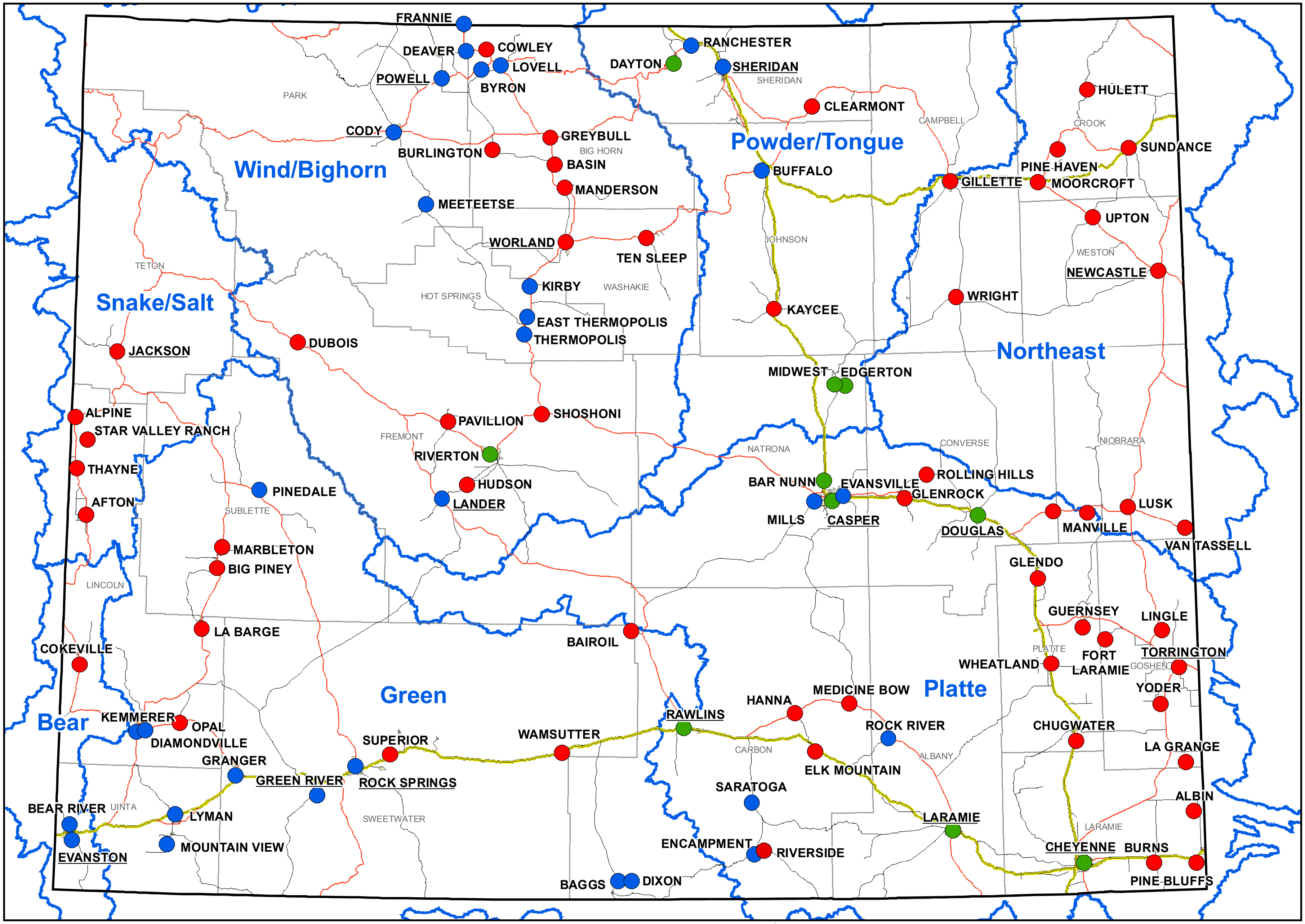
Active Irrigation Well

Source: Wyoming State Engineer's Office GIS files compiled June 2006

Figure 5-2
Active Irrigation Wells

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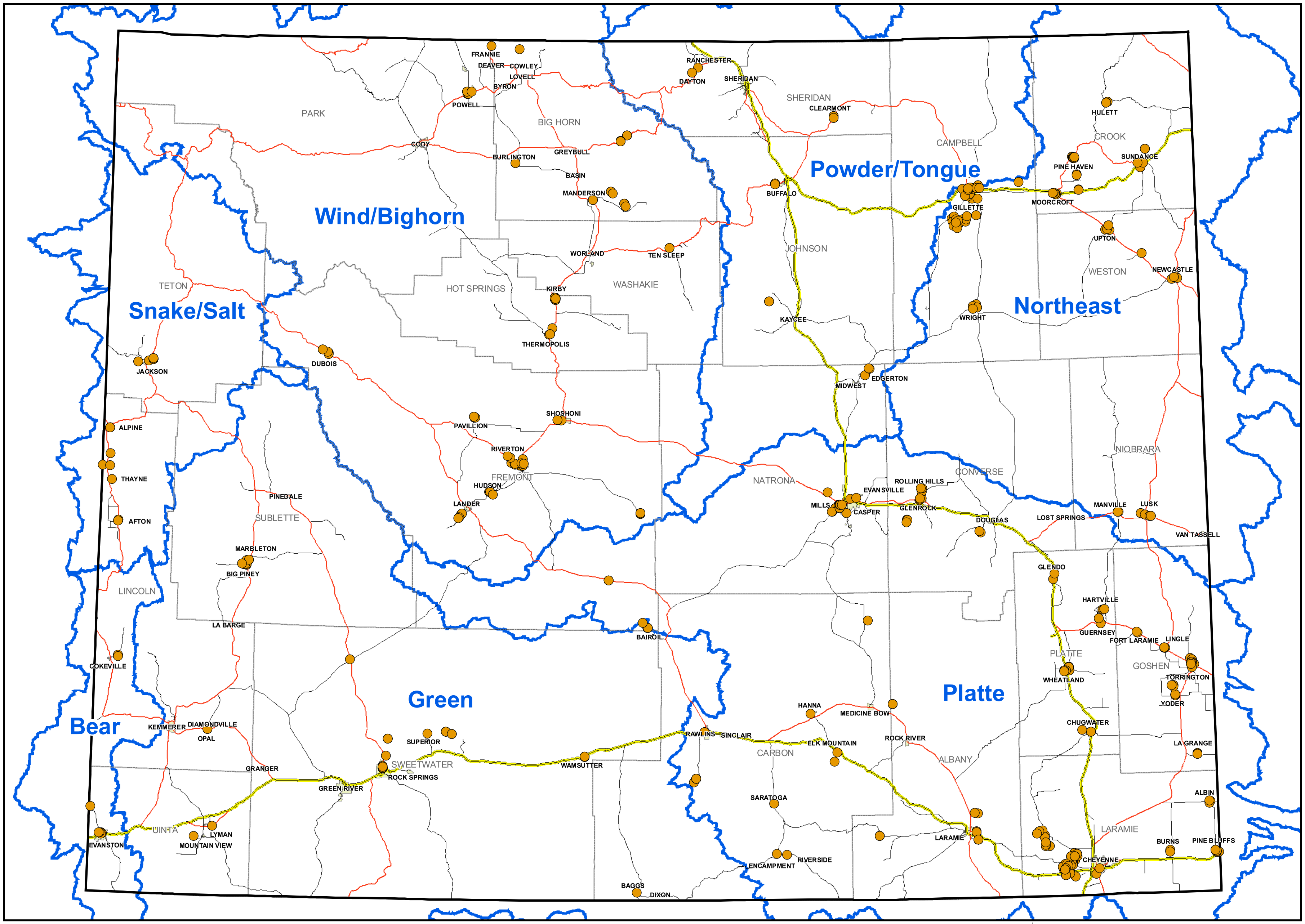
Groundwater   Surface Water   Combination

**Figure 5-3**
**Municipalities and Source of Supply**

Underlined text denotes first class cities. WS 15-3-101 defines a first class city as having at least 4,000 inhabitants and having made a public proclamation.

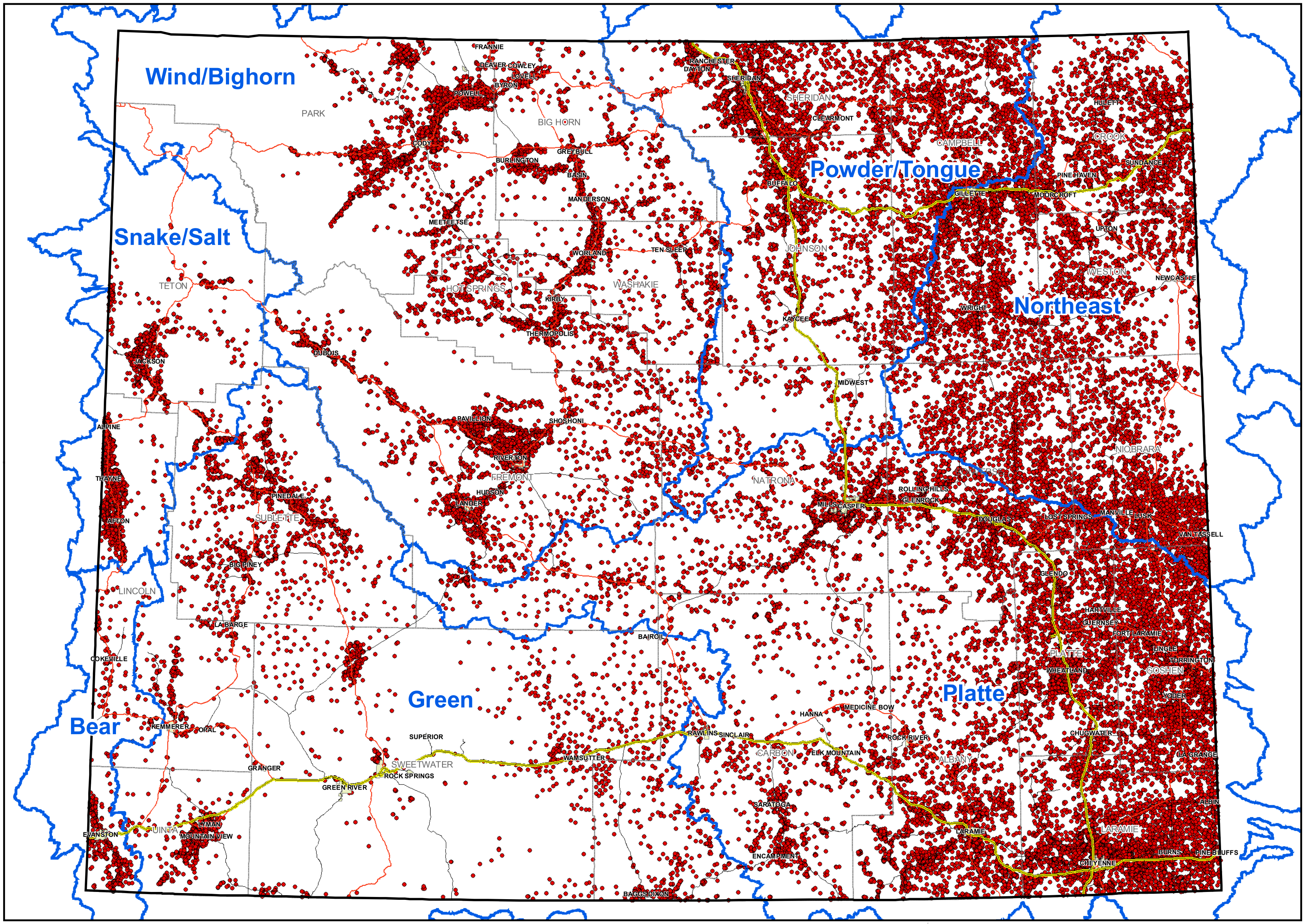



**LEGEND**

Municipal Well

Source: Wyoming State Engineer's Office GIS files compiled June 2006. All wells with municipal use in the water right were included.

**Figure 5-4**
**Municipal Wells**

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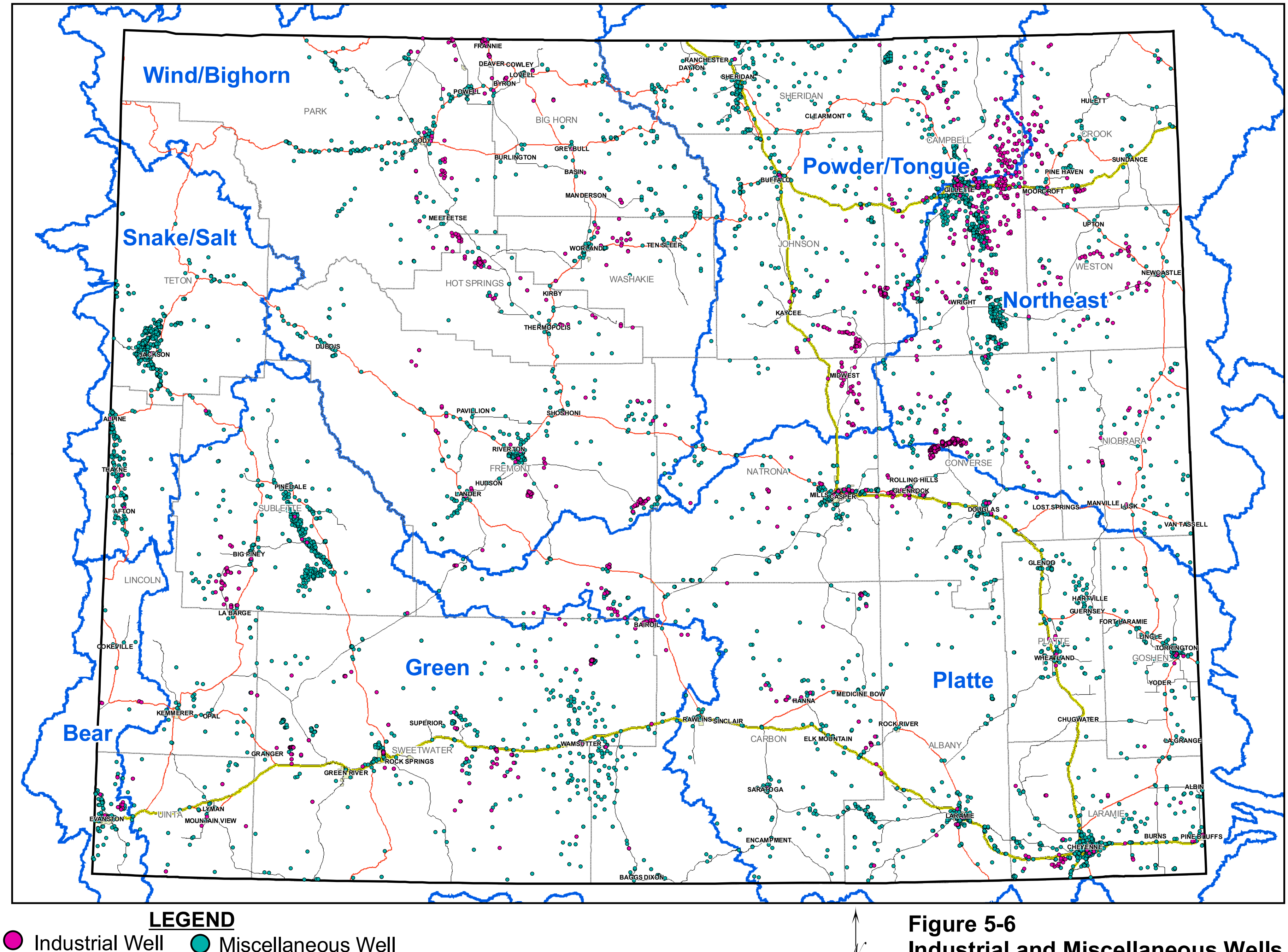
Domestic Well

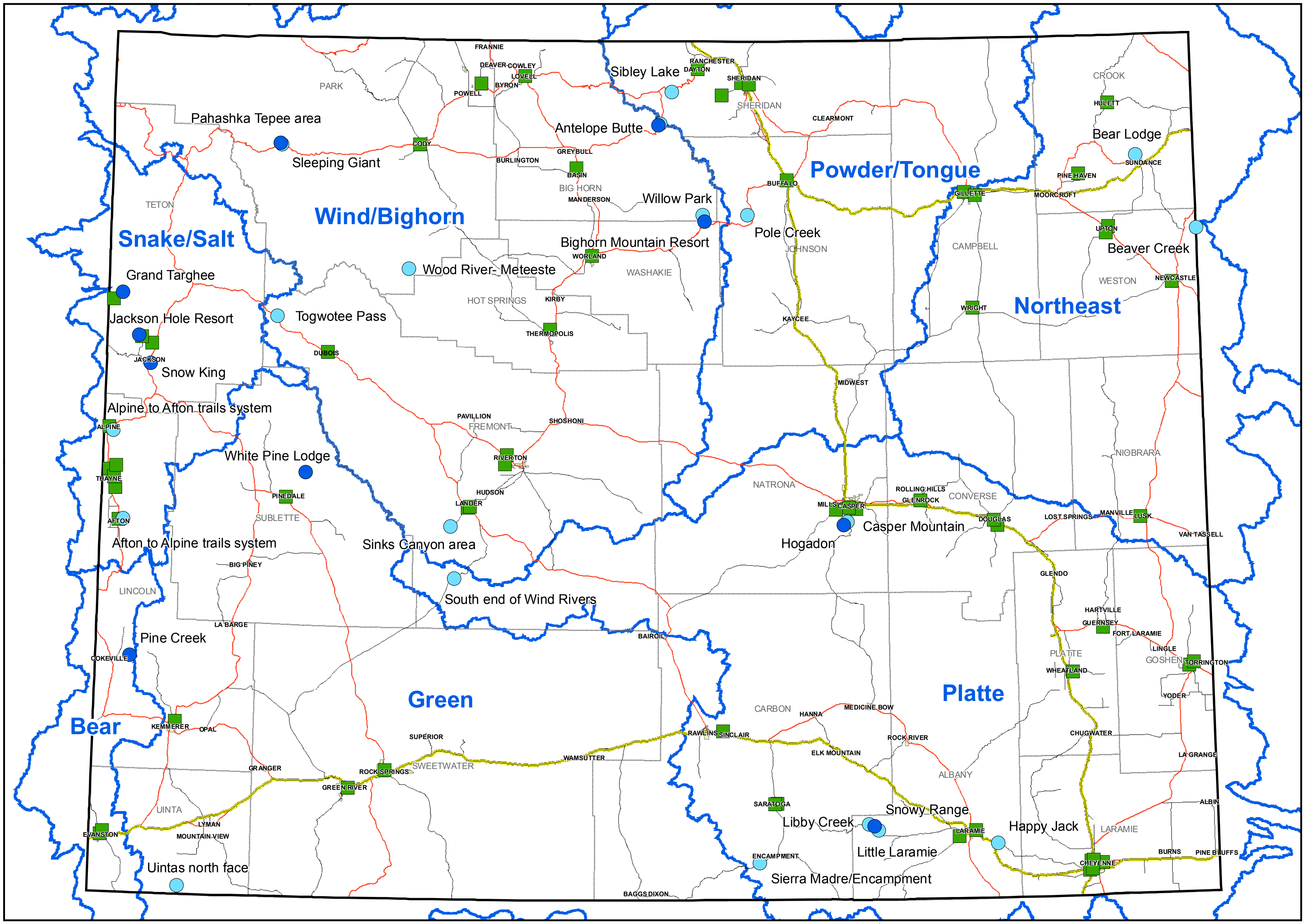
Source: Wyoming State Engineer's Office GIS files compiled June 2006. All wells with either domestic or stock uses are shown.

**Figure 5-5**
**Domestic Wells**




Source: SEO GIS files compiled June 2006. All wells with industrial and miscellaneous use in the water right were included.

**Figure 5-6**
**Industrial and Miscellaneous Wells**

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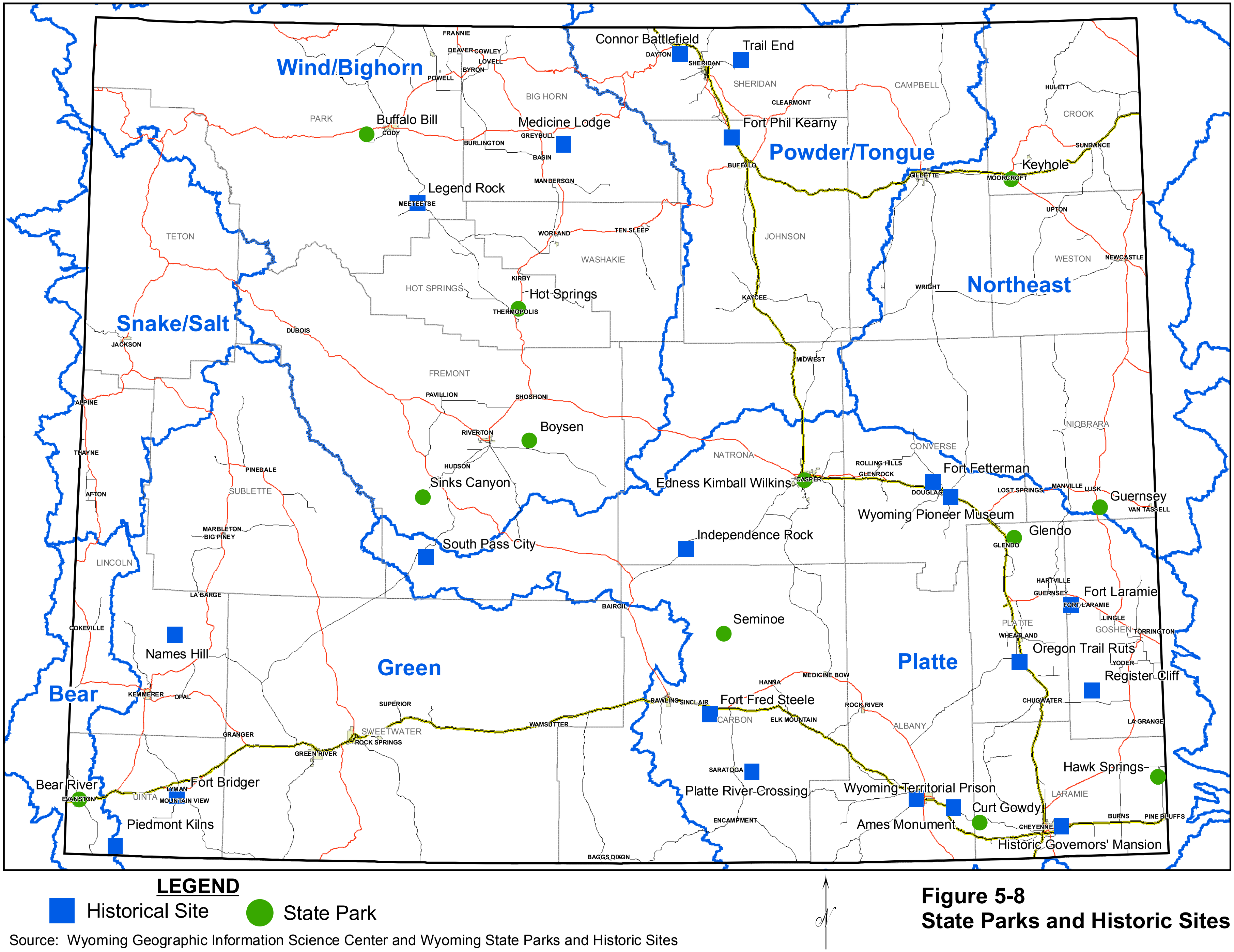
Downhill Ski Area
Cross Country Ski Area
Golf Course

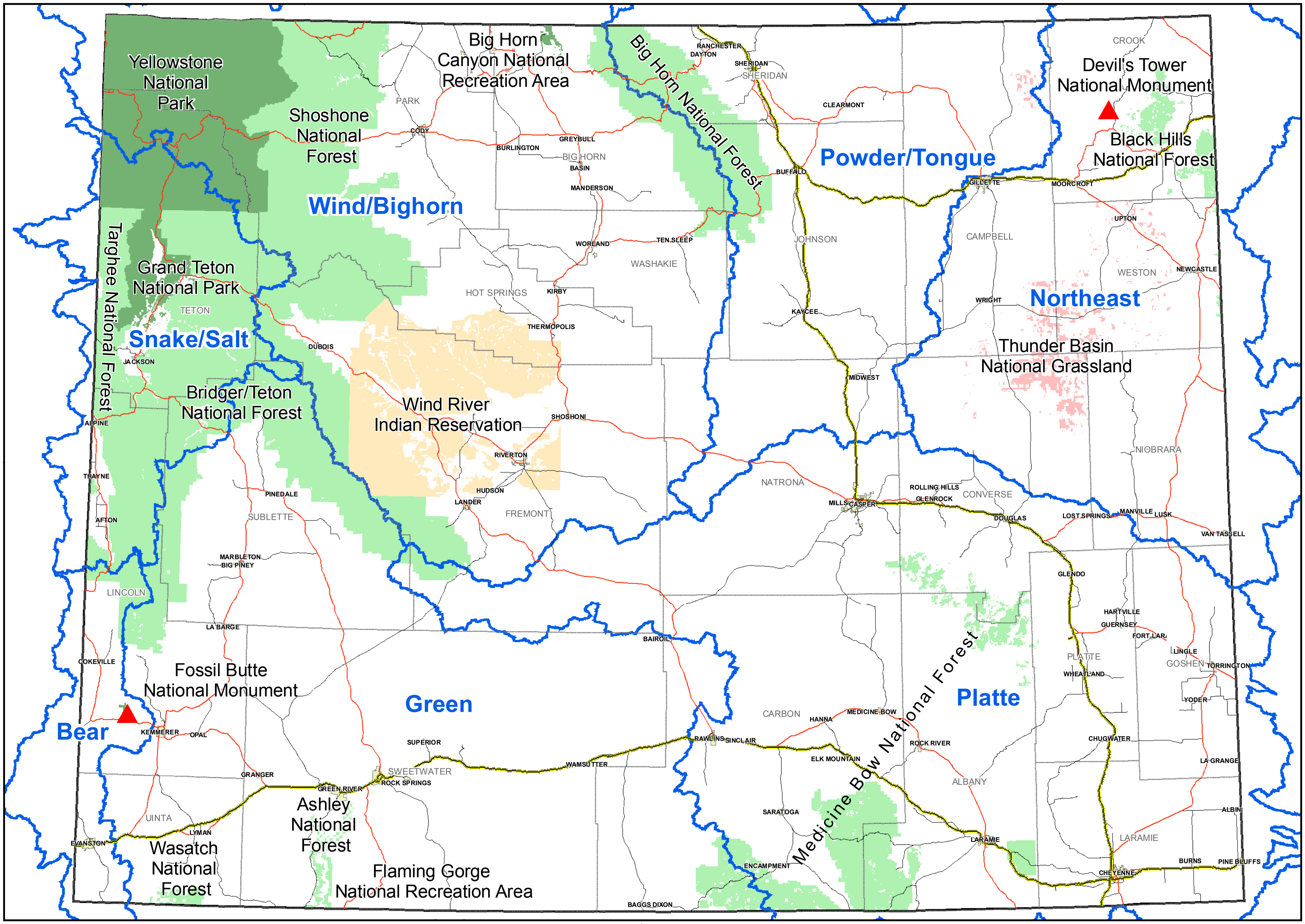
Source: Wyoming Geographic Information Science Center

**Figure 5-7**
**Ski Areas and Golf Courses**




Source: Wyoming Geographic Information Science Center and Wyoming State Parks and Historic Sites

**Figure 5-8**
**State Parks and Historic Sites**



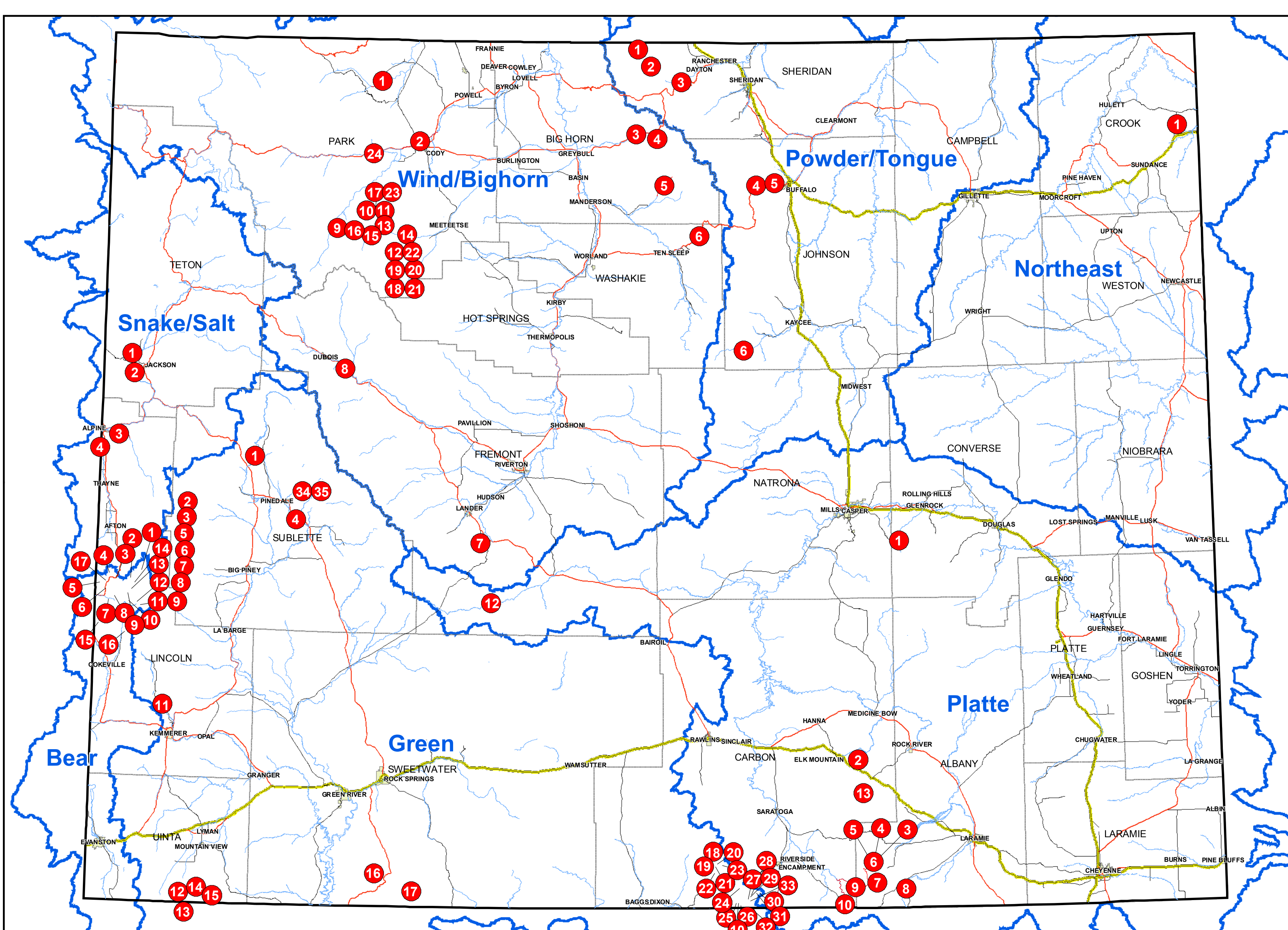

**LEGEND**

▲ National Monument

**Figure 5-9**
**National Parks, Forests, and Monuments**

| Basin | Map Number | Stream |
|---|---|---|
| Bear River | 1 | Poker Hollow Creek |
| | 2 | North Fork Smiths Fork River |
| | 3 | Water Canyon Creek |
| | 4 | Little White Creek |
| | 5 | Giraffe Creek |
| | 6 | Salt Creek |
| | 7 | Huff Creek |
| | 8 | Coal Creek |
| | 9 | Smiths Fork |
| | 10 | Porcupine Creek |
| | 11 | Coantag Creek |
| | 12 | Hobble Creek |
| | 13 | Trespass Creek |
| | 14 | Lander Creek |
| | 15 | Raymond Creek |
| | 16 | Coal Creek |
| | 17 | Packstring Creek |
| Northeast Wyoming | 1 | Redwater Creek |
| Platte River | 1 | Deer Creek |
| | 2 | Wagonhound Creek |
| | 3 | Camp Creek |
| | 4 | Nugget Gulch Branch |
| | 5 | Horse Creek |
| | 6 | Beaver Creek |
| | 7 | Lake Creek |
| | 8 | Laramie River |
| | 9 | Douglas Creek |
| | 10 | North Platte River |
| | 11 | South Fork of the Grand Encampment River |
| | 12 | Sweetwater River |
| | 13 | Rock Creek |
| Wind/Bighorn River | 1 | Clarks Fork River |
| | 2 | Shoshone River No. 1 |
| | 3 | Shell Creek No. 1 |
| | 4 | Shell Creek No. 2 |
| | 5 | Medicine Lodge No. 1 |
| | 6 | Tensleep Creek |
| | 7 | Little Popo Agie |
| | 8 | Big Wind River |
| | 9 | Currant Creek |
| | 10 | Pickett Creek No. 1 |
| | 11 | Pickett Creek No. 2 |
| | 12 | Francs Fork No. 1 |
| | 13 | Jack Creek No. 1 |
| | 14 | West Timber Creek No. 1 |
| | 15 | Piney Creek No. 1 |
| | 16 | Greybull River No. 1 |
| | 17 | N.F. Pickett Creek No. 1 |
| | 18 | Middle Fork Wood River |
| | 19 | Wood River above Middle Fork |
| | 20 | Wood River below Middle Fork |
| | 21 | South Fork of Wood River |
| | 22 | Dick Creek |
| | 23 | Marquette Creek |
| | 24 | Trout Creek |

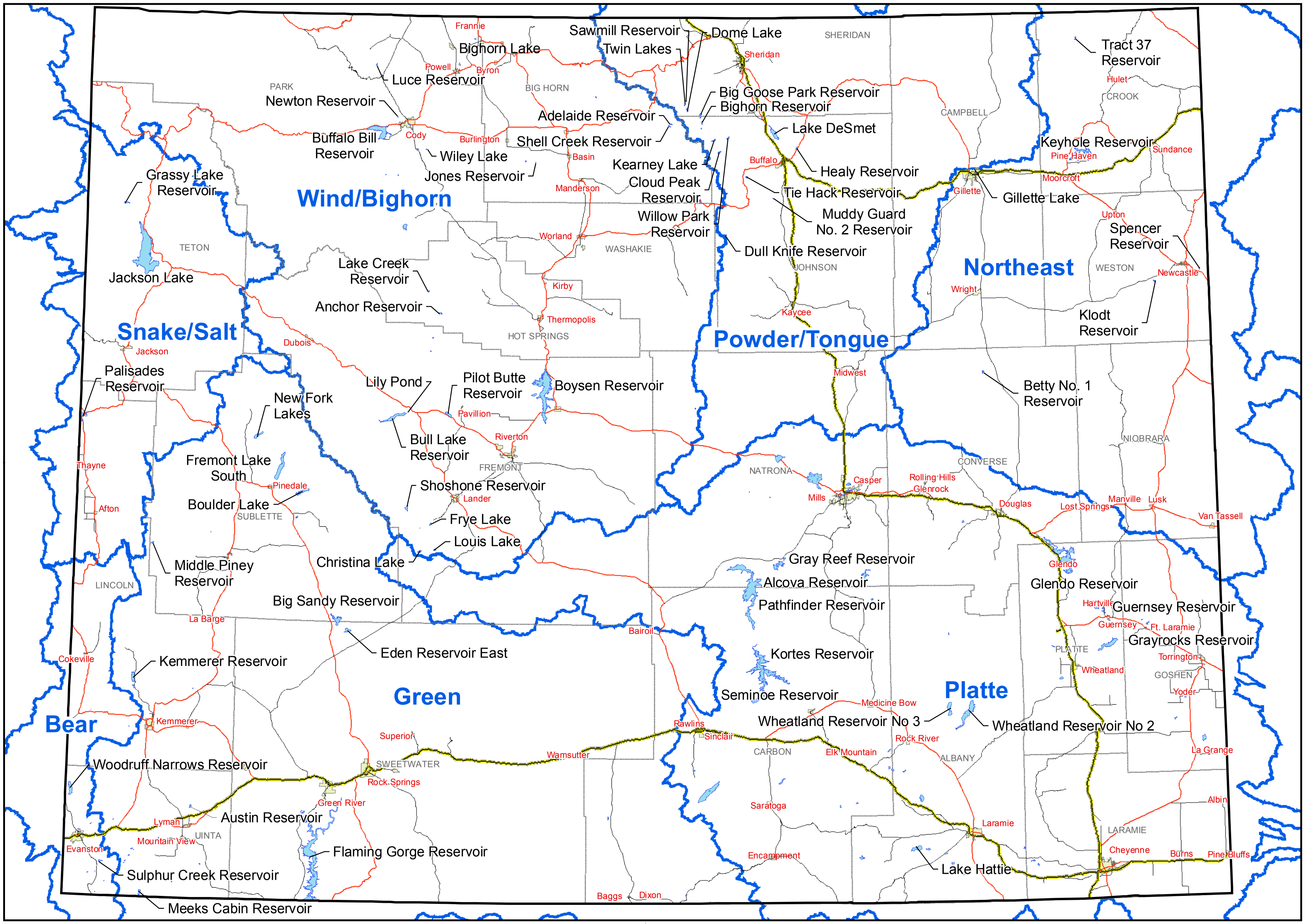
| Basin | Map Number | Stream |
|---|---|---|
| Snake/Salt River | 1 | Fish Creek No. 1 |
| | 2 | Fish Creek No. 2 |
| | 3 | Greys River |
| | 4 | Salt River |
| Green River | 1 | Green River |
| | 2 | North Cottonwood Creek |
| | 3 | South Cottonwood or Lander Creek |
| | 4 | West Fork New Fork River |
| | 5 | North Piney Creek |
| | 6 | Middle Piney Creek |
| | 7 | Fish Creek |
| | 8 | South Piney Creek |
| | 9 | LaBarge Creek |
| | 10 | Rabbit Creek |
| | 11 | Ham's Fork |
| | 12 | Gilbert Creek IF Seg. No. 1 |
| | 13 | Little Gilbert Creek IF Seg. No. 1 |
| | 14 | East Fork Smith's Fork Creek |
| | 15 | Sage Creek IF Seg. No. 1 |
| | 16 | Trout Creek IF Seg. No. 1 |
| | 17 | Red Creek IF Seg. No. 1 |
| | 18 | Dirtyman Fork Seg. No. 1 |
| | 19 | Deep Creek Seg. No. 1 |
| | 20 | Douglas Creek Seg. No. 1 |
| | 21 | Big Sandstone Creek Seg. No. 1 |
| | 22 | Mill Creek Seg. No. 1 |
| | 23 | North Fork Big Sandstone Creek Seg. No. 1 |
| | 24 | Roaring Fork L. Snake River Seg. No. 1 |
| | 25 | West Fork North Fork Little Snake River |
| | 26 | North Fork Little Snake River |
| | 27 | Solomon Creek |
| | 28 | Deadman Creek |
| | 29 | Harrison Creek |
| | 30 | Ted Creek |
| | 31 | Third Creek |
| | 32 | Rose Creek |
| | 33 | Granite Gulch/Green Timber |
| | 34 | Pine Creek No. 1 - from Fremont Lake |
| | 35 | Pine Creek No. 1 |
| Powder/Tongue River | 1 | Little Bighorn River |
| | 2 | Dry Fork |
| | 3 | Tongue River |
| | 4 | Clear Creek No. 1 |
| | 5 | Clear Creek No. 2 |
| | 6 | Middle Fork Powder River |




**LEGEND**

Instream Flow Segment

**Figure 5-10**
**Instream Flow Segments**

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Reservoir

**Figure 5-11**
**Selected Reservoirs Greater Than 1,000 ac-ft**

# 6.0 PROJECTIONS

This chapter presents future water demand projections for the state for three growth scenarios (high, mid, and low). Demographic and economic information is developed and relationships with water use are established for the various economic sectors within the state. The economic and demographic data are applied to develop water demand projections for the three growth scenarios.

## 6.1 FUTURE ECONOMIC AND DEMOGRAPHIC SCENARIOS

### 6.1.1 Overview of Planning Scenarios

Three alternative planning scenarios were developed for the seven river basin studies. This development employed various forecasting approaches that incorporated insights on overall regional growth patterns from local planning officials and industry representatives. An overview of each of these scenarios is provided below. More specific details about the assumptions for the key economic sectors in each river basin and the local insights on regional growth are provided in the technical memoranda associated with each of the individual river basin studies.

*High Scenario*

In the simplest terms, the High Scenario incorporates an estimation of the most growth in each of the key sectors and in the region that could potentially occur over the forecast horizon.

*Mid Scenario*

The Mid Scenario represents the assumed most realistic level of growth likely to occur in each of the key sectors and in the region over the planning horizon. Although the actual economic growth experienced in the basin may vary somewhat from this projection, the assumed activity levels represent the rate of growth most likely to be experienced in the river basins and in the state. As such, *this scenario may be the most useful for water planning purposes.*

*Low Scenario*

The Low Scenario embodies the estimated lowest simultaneous growth (or largest contraction) reasonably likely to occur in each of the key sectors and in the region over the planning horizon.

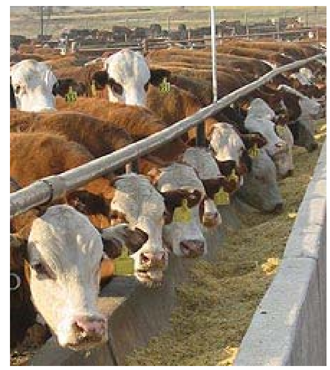
## 6.2 AGRICULTURAL DEMAND PROJECTIONS

### 6.2.1 Introduction

As discussed in Chapter 3, agriculture in Wyoming is dominated by livestock production and this holds true in all of the seven river basins. Much of the irrigated acreage in Wyoming is devoted to the production of forage in the form of alfalfa hay, other hay, feed grains, and irrigated pasture.

The factors that will most likely have the largest potential impact on the economic prospects for state agriculture are the demand for and price of beef. Sales of beef cattle and calves have comprised slightly over 75 percent of total agricultural cash receipts for the period 2000 to 2004 (Equality State Almanac, 2006). Other potential factors that may significantly impact agriculture include changes in public land grazing policies, second home and subdivision development, the aging of the ranching population, and management of cattle range with stockwater supplies. The following are summary descriptions about prospects for agriculture in Wyoming over the planning horizon under each of the planning scenarios.

*High Scenario*



The High Scenario for livestock production reflects what are considered to be the most optimistic stocking assumptions given production of feed from irrigated lands and public rangelands and strong demand and prices for beef, wool, and lamb. Other positive influences on agriculture in the High Scenario might be slower urban development and land subdivision or consolidation of ranches; investment in stockwater developments to increase range productivity; steady prices of inputs like fertilizer; and fewer cattle from outside areas grazing in the state as state cattle inventories increase. Sheep inventories would remain constant or decline slightly while cattle numbers would remain steady or increase, potentially to historic highs with exception of the Snake/Salt River Basin where all scenarios indicate declines in all livestock numbers.

Under the High Scenario, irrigated acreage will increase from current levels or remain constant in all river basins. Increases may be driven by increased production of hay for export as well as to support the increased livestock. The Wind/Bighorn River Basin will experience the most increase in irrigated acreage as the Tribal Futures Projects are brought on line and other projects in the basin are developed.

*Mid Scenario*

The Mid Scenario for livestock production reflects the most realistic stocking assumptions for lands in Wyoming, given production of feed from irrigated lands and arid rangelands. This scenario also assumes steady demand and prices for beef, wool, and lamb. Mid Scenario assumptions for agriculture in Wyoming are moderate urban development and land subdivision or consolidation of ranches; steady investment in stockwater developments to increase range productivity; and stable prices for inputs like fertilizer. Across the state, livestock numbers would remain fairly stable. Some river basins will likely experience continued declines in sheep numbers, or numbers will remain stable as is anticipated in the Platte River Basin. Most of the river basins will experience steady to slight increases in cattle numbers; however, the Snake/Salt River Basin is expected to experience declines in both sheep and cattle over the planning horizon. In the Snake/Salt River Basin, horse numbers make up a larger percentage of total livestock than in any other basin. Horse numbers are expected to continue to grow in the Snake/Salt River Basin as the area continues to be a major recreation area with a high demand for recreation horses.

Under the Mid Scenario, irrigated acreage in most of the river basins will remain relatively constant through the planning horizon. It is expected that most irrigated acreage will remain in production but that some acreage will be lost as a result of ranch sales to large corporations or to developers in the areas around Cheyenne, Laramie, and Casper and in the Teton and Lincoln County area. Ranchers will make up some of these losses by bringing additional acreage under irrigation. In the

Wind/Bighorn River Basin, some fairly significant increase may be expected with the development of some of the Tribal Futures Projects.

*Low Scenario*

The Low Scenario for livestock production reflects what are considered to be the most pessimistic stocking assumptions for the state given production of feed from irrigated lands and arid rangelands. This scenario also assumes weak demand and prices for beef, wool, and lamb. Other negative influences on agriculture assumed under the Low Scenario are faster urban development and land subdivision or consolidation of ranches; no investment in stockwater developments to increase range productivity; rising prices of inputs like fertilizer; and large numbers of outside cattle. Sheep inventories will continue to fall and cattle numbers will remain steady or decline, potentially to historic lows.

Under the Low Scenario, irrigated acreage will remain constant or decrease from current levels. The statistics on livestock numbers and irrigated acreage suggest that when economic conditions deteriorate in the river basin areas, ranchers respond primarily with changes in livestock herds and not as much with changes in irrigated acreage patterns. Under the Low Scenario, the crop mix is anticipated to remain unchanged with the highest percent of irrigated acreage planted in alfalfa, other hays, and pasture.

### 6.2.2 Future Water Needs and Demands

Needs and demands for irrigation water must be differentiated. A need for additional irrigation water is an identifiable current or future use that would enhance the economic well-being of the irrigator and/or the economy of the region as a whole. Demands are distinguished from needs by the fact that they are measured in relationship to price. To give a simple example, an irrigator may need additional irrigation water in a dry year to grow enough hay to provide winter feed for his cattle. However, if additional water costs $500 per acre-foot, the irrigator’s demand for additional water would probably be zero because it would be more cost-effective to either buy additional forage from other producers or reduce the size of his herd.

In analyzing municipal and industrial water uses, needs and demands are often viewed interchangeably. The cost of water is usually a relatively minor part of the costs involved in developing water intensive manufacturing facilities such as electric power plants. As a result, it can be assumed that industrial users will demand the water that they need to expand production over a reasonable range of prices. Similarly, municipal needs are usually assumed to be essential and thus will be translated into demands over a reasonable price range. That convention was used for projecting municipal and industrial demands. Irrigated agriculture, however, is an industry in which producers are very sensitive to the price of water, and their demands for water can change dramatically as a function of price.

To determine the level of need and demand for irrigation water, all irrigated lands in the seven river basins were mapped as part of the river basin planning efforts. Table 6-1 shows the current level of irrigation in each of the river basins and also shows the projected increase in irrigated acreage for each basin.

**Table 6-1 Presently Irrigated Acreage and Projected Irrigation Development**

| River Basin | Current | 30 Year Projections | | |
|---|---|---|---|---|
| | | High Scenario | Mid Scenario | Low Scenario |
| | acres | | | |
| Bear | 64,000 | 69,000 | | 61,000 |
| Green | 330,000 | | | 330,000 |
| Northeast | 87,000 | | | 87,000 |
| Platte | 612,000 | 649,000 | 612,000 | 602,000 |
| Powder/Tongue | 170,000 | | | 170,000 |
| Snake/Salt | 99,000 | 103,000 | 87,000 | 76,000 |
| Wind/Bighorn[1] | 600,000 | 810,000 | 670,000 | 600,000 |

Note: Blanks indicate that no data was developed for this scenario.

[1] Current Wind/Bighorn figure is modeled irrigated acreage for full-supply scenario and does not include Popo Agie Basin or Tribal Futures projects.

Irrigation in Wyoming requires large volumes of water, and is the largest single water use in Wyoming. Irrigation requirements are expressed in terms of diversion requirements and consumptive irrigation requirements (CIR). Table 6-2 presents the irrigation diversion requirement for each river basin. Diversion data presented are based on the normal year. Dry year and wet year information is contained in the individual river basin plans.

**Table 6-2 Current and Projected Irrigation Diversions**

| River Basin | Current Diversions | 30 Year Projections | | |
|---|---|---|---|---|
| | | High Scenario | Mid Scenario | Low Scenario |
| | ac-ft | | | |
| Bear[1] | 295,000 | 312,000 | | 277,000 |
| Green[2] | | | | |
| Northeast | 152,000 | 258,000 | 194,000 | 152,000 |
| Platte | 1,553,000 | 1,640,000 | 1,553,000 | 1,522,000 |
| Powder/Tongue | 381,000 | 594,000 | 465,000 | 381,000 |
| Snake/Salt | 363,000 | 382,000 | 319,000 | 285,000 |
| Wind/Bighorn | 3,278,000 | 4,070,000 | 3,549,000 | 3,278,000 |

[1] A Mid Scenario was not developed in this plan.

[2] Diversion data were developed for only those ditches that had measured flow data and are not presented due to the incomplete nature of the data.

The CIR or use for each river basin is displayed in Table 6-3.

**Table 6-3 Current and Projected Consumptive Irrigation Use**

| River Basin | Current Use | 30 Year Projections | | |
|---|---|---|---|---|
| | | High Scenario | Mid Scenario | Low Scenario |
| | ac-ft | | | |
| Bear[1] | 95,000 | 100,000 | 95,000 | 89,000 |
| Green | 401,000 | 438,000 | 423,000 | 408,000 |
| Northeast | 86,000 | 94,000 | 91,000 | 86,000 |
| Platte | 663,000 | 700,000 | 661,000 | 650,000 |
| Powder/Tongue | 184,000 | 205,000 | 194,000 | 184,000 |
| Snake/Salt | 122,000 | 128,000 | 107,000 | 95,000 |
| Wind/Bighorn | 1,165,000 | 1,576,000 | 1,306,000 | 1,165,000 |

[1] A Mid Scenario was not developed in this plan. Current use was used in place of the Mid Scenario.

Tables 6-2 and 6-3 present the volumes of water that will be required in each river basin to provide for the irrigation water needs and demand to satisfy the CIR and the diversion requirement.

### 6.2.3 Tribal Futures Agricultural Projects

The Wind/Bighorn River Basin shows the greatest potential for new irrigation development. The tribal awards for future development commonly known as the "Futures Projects" encompass a fairly large acreage and have an associated senior irrigation diversion right.

As part of the Bighorn Decree (Roncolio, 1982), the Eastern Shoshone and Northern Arapaho Tribes were awarded Federal Reserved Water Rights for not only lands with existing irrigation, but also lands that could be economically irrigated as determined through a Potentially Irrigable Acres (PIA) study. PIA studies have become the benchmark for quantification of Federal Reserved Water Rights throughout the western United States. A PIA study is a compilation of agronomy, engineering, and economic analysis that identifies currently undeveloped land that could feasibly be irrigated. The results of this PIA study were the conceptual development of five projects encompassing approximately 54,000 acres on the Wind River Reservation. The projects, conceptual land area, and awarded diversion requirement are shown in Table 6-4. Figure 6-1 shows the location of the Futures Projects.

**Table 6-4 Tribal Futures Projects**

| Futures Project | Awarded (Roncolio, 1982) | | | Modeled | | |
|---|---|---|---|---|---|---|
| | Land Area | Diversion Requirement | | Land Area | Diversion Requirement | |
| | acres | ac-ft | ac-ft/ac | acres | ac-ft | ac-ft/ac |
| North Crowheart | 38,800 | 147,800 | 3.8 | 40,800 | 155,100 | 3.8 |
| South Crowheart | 4,700 | 20,100 | 4.3 | 5,000 | 19,700 | 3.9 |
| Arapahoe | 3,800 | 16,700 | 4.4 | 3,800 | 16,700 | 4.4 |
| Riverton East | 3,800 | 17,500 | 4.6 | 4,000 | 15,100 | 3.7 |
| Big Horn Flats | 2,700 | 7,200 | 2.7 | 2,800 | 7,800 | 2.8 |
| **Total** | **53,800** | **209,300** | **3.9**[1] | **56,400** | **214,400** | **3.8**[1] |

[1] Average Diversion Requirement.

Tribal Futures Projects were included in water supply modeling runs to determine their general effect on streamflows and other diversions within the WBHB. The data included in the model for the Futures Projects were developed the same as the other diversion data for the model. An overall efficiency of 55 percent was utilized for those projects, where conveyance was proposed through open ditches, while an overall efficiency of 62 percent was used for conveyance through pipelines. Both of these efficiencies assume improved onfarm applications, such as gated pipe and/or sprinklers as developed in previous studies for Riverton East (Nelson Engineering, 2001) and the Soil Conservation Service (SCS, 1992).

As shown in Table 6-4, there are slight differences between the awarded and modeled acreages and diversion requirements for the Futures Projects. The information for the Wind/Bighorn River Basin plan was developed using the most current reasonable data for climate, crop water requirements, and anticipated efficiencies for the Projects, thus accounting for the differences in developed values. The information presented in the Wind/Bighorn River Basin plan regarding Futures Projects is in no way intended to imply or suggest proposed changes to the decree.

The effects of Tribal Futures Projects on flows within the Wind/Bighorn River Basin and on other diversions within the basin are more fully described in the Wind/Bighorn River Basin technical memorandum, “Available Surface Water Determination”. A brief description of each potential Futures Project within the Wind/Bighorn River Basin is contained in the basin plan. The Arapahoe Irrigation Project is discussed in the WWDC’s Popo Agie Watershed Study (Anderson Consulting Engineers, 2003).

### 6.2.4 Irrigable Lands

All of the new irrigation projects identified in the river basin planning area studies are in the WBHB planning area. New irrigation identified in the other river basin planning areas, is primarily individual development and on a much smaller scale than in the WBHB.

In addition to Tribal Futures Projects, there are other potential agricultural development projects within the WBHB that have been discussed over the years. Table 6-5 presents the potentially irrigable areas. The potentially irrigable areas are also shown on Figure 6-1. The annual CIR and diversion requirements shown in the table were developed similar to existing irrigated lands.

**Table 6-5 Summary of Potentially Irrigable Lands Within the Wind/Bighorn Basin**

| Basin | Name | Subbasin | Irrigable Area | Annual CIR | | Annual Div. Req. | |
|---|---|---|---|---|---|---|---|
| | | | | Total | Unit | Total | Unit |
| | | | acres | ac-ft | ac-ft/ac | ac-ft | ac-ft/ac |
| Bighorn, Clarks Fork | Polecat Bench[1] | Clarks Fork, Shoshone | 19,200 | 38,400 | 2.0 | 72,960 | 3.8 |
| Bighorn | North Cody[1] | Shoshone | 500 | 850 | 1.7 | 1,600 | 3.2 |
| | South Cody[1] | Shoshone | 2,000 | 3,400 | 1.7 | 6,400 | 3.2 |
| | West Greybull[1] | Big Horn Lake, Greybull | 1,000 | 2,200 | 2.2 | 4,300 | 4.3 |
| | Westside[1] | Upper Bighorn | 11,700 | 23,400 | 2.0 | 45,630 | 3.9 |
| | YU Bench[1] | Greybull | 17,300 | 29,410 | 1.7 | 57,090 | 3.3 |
| Wind | Arapahoe | Little Wind, Popo Agie | 3,800 | 7,980 | 2.1 | 14,820 | 3.9 |
| | Bighorn Flats | Little Wind, Upper Wind | 2,700 | 4,590 | 1.7 | 8,640 | 3.2 |
| | North Crowheart | Lower Wind, Upper Wind | 38,800 | 85,360 | 2.2 | 162,960 | 4.2 |
| | Riverton East | Little Wind, Upper Wind | 3,800 | 7,980 | 2.1 | 15,960 | 4.2 |
| | Sand Mesa[1] | Lower Wind | 1,700 | 4,250 | 2.5 | 8,330 | 4.9 |
| | South Crowheart | Little Wind, Upper Wind | 4,700 | 9,400 | 2.0 | 18,330 | 3.9 |
| Total (Tribal Futures Projects) | | | 53,800 | 115,310 | 2.1[2] | 220,710 | 4.1[3] |
| Total (Non-Tribal Futures Projects) | | | 53,400 | 101,910 | 1.9[2] | 196,310 | 3.7[3] |
| **Total** | | | **107,200** | **217,220** | **2.0**[2] | **417,020** | **3.9**[3] |

Note: Project names based on general location within WBHB because they are not associated with other previously identified projects.

[1] Projects not associated with Tribal Futures.

[2] Average Annual CIR.

[3] Average Annual Div. Req.

The largest non-Futures Projects irrigable land groups are the Westside Irrigation Project in the Upper Bighorn River subbasin, lands on the YU Bench in the Greybull River subbasin, and lands on the Polecat Bench in the Shoshone and Clarks Forks subbasins. More information is contained in the river basin plan.

Another water use by the agriculture sector is livestock water. While this use is relatively small, it is closely associated with irrigated agriculture and the production of forage for livestock. Table 6-6 presents estimates of livestock water usage for the three scenarios.

**Table 6-6 Livestock Consumptive Use**

| River Basin | Current | 30-Year Projections | | |
|---|---|---|---|---|
| | | High Scenario | Mid Scenario | Low Scenario |
| | ac-ft | | | |
| Bear | 530 | 610 | 540 | 490 |
| Green[1] | 3,200 | | | |
| Northeast[1] | 2,900 | | | |
| Platte | 6,300 | 7,600 | 6,600 | 5,200 |
| Powder/Tongue[1] | 2,700 | | | |
| Snake/Salt | 470 | 410 | 340 | 210 |
| Wind/Bighorn[1] | 3,100 | | | |

[1] Current use for these river basin planning areas was estimated based on information in the technical memoranda for each basin area. Projections for these areas were not prepared as part of the river basin plans for the areas.

## 6.3 MUNICIPAL AND DOMESTIC DEMAND PROJECTIONS

### 6.3.1 Introduction

Municipal and domestic use projections were created by combining current use rates with population projections for each river basin planning area. Current municipal and domestic consumption or use is described in Chapter 5.

### 6.3.2 Population Projections

This section presents population projections for the communities and rural areas of the planning region for the time period from 2000 through 2030 for low, moderate, and high growth planning scenarios. The projections also provide a basis for assessing water-based recreational resource needs.

*Current and Projected Population Estimates*

The first step in developing population projections is to estimate current population. Population estimates for cities and towns were taken from the results of the 2000 census or recent estimates. Because the geographical boundaries of the river basin planning areas do not adhere to county lines, it was necessary to adjust the county population estimates from the 2000 census to reflect only the proportion of each county that lies within each river basin planning area boundary. (Chapter 3 provides more detailed information.)

The geographical distribution of the current population by county by river basin planning area is described in the individual river basin plans. The individual river basin plans used or referred to one or more of the following three population projection methods in developing the individual river basin plan projections:

- Wyoming Department of Administration and Information (WDAI) projections
- U.S. Census Bureau (USCB) projections
- Historical growth projections

These three methods were used to generate population forecasts through the year 2030 for communities and rural areas. The WDAI extended forecasts generally resulted in the smallest population projections, followed by the USCB projections and the historical growth projections in that order.

Table 6-7 shows the 30-year projected populations of the seven river basins for the high, mid and low scenarios.

**Table 6-7 Actual and Projected Populations**

| River Basin | Population[1] | 30-Year Projections | | |
|---|---|---|---|---|
| | | High Scenario | Mid Scenario | Low Scenario |
| | number of people | | | |
| Bear | 14,550 | 29,400 | 21,500 | 15,100 |
| Green | 54,760 | 91,400 | 75,000 | 62,500 |
| Northeast | 45,600 | 75,900 | 60,700 | 55,600 |
| Platte | 227,330 | 402,000 | 343,000 | 322,000 |
| Powder/Tongue | 38,420 | 52,400 | 49,100 | 45,000 |
| Snake/Salt | 27,480 | 75,100 | 46,700 | 29,300 |
| Wind/Bighorn | 86,050 | 114,400 | 94,600 | 90,400 |
| **Total** | **494,190** | **840,600** | **690,600** | **619,900** |

[1] Individual basin numbers do not total to 493,782, the 2000 census population, due to differences experienced in disaggregation and assignment of census block data to the river basin areas.

Source: Wyoming Department of Administration and Information, Economic Analysis Division. Profile of General Housing Characteristics by County and Place, 2000. Census Tracts from 2000 Census of Population and Housing, Census 2000, U.S. Census Bureau.

*WDAI Population Projections*

The Economic Analysis Division of the WDAI produces population forecasts for Wyoming counties, cities, and towns.

The Economic Analysis Division forecasts population only 10 or fewer years into the future because of the uncertainties associated with such projections. A reasonable set of low growth rate population projections can be derived by computing the WDAI's average annual population growth rates for the river basin planning area by using the most recent forecasts and extending those growth rates through the planning horizon.

*USCB Projections*

The USCB periodically produces population forecasts for each of the 50 states using a cohort survival approach, which is based on births and deaths. USCB forecasts for Wyoming are contained in two sets of population projections, the Series A and Series B forecasts.

Both series of projections indicate moderate future population growth for Wyoming based upon migration patterns in the mid-1990s. During that period, there was a moderate influx of new residents into some parts of Wyoming from elsewhere in the country. The USCB projections are based upon the assumption that this moderate rate of net in-migration will continue into the future.

*Historical Growth Projections*

A third set of population projections was developed from an analysis of historical population growth. The state experienced rapid population growth during the 30-year period from 1970 through 2000. A reasonable set of high growth population projections can be developed by assuming that the absolute population growth that occurred during that period will occur during the next 30 years.

*Economic Base Methodology*

The economic and demographic projection approach employs an established technique in regional economics known as "economic base analysis". The economic base approach is a "bottom-up" method that focuses directly on specific activities that are likely to drive economic and demographic changes in the future, while at the same time being less data-intensive than econometric modeling approaches.

A modified version of the economic base forecasting approach was used in some of the river basin plans. A more detailed discussion of the population projection technique used in each river basin plan is included in the final river basin plans and the associated technical memorandum.

### 6.3.3 Municipal and Domestic Use Projections

Current per capita use rates for municipal water consumption are presented in Chapter 5. These rates were applied to population projections for incorporated cities and towns in the planning area to estimate future municipal use. For purposes of projecting future use, small, unincorporated areas were included in the domestic demand projections. A more detailed discussion, of both municipal and domestic use, is contained in the seven river basin plans.

Table 6-8 shows the projected municipal and domestic water use for the High, Mid, and Low Scenarios.

**Table 6-8 Projected Municipal and Domestic Water Use**

| River Basin | 30-Year Projections | | |
|---|---|---|---|
| | High Scenario | Mid Scenario | Low Scenario |
| | Surface Water (ac-ft) | | |
| Bear | 4,700 | 3,400 | 2,400 |
| Green | 24,500 | 22,500 | 21,000 |
| Northeast | 0 | 0 | 0 |
| Platte | 33,500 | 28,400 | 26,600 |
| Powder/Tongue | 10,000 | 9,300 | 8,600 |
| Snake/Salt | 0 | 0 | 0 |
| Wind/Bighorn | 18,000 | 14,900 | 14,200 |
| **Total** | **90,700** | **78,500** | **72,800** |
| | Groundwater (ac-ft) | | |
| Bear | 1,500 | 1,100 | 900 |
| Green | 3,700 | 3,500 | 3,000 |
| Northeast | 15,900 | 12,700 | 11,600 |
| Platte | 11,200 | 9,500 | 8,900 |
| Powder/Tongue | 3,300 | 3,200 | 2,800 |
| Snake/Salt | 18,600 | 11,500 | 7,200 |
| Wind/Bighorn | 8,500 | 7,000 | 6,700 |
| **Total** | **62,700** | **48,500** | **41,100** |

Note: None of the municipal or rural domestic water systems in the Northeast Wyoming River Basin or in the Snake/Salt River Basin use surface water.

Source: River basin plans and associated technical memoranda.

Under the Mid Scenario, it is projected that in 30 years the state will require about 64,000 acre-feet of surface water to satisfy the municipal and domestic water demands. The largest basin in terms of municipal and domestic water demand is the Platte River Basin, and it will annually need to supply over 28,000 acre-feet of consumptive use.

Municipal and domestic groundwater use for the state under the Mid Scenario will require about 48,500 acre-feet to satisfy the projected municipal and domestic water demand. The largest basin in terms of municipal and domestic consumptive groundwater demand is the Northeast Wyoming River Basin with a Mid Scenario demand of about 12,700 acre-feet annually in 30 years.

As can be seen from Table 6-8, the state will need to supply a considerably larger amount of both surface water and groundwater under the High Scenario to satisfy municipal and domestic needs and demands over the 30-year planning horizon.

## 6.4 INDUSTRIAL DEMAND PROJECTIONS

Current industrial water uses are described in Chapter 5. This section presents projections of industrial water needs for the 30-year planning period. These projections provide a basis for gauging the adequacy of current water supplies in the individual river basin planning areas and the state to meet potential future needs. Projections were developed for high, mid, and low level growth scenarios.

### 6.4.1 Future Coal-fired and Natural Gas-fired Electric Power Production

Several companies have announced plans to build additional generating capacity in the Northeast Wyoming River Basin, and those plans are in various stages of implementation. The plans for plants involve dry cooling towers and limited usage of groundwater for process purposes. Water requirements for dry-cooled plants are less than for plants with wet cooling towers which are in use at other locations, including the Dave Johnston Power Plant in Converse County, Laramie River Station in Platte County, Naughton Power Plant in Lincoln County, and Jim Bridger Power Plant in Sweetwater County. While wet-cooled plants are more efficient and less costly to run than dry-cooled plants, their water requirements are much larger. Given the fact that there is relatively little surface water available in proximity to the coal resources of Northeast Wyoming, it appears likely that dry cooling will remain the technology of choice in Northeast Wyoming for power production for the foreseeable future.

In the Green River Basin, the expansion would be wet-cooled plants supplied by surface water from the Green River.

The most agressive development in the Platte River Basin would include the addition of natural gas-fired generation capacity and coal conversion. This additional capacity would be two wet-cooled plants.

In the Powder/Tongue River Basin, additional generating capacity would be wet-cooled and likely associated with Lake DeSmet Reservoir where substantial volumes of water are available.

The Wind/Bighorn River Basin is the remaining basin where coal or natural gas-fired generation capacity might be built. The development of two coal-fired power plants and two natural gas-fired power plants would be wet-cooled.

The Bear River Basin and the Snake/Salt River Basin will not likely see any development of coal-fired or natural gas-fired electrical power generation during the planning period.

Projections of future water needs for electric power generation are described below for high, moderate, and low growth scenarios. The Northeast Wyoming projections are based upon the assumption that dry cooling and limited groundwater pumping for process water will continue to be the predominant technology employed. An added assumption for the High and Mid Scenarios is that the transmission bottleneck out of Wyoming will be eliminated and thus encourage the construction of additional electrical generating capacity.

*High Scenario*

In the Green River Basin, the High Scenario assumes that in addition to a 1,000 MW expansion of the Jim Bridger Power Plant, a new 3,000 MW coal-fired generating facility will be built in the vicinity of coal deposits near Creston Junction, using water piped from the Green River. This will require an additional 68,700 acre-feet of cooling water.

The High Scenario for electric power production in Northeast Wyoming assumes that 2,390 MW of planned capacity addition will take place, and that an additional 1,200 MW of capacity not yet announced will be added to help meet the nation’s growing energy needs. This additional capacity may require the adoption of new emissions control technology to meet air quality standards or the relaxation of those standards to allow increased production, neither of which is assured. Nevertheless, the addition of 3,590 MW of generating capacity constitutes a reasonable High Scenario forecast for Northeast

Wyoming. Under all scenarios the 33 MW Osage Power Plant is assumed to be retired. Total generating capacity for the High Scenario in Northeast Wyoming is 4,020 MW, and total water requirements would be about 10,100 acre-feet annually. Using wet cooling technology for the new capacity would bring total water requirements to slightly over 70,000 acre-feet annually.

The Platte River Basin High Scenario assumes the development of 1,000 MW of natural gas-fired generation capacity plus 500 MW of coal-based generation capacity. The 500 MW of generation capacity are associated with a coal conversion plant that will produce about nine million barrels of diesel fuel per day. The natural gas-fired power plant will require about 10,000 acre-feet of water annually. The coal conversion plant will require about 15,000 acre-feet per year.

In the Powder/Tongue River Basin the High Scenario assumes the development of 2,000 MW of coal-fired generation capacity in the area of Lake DeSmet Reservoir. With the relatively cheap and already developed water in Lake DeSmet, it is likely that a 2,000 MW plant will be built during the planning period. This plant will be wet-cooled and will require about 34,000 acre-feet of water annually.

The High Scenario for the Wind/Bighorn River Basin assumes that there will be two 200 MW coal-fired power generating plants built in the basin and that there will be two 500 MW natural gas-fired power plants built in the basin during the planning period. The two coal-fired plants would require 8,000 acre-feet of water while the two natural gas-fired plants would require 10,000 acre-feet of water annually.

The Bear River Basin and the Snake/Salt River Basin are not projected to have any coal-fired or natural gas fired electrical power generation development during the 30-year planning period.

Future electric power generation water use projections for the High Scenario are presented in Table 6-9.

*Mid Scenario*

The moderate growth scenario is based upon the reasonably foreseeable possibility that co-generation facilities will not be developed at a rate sufficient to meet regional power needs over the next 30 years.

In the Green River Basin, the logical location for a moderate expansion of generating capacity is the Jim Bridger Power Plant near Point of Rocks, east of Rock Springs. The facility was originally designed for up to six 500 MW coal-fired generating units, although only four such units have been installed. The existing units are among the most cost-efficient in the Rocky Mountain Power generating system, and an expansion to six coal-fired units at Jim Bridger would be a logical step to increase regional power production in a cost-effective manner. The moderate growth scenario for electric power production in the basin projects a 50 percent increase in water requirements for the Jim Bridger Power Plant over the next 30 years, with water requirements at the Naughton facility remaining constant at current levels. Total water use for the moderate growth scenario is projected to grow from a current rate of 47,800 acre-feet annually to approximately 65,000 acre-feet in 30 years.

The moderate growth scenario for electric power production in Northeast Wyoming River Basin assumes that the permitting and financial uncertainties surrounding future expansion will be resolved over the next 30 years and that all currently planned capacity additions will be online by then. In that case, 2,390 MW of additional generating capacity would be in place by the year 2030, bringing the total to 2,820 MW. If dry cooling technology is used, total water requirements would be about 6,900 acre-feet annually. If wet cooling technology is used for new generating units, total water requirements would rise to about 41,100 acre-feet annually.

**Table 6-9 Projected Electrical Generation Water Needs**

| River Basin | Type of Generation | Existing Generation Capacity | 30-Year Projections | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Additional Projected Generation Capacity | | | Cooling Water Total Use - Surface Water | | | Cooling Water Total Use - Groundwater | | |
| | | | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario |
| | | MW[1] | MW[1] | | | ac-ft | | | ac-ft | | |
| Bear | None | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Green | Coal | 2,700 | 4,000 | 1,000 | 0 | 116,500 | 65,000 | 47,800 | 0 | 0 | 0 |
| Northeast[2] | Coal | 500 | 3,600 | 2,400 | 1,200 | 0 | 0 | 0 | 10,100 | 6,900 | 3,700 |
| Platte | Coal | 2,500 | 500 | 0 | 0 | 15,000 | 31,900 | 31,900 | 0 | 0 | 0 |
| | Natural Gas | 0 | 1,000 | 1,000 | 0 | 10,000 | 10,000 | 0 | 0 | 0 | 0 |
| Powder/Tongue | Coal | 0 | 2,000 | 1,000 | 0 | 34,000 | 17,000 | 0 | 0 | 0 | 0 |
| Snake/Salt | None | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wind/Bighorn | Coal | 0 | 400 | 200 | 0 | 8,000 | 4,000 | 0 | 0 | 0 | 0 |
| | Natural Gas | 0 | 1,000 | 500 | 0 | 10,000 | 5,000 | 0 | 0 | 0 | 0 |
| **Total** | | **5,700** | **12,500** | **6,100** | **1,200** | **193,500** | **132,900** | **79,700** | **10,100** | **6,900** | **3,700** |

[1] MW = megawatts

[2] The 33MW Osage Power Plant is assumed to be retired

The Platte River Basin Mid Scenario assumes that a 1,000 MW natural gas-fired power plant is constructed in the 30-year planning period. This plant would require 10,000 acre-feet of cooling water.

In the Powder/Tongue River Basin for the Mid Scenario, it is assumed that a 1,000 MW coal-fired power plant is constructed near Lake DeSmet Reservoir. The annual water need for this plant is 17,000 acre-feet.

The Mid Scenario for the Wind/Bighorn River Basin assumes that there will be a 200 MW coal-fired power generating plant built in the basin and that there will be a 500 MW natural gas-fired power plant built in the basin during the planning period. The coal fired plant would require 4,000 acre-feet of water while the natural gas-fired plant would require 5,000 acre-feet of water annually.

Future electric power generation water use projections for the Mid Scenario are presented in Table 6-9.

*Low Scenario*

In the Green River Basin, the Low Scenario for future power generation projects current levels of water consumption for power generation to remain constant over the next thirty years (approximately 47,800 acre-feet annually).

The Low Scenario is based upon the assumption that additional power needs in the western U.S. over the next 30 years will be met by the construction of new generating facilities outside of the basin, possibly co-generation facilities developed in conjunction with industrial plants in other states.

The Low Scenario for Northeast Wyoming future electric power production assumes that only 50 percent of the 2,390 MW of announced new capacity will eventually be built. That additional capacity would bring total generating capacity in the planning area to 1,625 MW during the 30-year planning period. If dry cooling technology is used, total annual water use for power generation would rise to about 3,700 acre-feet annually. Almost all of this water would be supplied by ground water wells. If low cost surface water or CBM water were available in sufficient quantities to make wet cooling technology practical for the new plants, water consumption would rise to about 20,800 acre-feet annually.

The Low Scenarios for the Platte River, Powder/Tongue River, and Wind/Bighorn River Basins assume that no new-coal fired or natural gas-fired power generation capacity is developed.

Future electric power generation water use projections for the Low Scenario are presented in Table 6-9.

### 6.4.2 Coal, Uranium, and Miscellaneous Mining

*Coal*

Wyoming is the number one coal-producing state with the bulk of Wyoming's coal being mined in the Northeast Wyoming River Basin planning area. Northeast Wyoming has enormous resources of low-sulfur, low-BTU coal that can be mined from the surface due to relatively shallow overburden. During the year 2000, there were 14 active mines in the planning area with a total annual production of 322.7 million tons.

These coal mines use water primarily for dust abatement and reclamation, with lesser amounts used for equipment wash-down and typical sanitary purposes. The primary sources of water for most mines are dewatering wells drilled into the coal seam ahead of advancing pit operations and sump wells to remove water from the pit. A few mines are extracting dry coal, however, and have drilled groundwater wells away from the coal seam to meet their needs.

In the Green River Basin, coal is produced primarily to supply the two coal-fired electric generation plants. During the year 2000, there were two active mines in the planning area with a total annual production of almost 13.7 million tons. Coal mining water uses in the Green River Basin are very similar to the uses in the Northeast Wyoming River basin.

In the Platte River Basin, there were two active coal mines at the start of the planning period, however, one is in the process of closing and going into reclamation. In 2000 these two mines produced about 2 million tons of coal.

The remaining river basin with coal-producing potential is the Powder/Tongue River Basin. This basin presently has no active producing mines.

Future water use by the coal industry is expected to increase slightly for two reasons. First, the pits at some mines are expanding away from the coal processing facilities onsite, thus requiring longer hauls and more water use for dust suppression. Second, some mines anticipate expanding production in the future if coal prices remain firm at current levels or increase. Nevertheless, most mines will continue to meet their operational water needs from dewatering wells and sumps on site. These activities are not expected to affect either surface water resources or other groundwater users.

*Uranium*

Uranium has been mined in several of the river basin planning areas. The only active uranium mines are in the Platte River Basin. It is projected in the High Scenario that Jackpot Mine above Pathfinder Reservoir will reopen and an in situ mine will open in the Gas Hills area of the Wind/Bighorn River Basin. The Kennecott Uranium Company is not anticipated to reopen its mine in the Great Divide Basin of the Green River Basin planning area.

*Miscellaneous Mining*

Other minerals that are mined in Wyoming are bentonite, gypsum, aggregates, sand, and gravel. Active bentonite and gypsum mining is primarily located in the Wind/Bighorn River Basin. Small mining operations, extracting aggregate, sand, and gravel, are widely scattered across the state and use varying but small amounts of water.

#### 6.4.3 Oil Production and Refining

All but three of the counties in Wyoming have active crude oil production. In 2000 Wyoming produced 60,607,000 barrels of crude oil. Production dropped to 51,651,000 barrels in 2004 (Equality State Almanac, 2006). This is consistent with the long-term trend of declining oil production in Wyoming. In addition to the actual extraction of the oil, the state also has oil refining capabilities. The bulk of the refineries are located in the Platte River Basin.

Water use in this sector varies across the state but typically is relatively minor. Water is often produced as a by-product of oil extraction. This water is reinjected, used for enhanced oil recovery, or discharged. The companies also drill water wells to provide water for enhanced recovery of oil. Actual water withdrawals are not monitored so the actual amount of water used or discharged by the industry is difficult to determine. Approaches to estimating water use for oil production and refining in the seven river basin areas differ considerably. Detailed information on the approach used and results are contained in the individual river basin plans and associated technical memoranda.

### 6.4.4 Coalbed Methane and Natural Gas Production

Natural gas and coalbed methane (CBM) development use little water in exploration and production. CBM usually produces water during the methane extraction process.

CBM production has become widespread in the Northeast Wyoming River Basin and the Powder/Tongue River Basin over the past few years and is expected to increase in the future. CBM development is not a consumptive user of water resources but produces groundwater as a by-product of gas production. The process involves pumping water from coal seams to relieve pressure on methane gas so that it can be captured at the surface. The availability and disposal of CBM process water present both problems and opportunities in the formulation of a water plan. Figure 6-2 shows the locations of CBM wells and development areas.

In the Northeast Wyoming River Basin Plan, projected CBM water production for Northeast Wyoming was expected to reach a peak of about 55,000 acre-feet annually by the year 2004. Production was expected to remain at that level for about five years and then drop off to less than 2,000 acre-feet annually by the year 2019.

In the Powder/Tongue River Basins Plan, projected water production for Powder/Tongue River Basin CBM wells was expected to reach a peak of about 190,000 acre-feet annually by the year 2005. Production was expected to remain at that level for about five years, and then drop off to less than 25,000 acre-feet annually by the year 2019. More recent studies by the Wyoming State Geological Survey (Trihydro, 2005) reduced previously published estimates for CBM production through 2010. Figure 6-3 shows the historical and projected numbers of producing wells and production from that report. Figure 6-4 shows the cumulative production of both water and gas from CBM development. Significant volumes of water have been produced by this industry. Figure 6-5 shows the CBM production regions and the volumes of water and CBM that have been produced.

If the dramatic projected drop-off in CBM production water occurs as indicated in the Northeast Wyoming River Basin and the Powder/Tongue River Basin, it poses problems for the potential use of CBM production water for industrial purposes such as electric power generation. Most large industrial facilities have design lives of 35 to 50 years or longer, while the projections show that large amounts of CBM water will be available for only a relatively short period.

At least one power company has expressed an interest in using CBM water for cooling purposes in Northeast Wyoming. There are several potential problems with implementing such a proposal, however. One problem is the life expectancy of the resource as mentioned above. Also, the CBM industry is composed of a large number of companies. Organizing those individuals and companies and providing the infrastructure needed to transport a consistent volume of water to a site for cooling purposes could prove to be a daunting challenge. Nevertheless, the potential use of CBM water for industrial purposes remains an interesting possibility.

The Green River and the Wind/Bighorn River Basins are just entering the CBM production arena. The Bureau of Land Management (BLM) has projected that employment in this sector in the Great Divide Basin of the Green River Basin could approach 3,300 jobs during the planning period.

Natural gas is produced in all but three counties in Wyoming. Natural gas production is reported in thousands of MCF (MCF is thousand cubic feet). In 2000, Wyoming produced 1,454,793 thousand MCF of natural gas. Natural gas production increased to 1,927,837 thousand MCF in 2004 (Equality State Almanac). Experts anticipate that natural gas production across the state will continue to increase as it has over the past 20 years. However, some of the minor natural gas producing counties will see declines in production over the 30-year planning period.

### 6.4.5 Coal Conversion Facilities

Several companies have studied the possibility of building coal conversion facilities in Campbell County over the past 20 years. There appear to be two rationales for such facilities. One rationale is the fact that coal contains a high percentage of water by weight, meaning that eliminating or reducing the water content of coal prior to shipment could result in substantial savings in transportation costs to out-of -state utilities and other users. The second rationale is that the vast coal reserves of the region could be used to produce synthetic versions of fuels such as gasoline if petroleum prices were to increase or government programs were in place to stimulate domestic energy production.

Since 1980, three coal conversion facilities have been planned for Northeast Wyoming and have been issued construction permits by the Wyoming Industrial Siting Administration, although none have been built to date. The Platte River Basin also has potential for a coal conversion plant.

For the low growth scenario, it was assumed that the market forces that have prevented the construction of such facilities in the past would continue throughout the 30-year planning period.

For the moderate growth scenario, it was assumed that two such facilities would become operational in the Northeast Wyoming River Basin, one to convert coal to solid fuels and one to convert coal to liquid fuels. The water requirements of the two plants are 2,200 acre-feet annually. This demand would probably be met from groundwater sources.

The high growth scenario assumes that in addition to the coal conversion facilities described above, one coal-to-gasoline plant will become operational in Northeast Wyoming over the next 30 years. This plant would have an annual consumptive water use requirement of approximately 5,000 acre-feet, bringing total Northeast Wyoming water use for the high growth scenario to 7,200 acre-feet annually. This requirement would most likely be met from groundwater sources. In the Platte River Basin, a coal-to-diesel fuel plant would be constructed over the next 30 years. The plant would also generate electrical power. Annual water consumption would be 15,000 acre-feet (as shown in Table 6-9).

### 6.4.6 Soda Ash Production

Soda ash is produced only in the Green River Basin planning area. One of the major uses of soda ash is in the production of glass. The Green River Basin is the site of five industrial facilities that convert trona to soda ash. As a group, these five facilities produced approximately 11.7 million tons of soda ash in 1999 and consumptively used about 17,900 acre-feet of water from the Green River. Not all of this water is used in soda ash production or related work; some soda ash facilities use cooling water for onsite electric power generation and sell their excess power. Total industry water usage in 1999 for all purposes was estimated at about 18,100 acre-feet annually.

Future growth in soda ash production in the Green River Basin will be largely dependent upon foreign export markets. U.S. consumption has been relatively flat in recent years and is expected to grow by only 1.0 to 1.5 percent annually for the foreseeable future. This relatively low growth rate is attributable to the fact the U.S. market is relatively mature in terms of per capita consumption of soda ash products.

Foreign demand for soda ash, especially in developing countries, is expected to increase at a more rapid rate than in the U.S. over the next 30 years. As disposable income rises in developing countries, consumption of beverages in glass containers is expected to become commonplace. The increased use of glass containers in foreign markets is expected to translate into increased demand for U.S. soda ash because the U.S. has the world's largest deposits of trona and is the lowest-cost producer of soda ash.

Other factors that affect future U.S. soda ash production include trade barriers that many countries have established to protect their domestic soda ash industries. Over the next 30 years, there is the potential for lowering trade barriers and opening up new markets for U.S. soda ash. Soda ash exports from the Green River Basin may also receive a boost from future cost savings in the production (using solution mining) and transportation of soda ash.

Three scenarios for future water needs for the Green River Basin's soda ash industry are described below.

*High Scenario*

The high growth scenario for soda ash production in the Green River Basin, projects increasing efficiencies in production and transportation through solution mining and competition in rail transportation of the finished product. If trade barriers to U.S. exports of soda ash are gradually lowered or eliminated over the next 30 years, Wyoming producers could be expected to benefit enormously because they have a competitive advantage with respect to production costs that few other suppliers can equal. The high growth scenario for Wyoming producers is based upon the assumption that they could reasonably capture one-third of the total world market of 53.8 million tons by the year 2030.

If domestic production grows at 1.25 percent annually and that exports grow to one-third of foreign consumption by the year 2030, total estimated soda ash production in the Green River Basin would be 28.1 million tons in 30 years. If 50 percent of the increased production comes from solution mining (750 gallons per ton) and 50 percent from conventional processes (450 gallons per ton), the increase in annual water requirements for the industry by the year 2030 would be 30,200 acre-feet. Total water requirements for the industry would be 48,300 acre-feet annually, an increase of 167 percent over current levels.

*Mid Scenario*

The moderate growth scenario projects no significant changes in the structure of domestic or international markets for soda ash over the next 30 years. This scenario projects the possibility that producers will be able to achieve an additional competitive advantage in the export marketplace through reductions in rail transportation costs and the implementation of solution mining for a portion of their future production.

Wyoming producers could reasonably expect to increase their share of foreign market penetration from 20 to 25 percent, meaning that total foreign sales would approach 13.5 million tons annually by the year 2030. If domestic sales continue to grow at the projected rate of 1.25 percent per year, total soda ash production would be 23.8 million tons by the year 2030, an increase of 12.1 million tons over current levels.

For purposes of estimating water requirements for this scenario, it was assumed that 50 percent of future production increases would come from solution mining and that solution mining techniques would require 750 gallons of water per ton of soda ash production. Based upon these assumptions, the consumptive use of water by soda ash industry in the Green River Basin would grow by 22,300 acre-feet annually by the year 2030 to a total of 40,400 acre-feet. This figure represents a 123 percent increase over current water consumption levels.

*Low Scenario*

The low growth scenario for future soda ash production projects no significant changes in the structure of domestic or international markets for soda ash over the 30 year planning period, and no significant changes in production and transportation costs for Wyoming producers. Under these conditions, Green River Basin producers would be expected to maintain their current shares of both domestic and international markets, and their production would be expected to grow proportionally to growth in consumption. The overall future growth rate for soda ash production in the basin is projected to be 1.75 percent annually for the low growth scenario.

Based upon industry interviews, the overall average consumptive use rate for current production in the Green River Basin is approximately 450 gallons of water per ton of soda ash production. This figure was used to project future water requirements for the industry for the low growth scenario.

At a 1.75 percent annual growth rate, soda ash production in the Green River Basin will grow from 11.7 million tons in 1999 to 20.0 million tons by the year 2030. The production increase of 8.3 million tons annually will require approximately 11,500 acre-feet of water. That increase would bring total consumptive use up to 29,600 acre-feet by the year 2030, an increase of 64 percent over current levels.

### 6.4.7 Miscellaneous Industry

Miscellaneous industrial use is generally an unverifiable use throughout Wyoming. Most of this use is assumed to remain constant over the 30-year planning period. Miscellaneous use includes sugar refineries, hydroelectric and wind generation plants, chemical plants, fertilizer plants, and new industry.

There are three sugar refineries in Wyoming, one in the Platte River Basin and two in the Wind/Bighorn River Basin. Based on interviews in the Platte River Basin, the High Scenario assumes a 10 percent increase in production and water use. The Low Scenario assumes a 10 percent decline in production and water use. In the Mid Scenario, it is assumed that production and water use will remain constant over the planning period.

In the Wind/Bighorn River Basin, it is anticipated that the two sugar refineries, located in Worland and Lovell will continue to operate at current levels for all three scenarios.

Hydroelectric power generation is a nonconsumptive use but does provide employment and a resource to the economy of the state. The U.S. Bureau of Reclamation (USBR) operates plants at 13 sites; six are located in the Platte River Basin, six in the Wind/Bighorn River Basin, and one in the Green

River Basin. Several small private hydroelectric plants are located throughout the state. In addition to the hydroelectric plants, there are two wind farms generating electricity from wind power. One is located in the Bear River Basin, and one is located in the Platte River Basin.

Chemical plants in Wyoming are not large and do not consume large amounts of water. Examples of chemical plants include the Wyoming Ethanol plant in Torrington and the Dyno Nobel ammonium nitrate plant near Cheyenne. Similar assumptions were made for future operation of these plants. In the High Scenario, a 10 percent increase in production and water use would occur; in the Low Scenario, a 10 percent decrease in production and water use would occur; and in the Mid Scenario, they would hold steady.

FS Industries operates a fertilizer plant in Rock Springs and is supplied water by the Joint Powers Water Board. This industry presently consumes about 560 acre-feet annually. In the High Scenario, it is anticipated that this use could go to 1,500 acre-feet annually. In the Mid Scenario, use would increase to 1,000 acre-feet annually. In the Low Scenario, use would remain steady at present levels.

### 6.4.8 Industrial Summary

Industrial water use projections for Wyoming described above focus on existing industries and their future water needs. The potential for new industries to locate in the state to take advantage of available water resources also merits discussion. According to the U.S. Census Bureau (USCB), four industry groups account for over 95 percent of all of the industrial water used in this country each year. These industries are electric power producers, chemical and allied products manufacturers, primary metals producers, and paper and allied products manufacturers. Electric power producers alone consume over 80 percent of all industrial water used in this country each year. The other three industry groups account for roughly 14 percent of all industrial water use.

Wyoming is already well represented with respect to electric power production and chemical manufacturers (the soda ash, phosphate, and ammonium nitrate industries fall into this group). It appears likely that any new water-intensive industrial developments over the next 30 years will fall into the electric power generation and/or chemical products categories. The other two intensive water use industries, primary metals and paper producers, tend to locate near the source of their largest process inputs -- metals and wood, respectively.

The possibility remains that new industrial water uses not discussed in this report will develop over the next 30 years; however, the nature and extent of such developments is not foreseeable at this time, and water requirements for such developments are not included in these projections.

Table 6-10 shows the projected industrial demands over the 30-year planning period. It can be easily seen that industrial use varies greatly across the state. It should also be noted that some small unquantified mining use has not been included in all basin projections due to lack of data and small volume of use. In the Wind/Bighorn River Basin water rights were used to estimate and project use. This likely overstates actual consumptive use somewhat in that basin.

**Table 6-10 Total Industrial Water Demand Projections**

| River Basin | 30-Year Projections | | |
|---|---|---|---|
| | High Scenario | Mid Scenario | Low Scenario |
| | ac-ft | | |
| Bear | 500 | 0 | 0 |
| Green | 166,300 | 106,400 | 78,000 |
| Northeast[1] | 17,300 | 9,100 | 3,700 |
| Platte | 115,800 | 92,500 | 75,300 |
| Powder/Tongue | 35,000 | 17,000 | 0 |
| Snake/Salt | 50 | 48 | 24 |
| Wind/Bighorn | 115,000 | 106,000 | 92,000 |
| **Total** | **449,950** | **331,048** | **249,024** |

[1] In Northeast Wyoming, industrial water use is assumed to use dry cooling technology. If wet cooling is used, then demands would increase to 77,200 for the High Scenario; 20,800 for the Low Scenario; and 43,300 for the Mid Scenario.

## 6.5 RECREATIONAL DEMAND PROJECTIONS

### 6.5.1 Introduction

The tourism and recreation sector is important throughout the state and contributes to sales, income, and employment in two of the state's large economic sectors--retail trade and services. As tourism and recreation contribute to providing jobs and income for the state, the effects on economic and population projections are captured in the municipal and rural domestic projections. More importantly, tourism and recreation create notable consumptive and nonconsumptive demands on water in Wyoming for golfing, alpine skiing, angling, boating, swimming, waterskiing, and enjoying amenities such as creeks, rivers, lakes, reservoirs, and the scenery and habitats that accompany them.

It was assumed that local, state, and federal agencies will continue to develop and maintain recreational amenities across the state to take advantage of water resources. No new reservoirs or other large water-based recreational facilities were identified in the river basin plans. However, water-based recreation activities were noted to be on the rise in some sectors in some river basins. Examples are guided angling and river floating. While travel, tourism, and recreation are important to the economy of the state and the individual river basin planning areas, some river basin planning areas lack large destination tourist attraction.

### 6.5.2 Future Recreational Demand

Future demands for recreational water resources in Wyoming depend upon numerous factors, including population growth, tourism growth, and participation rates in various water-based recreational activities. Future participation rates depend upon changes in preferences over time as well as the availability of water resources and the amount of congestion encountered at recreational sites. Changes in future recreational preferences are hard to predict, so the projections described in this section are based upon the assumption that participation rates remain constant over the planning period. This assumption means that projected recreational demands are proportional to growth in population and tourism in the respective basins.

Projections of population growth are summarized in Table 6-11 in terms of average annual growth rates for the high, low, and mid growth planning scenarios. Table 6-11 also projects tourism growth over the planning period for the three scenarios. The other information needed to project future recreation demand is a breakdown of recreational activity between residents and nonresidents. No precise estimates exist, but based upon what information is available and the judgment of professionals in the WGFD, it was assumed that 80 percent of future hunting and fishing activity would be by Wyoming residents and 20 percent by nonresidents.

**Table 6-11 Projected Annual Growth Rates: Population and Tourism**

| | 30-Year Projections | | | | | |
|---|---|---|---|---|---|---|
| | Average Annual Population Growth Rates - Percentage | | | Average Annual Tourism Growth Rates - Percentage | | |
| River Basin | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario |
| Bear | 2.31 | 1.25 | 0.05 | | | |
| Green | 1.35 | 0.68 | 0.08 | 3 | 2 | 1 |
| Northeast | 1.51 | 0.75 | 0.52 | 3 | 2 | 1 |
| Platte | 1.92 | 1.38 | 1.17 | | | |
| Powder/Tongue | 1.04 | 0.82 | 0.53 | 3 | 2 | 1 |
| Snake/Salt | 3.41 | 1.78 | 0.21 | | | |
| Wind/Bighorn | 0.91 | 0.32 | 0.00 | 3 | 2 | 1 |

Note: Tourism and recreation growth rates were not estimated for the Bear River Basin, the Platte River Basin, and the Snake/Salt River Basin.

This information was used to project future water-based recreational activity days for four river basin planning areas over the 30-year planning period. Those projections are given in Table 6-12. The demand for still water fishing in the planning areas is projected to expand significantly over the next three decades. Similar increases are projected for stream fishing demands. The demand for waterfowl hunting is also expected to increase, but at a lesser growth rate than for fishing.

**Table 6-12 Current and Projected Water-Based Recreational Activity Days**

| River Basin[1] | Activity | Current | 30-Year Projections High Scenario | Mid Scenario | Low Scenario |
|---|---|---|---|---|---|
| | | number of days | | | |
| Green | Still water fishing | 485,000 | 868,800 | 685,300 | 547,000 |
| | Stream fishing | 281,700 | 531,400 | 414,500 | 326,900 |
| | Waterfowl hunting | 10,600 | 17,600 | 14,100 | 11,500 |
| Northeast | Still water fishing | 50,000 | 93,000 | 72,000 | 62,000 |
| | Stream fishing | 15,000 | 28,000 | 22,000 | 19,000 |
| | Waterfowl hunting | 3,000 | 5,000 | 4,000 | 3,500 |
| Powder/Tongue | Still water fishing | 132,000 | 208,000 | 183,000 | 159,000 |
| | Stream fishing | 140,000 | 221,000 | 194,000 | 169,000 |
| | Waterfowl hunting | 2,000 | 2,700 | 2,500 | 2,300 |
| Wind/Bighorn | Fishing[2] | 488,000 | 722,000 | 577,000 | 488,000 |
| | Waterfowl hunting | 28,500 | 79,000 | 61,500 | 28,500 |

[1] Water-based recreational activity days were not developed and projected for the Bear River Basin, the Platte River Basin, and the Snake/Salt River Basin.

[2] Fishing in the Wind/Bighorn River Basin was not broken out into still water fishing and stream fishing.

In the Platte River Basin and in the Snake/Salt River Basin, projections of water consumption were prepared for golf course irrigation and snowmaking for alpine skiing. These projections are shown in Table 6-13. This effort was not conducted for the remaining river basin planning areas.

**Table 6-13 Current and Projected Water Consumption for Golf and Skiing**

| River Basin | Activity | Current | 30-Year Projections High Scenario | Mid Scenario | Low Scenario |
|---|---|---|---|---|---|
| | | ac-ft | | | |
| Platte | Golf Course Irrigation | 4,400 | 6,300 | 5,000 | 4,400 |
| | Alpine Skiing Snowmaking | 10 | 10 | 10 | 10 |
| Snake/Salt | Golf Course Irrigation | 880 | 1,440 | 1,240 | 880 |
| | Alpine Skiing Snowmaking | 60 | 140 | 100 | 60 |
| **Total** | | **5,350** | **7,890** | **6,350** | **5,350** |

### 6.5.3 Adequacy of Existing Resources

The WGFD in the past has estimated the supply of water resources available to meet the demands of fishermen in various regions of the state. These supply estimates were expressed in terms of fishermen days, and reflect the amount of pressure the WGFD believed that publicly accessible fisheries could withstand without significant deterioration. Although these estimates have not been updated in the past decade, they serve as one benchmark for judging the capacity of fisheries in the planning area to meet projected future demands. Unfortunately, the WGFD did not estimate fishery supplies separately for each river basin planning area. The Powder/Tongue, Little Missouri, Belle Fourche, Cheyenne, and Niobrara River Basins were grouped together as were the Green and Bear River Basins. Nevertheless, it is useful to review these supply estimates as background for assessing resource adequacy.

According to the WGFD, the Powder/Tongue and Northeast Wyoming planning areas combined provide an annual supply of 405,000 activity days of fishing opportunities. With the exception of Keyhole Reservoir, almost all of this supply is located in the Powder/Tongue River Basin. When this figure is contrasted with a current utilization rate of 272,000 activity days in the Powder/Tongue Basin, it is apparent that there is no current overall shortage of angling opportunities. Individual waters may experience overcrowding at times, however, because they are easily accessible.

The projections of future demands for fishing opportunities in the Powder/Tongue Basins (Table 6-12) range from 328,000 to 429,000 activity days annually over the planning period, depending upon the growth scenario used. These scenarios indicate that fishing pressure demands may approach the supply of resources available in the two river basin planning areas over the next 30 years. The implications of this conclusion are limited by the fact that there is a relatively fixed supply of streams in the area that are suitable for maintaining recreational fisheries. One inference that can be drawn is that future activities that would denigrate existing recreational stream fisheries could have significant negative recreational effects, while activities that enhance fisheries habitat could have significant positive effects.

According to the WGFD, the Green River Basin and the Bear River Basin combined provide an annual supply of 1,122,800 activity days of lake and reservoir fishing opportunities. Almost all of this supply is located in the Green River Basin. When contrasted with current utilization rates of about 485,000 activity days of use annually, it is apparent that there is no current shortage of still water angling opportunities in the Green River Basin. This observation is consistent with the fact that the region is endowed with numerous lake and reservoir fisheries ranging from small alpine lakes in the higher elevations of the Bridger-Teton National Forest to Flaming Gorge and Fontenelle Reservoirs in the lower part of the basin.

Projections of future demands for still water fishing opportunities in the Green River Basin (Table 6-12), range from 547,000 to 870,000 activity days annually over the planning period, depending upon the growth scenario used. None of these projections approach the estimated supply of over 1.1 million angling days, meaning that the supply of lake and reservoir fishery resources in the basin should be adequate to meet projected needs for the foreseeable future. Another inference that can be drawn from these projections is that private landowners who control access to good-quality stream fisheries in the basin own a valuable asset and may be able to derive income in the coming decades by allowing access to those fisheries, either through private leases, leases to public agencies such as the WGFD, or daily access fees.

The other water-based recreational pursuit for which demand projections were developed is waterfowl hunting. Those projections indicate that demand is expected to rise from the current level. The WGFD has not estimated the supply of waterfowl hunting opportunities in the basins, partially because populations are migratory and hunting seasons and bag limits are established in accordance with guidelines established by the U.S. Fish and Wildlife Service (USFWS).

## 6.6 ENVIRONMENTAL DEMAND PROJECTIONS

Current environmental uses of water in Wyoming are described in Chapter 5. Those uses include:

- Instream flows and reservoir bypasses
- Minimum reservoir pools
- Maintenance of wetlands, riparian habitat, and other wildlife habitat

Environmental water requirements are not necessarily related to changes in population or tourism. Instead, environmental water requirements are at least partially a function of human desires concerning the type of environment in which people want to live. These desires are expressed in many ways, including environmental programs and regulations promulgated by elected representatives at the state and federal levels. Thus, future environmental water requirements will be determined, at least partially, by existing and new legislation dealing with environmental issues at the state and federal levels, and how that legislation is implemented by federal and state agencies.

Future water requirements for instream flows depend largely upon how Wyoming's instream flow legislation is implemented over the 30-year planning period. Projecting the outcome of this process quantitatively would be difficult and is perhaps unnecessary because instream flows and other environmental water uses are largely nonconsumptive. Instream flow designations can conflict with potential new out-of-stream uses at specific locations, however, a topic that is discussed below.

### 6.6.1 Instream Flows

Wyoming's instream flow statutes recognize the economic fact that water resources have value in nonconsumptive uses such as instream flows. Such flows not only contribute to aesthetic character and biological diversity of the river basin planning areas; they also support recreational fisheries that are important to river basin residents and to the river basin and state economies.

The WGFD has a goal of maintaining and enhancing existing fisheries through the statutory designation of instream flow segments and other management strategies. Through 2006, a total of 100 instream flow applications have been filed with the SEO. The WWDC has completed 83 instream flow feasibility studies. The extent to which current filings and future instream flow requests may conflict with potential storage developments for supplemental irrigation water is unknown, but the potential for conflicts does exist. These conflicts would have to be resolved on a case-by-case basis, weighing the potential benefits to the state of instream water uses versus out-of stream consumptive in- state water uses.

### 6.6.2 Minimum Reservoir Pools

Another environmental water use is the provision of minimum reservoir pools for fish and wildlife purposes. Six reservoirs in the Powder/Tongue River Basin have minimum pools listed in their permitting documents: Park, Dull Knife, Willow Park, Kearney, Cloud Peak, and Tie Hack. Five reservoirs in the Green River Basin have similar permit conditions: Big Sandy, Boulder, Flaming Gorge, Fontenelle, and High Savery. In the Wind/Bighorn River Basin, the USBR has five reservoirs that have conservation pools that include fishery and wildlife uses as well as water quality and recreation: Bighorn Lake, Boysen Reservoir, Buffalo Bill Reservoir, Bull Lake Reservoir and Pilot Butte Reservoir. The USBR also operates Jackson Lake to provide a minimum pool for fisheries and other uses. The USBR also operates seven dams in the Platte River Basin. Given the current federal regulatory environment and public desires to maintain and enhance recreational fisheries in the Platte Basin, it is likely that any additional storage developed in the future will have a portion of its storage devoted to fish and wildlife purposes.

### 6.6.3 Minimum Releases and Reservoir Bypasses

Another tool for maintaining fisheries habitat in the river basin planning areas is the provision of minimum flow bypasses at reservoir sites or minimum releases from storage. The seven river basin reports indicate that currently there are three reservoirs in the Powder/Tongue River Basin that have minimum flow bypasses, four in the Green River Basin, one in the Snake/Salt River Basin, three in the Wind/Bighorn River Basin, and five in the Platte River Basin. The development of additional reservoir storage in the future would likely bring about requests by the WGFD and others for such minimum flow bypass requirements. As discussed elsewhere, the likelihood of additional storage being developed in the planning area will be greatly influenced by future trends in cattle and forage prices and state funding mechanisms available to irrigators in need of supplemental water.

The USBR is aware of the WGFD's desire to have a 280 cfs minimum flow just below Jackson Lake Dam. The USBR strives to meet or exceed this amount with its winter releases. A meeting is held each fall among the USBR, the SEO, and the WGFD to determine the winter release schedule for Jackson Lake Dam.

### 6.6.4 Wetlands and Wildlife Habitat

Another important environmental use of water in the river basin planning areas is the provision of habitat for wildlife. Wildlife habitat exists in wetland and riparian areas on public and private lands throughout the state, some of it occurring naturally and some of it as a result of human activity. A tabulation of wetlands wildlife habitat areas in the planning areas has been undertaken as a part of the geographical information system developed for this study. A description of the information in this database is contained in separate technical memoranda.

Three federal programs, the Conservation Reserve Program (CRP), the Wetlands Reserve Program (WRP), and the Wildlife Habitat Incentives Program (WHIP) encourage the development of wildlife habitat on private lands. The CRP is administered by the Farm Service Agency of the U.S. Department of Agriculture (USDA) and provides incentive payments for various conservation practices that will enhance wildlife habitat, as well as improve water quality and reduce erosion. The WRP is administered by the Natural Resources Conservation Service (NRCS) of the USDA. It is a voluntary program that provides financial and technical assistance to private landowners to reestablish wetlands on their property. The WHIP is also administered by the NRCS, and it provides technical and financial assistance to private landowners interested in improving wildlife habitat on their property. None of these programs result in significant amounts of consumptive water use. As a result, no projections of future water needs for such programs were developed as a part of this water plan.

In the Bear River Basin, a fairly large area has been designated as the Cokeville Meadows National Wildlife Refuge. If fully developed as recommended by the USFWS, the refuge would cover about 26,657 acres. This area contains significant wetland areas and areas that are presently hay meadows. Full implementation of the refuge could impact irrigated agriculture and irrigation consumptive use. This was considered in the agriculture demand projections above.

### 6.6.5 Direct Wildlife Consumption

As stated in Chapter 5, if all river basin planning areas are assumed to be the same as the Green River Basin, use would be about 3,500 acre-feet annually. This level of consumptive use is projected to remain relatively small and unchanged over the planning period.

## 6.7 SUMMARY OF FUTURE WATER DEMAND PROJECTIONS

Table 6-14 presents the projected demands for the four major water-using sectors in Wyoming for each scenario, high, mid, and low. Recreational consumptive water use projections were not prepared in the Bear River, Green River, Northeast Wyoming, Powder/Tongue, or Wind/Bighorn River Basin planning areas.

**Table 6-14 Projected Annual Total Consumptive Water Demands**

| River Basin | Type of Use | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture | | | Municipal & Domestic | | | Industrial | | | Recreational | | |
| | 30 Year Projections | | | 30 Year Projections | | | 30 Year Projections | | | 30 Year Projections | | |
| | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario | High Scenario | Mid Scenario | Low Scenario |
| | ac-ft | | | ac-ft | | | ac-ft | | | ac-ft | | |
| Bear[1] | 100,000 | 94,500 | 88,900 | 6,200 | 4,500 | 4,700 | 500 | 0 | 0 | | | |
| Green | 438,000 | 423,000 | 408,000 | 13,700 | 11,500 | 9,700 | 166,300 | 106,400 | 78,000 | | | |
| Northeast | 75,700 | 72,800 | 69,500 | 15,900 | 12,700 | 11,600 | 17,300 | 9,100 | 3,700 | | | |
| Platte | 700,000 | 661,000 | 650,000 | 44,600 | 37,800 | 35,400 | 115,800 | 92,500 | 75,300 | 6,300 | 5,000 | 4,400 |
| Powder/Tongue | 205,000 | 194,400 | 183,800 | 13,300 | 12,400 | 11,400 | 35,000 | 17,000 | 0 | | | |
| Snake/Salt | 128,100 | 107,100 | 94,900 | 18,600 | 11,500 | 7,200 | 50 | 48 | 24 | 1,600 | 1,300 | 950 |
| Wind/Bighorn[2] | 1,576,400 | 1,305,700 | 1,165,500 | 26,500 | 21,900 | 21,000 | 115,000 | 106,000 | 92,000 | | | |
| **Total** | **3,223,200** | **2,858,500** | **2,660,600** | **138,800** | **112,400** | **101,000** | **449,900** | **331,000** | **249,000** | **7,900** | **6,300** | **5,400** |

[1] In the Bear River Basin study, a Mid Scenario was not completed for agriculture. In this table the Mid Scenario is estimated based on the current uses.

[2] Wind/Bighorn River Basin Industrial use and projections are based on water rights rather than actual consumption. This tends to over state oil and gas industry use as well as other uses.

Table 6-15 presents the current and projected future water demands for each of the seven river basin planning areas and a total for the state for all sectors. These projections are presented by future scenario. The table presents both surface water and groundwater demands (demands presented in Table 6-15 may be compared to legally available flows as shown in Table 7–2).

**Table 6-15 Summary of Current and Projected Future Water Uses**

| River Basin | Water Source | Current Use[1] | 30-Year Projections[1] | | |
|---|---|---|---|---|---|
| | | | High Scenario | Mid Scenario | Low Scenario |
| | | ac-ft | | | |
| Bear[2] | Surface Water | 99,300 | 108,900 | 103,200 | 100,100 |
| Green | | 609,500 | 766,700 | 681,500 | 630,900 |
| Northeast | | 92,500 | 99,200 | 96,300 | 93,000 |
| Platte | | 780,700 | 962,000 | 898,200 | 883,200 |
| Powder/Tongue | | 207,600 | 267,200 | 237,300 | 209,300 |
| Snake/Salt | | 194,200 | 202,200 | 179,300 | 168,100 |
| Wind/Bighorn[3] | | 1,329,200 | 3,053,800 | 1,501,100 | 1,318,400 |
| **Total Surface Water** | | **3,313,000** | **5,460,000** | **3,696,900** | **3,403,000** |
| Bear[2] | Groundwater | 3,000 | 3,600 | | 2,600 |
| Green | | 800 | 1,100 | 1,100 | 900 |
| Northeast | | 30,500 | 56,300 | 44,100 | 35,200 |
| Platte | | 124,400 | 126,100 | 118,500 | 100,900 |
| Powder/Tongue | | 2,500 | 3,300 | 3,200 | 2,800 |
| Snake/Salt | | 6,800 | 18,700 | 11,700 | 7,400 |
| Wind/Bighorn[3] | | 6,400 | 8,500 | 7,000 | 6,700 |
| **Total Groundwater** | | **174,400** | **217,600** | **185,600** | **156,500** |

[1]Includes reservoir evaporation as a use.

[2] In the Bear River Basin study, a Mid Scenario was not completed for agriculture. Includes agriculture estimate.

[3] Wind/Bighorn River Basin industrial use and projections are based on water rights rather than actual consumption. This tends to over state oil and gas industry use as well as other uses.

## 6.8 REFERENCES


Anderson Consulting Engineers. 2003. *Popo Agie Watershed Plan*. Prepared for Wyoming Water Development Commission.

Economic Analysis Division. 2006. *Equality State Almanac.*

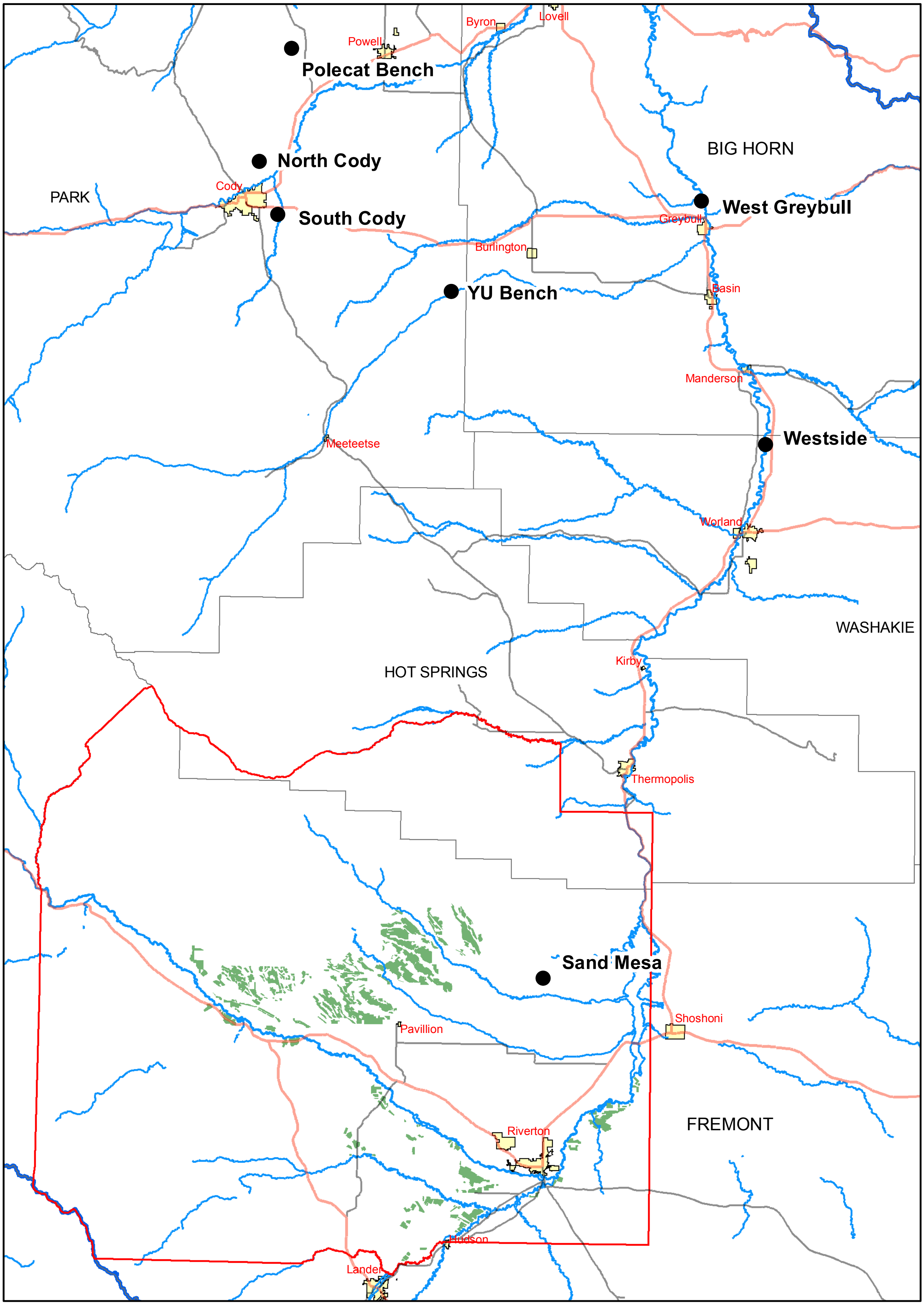
Nelson Engineering. 2001. *Riverton East Irrigation Project, Level II Feasibility Study*. Prepared for the Wyoming Water Development Commission.

Roncolio, Teno. 1982. *Report Concerning Reserved Water Right Claims By and On Behalf of the Tribes of the Wind River Indian Reservation, Wyoming.* Civil Case No. 4993, District Court of the Fifth Judicial District, State of Wyoming. December 15.

Trihydro Corporation. 2005. *Platte River Basin Plan Final Report.* De Bruin Interview.

Soil Conservation Service (SCS) 1992. *Interim Irrigation On-Farm Report for Wind River Basin Water Supply Study (DRAFT).*

Trihydro Corporation. 2005. *Platte River Basin Plan Final Report*. De Bruin Interview.

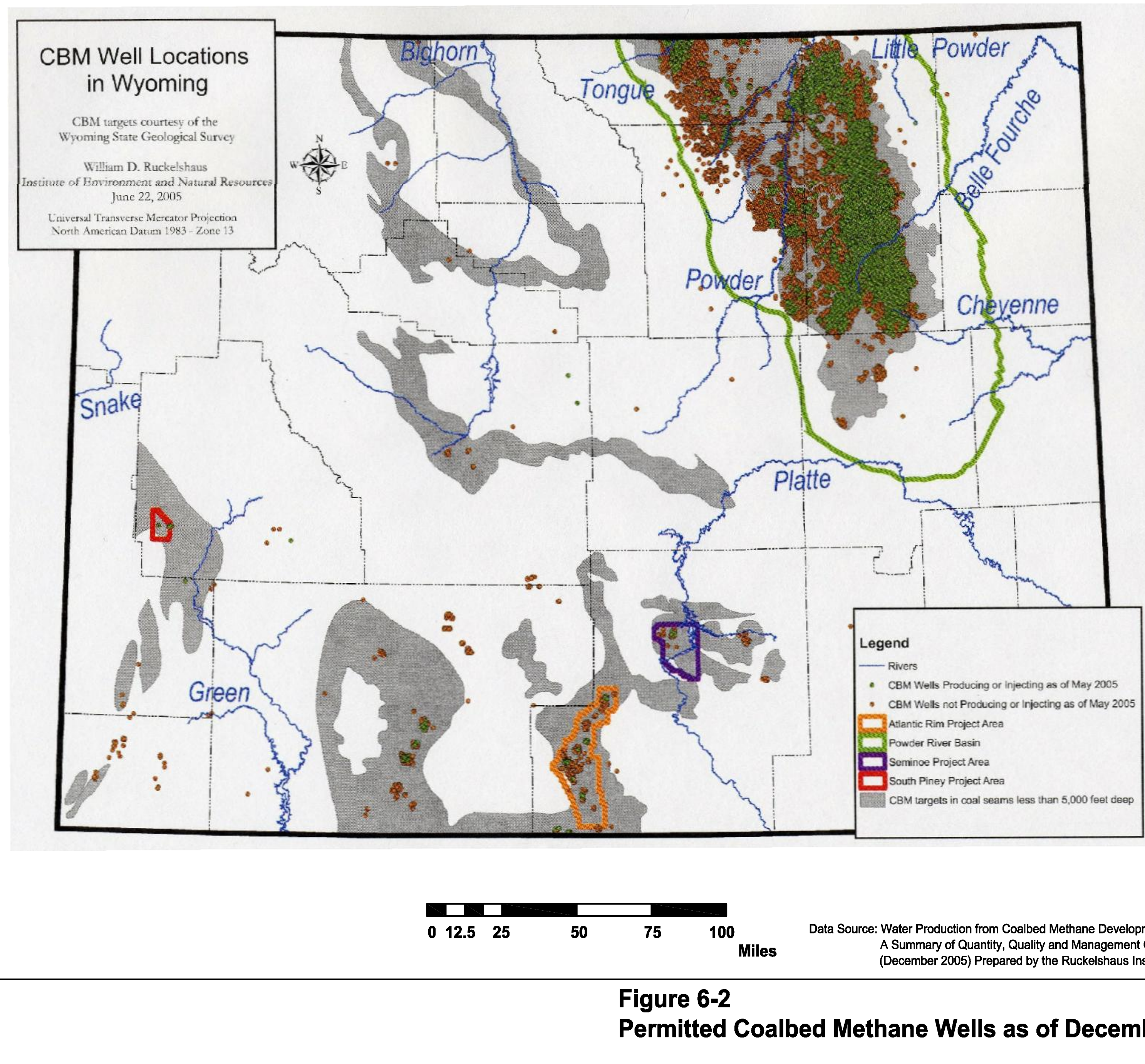



**LEGEND**

● Irrigable Lands — Wind River Indian Reservation Boundary — Tribal Futures Projects

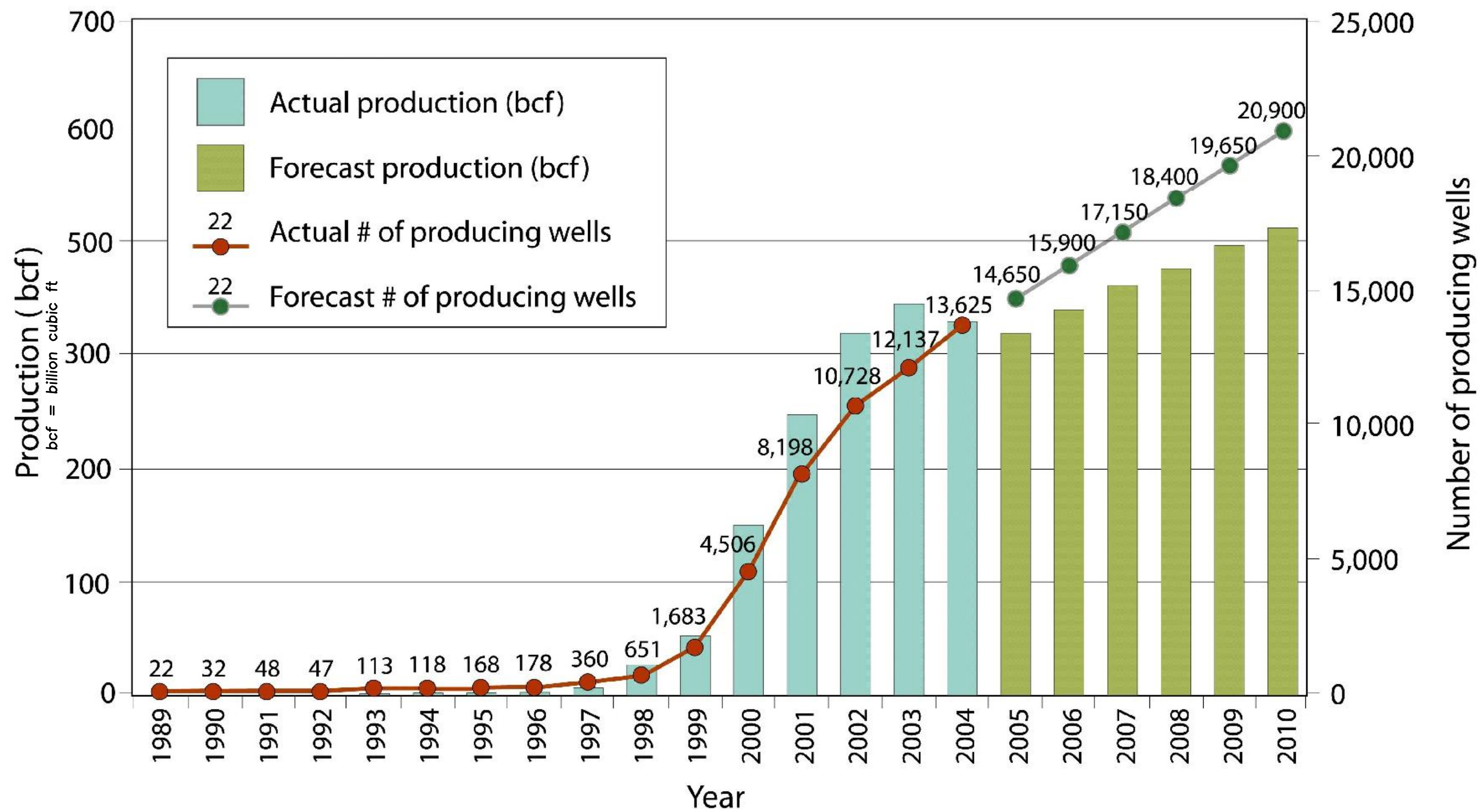
Note: A dot denotes the general location of irrigable lands.

**Figure 6-1**
**Tribal Futures Projects and Irrigable Lands**



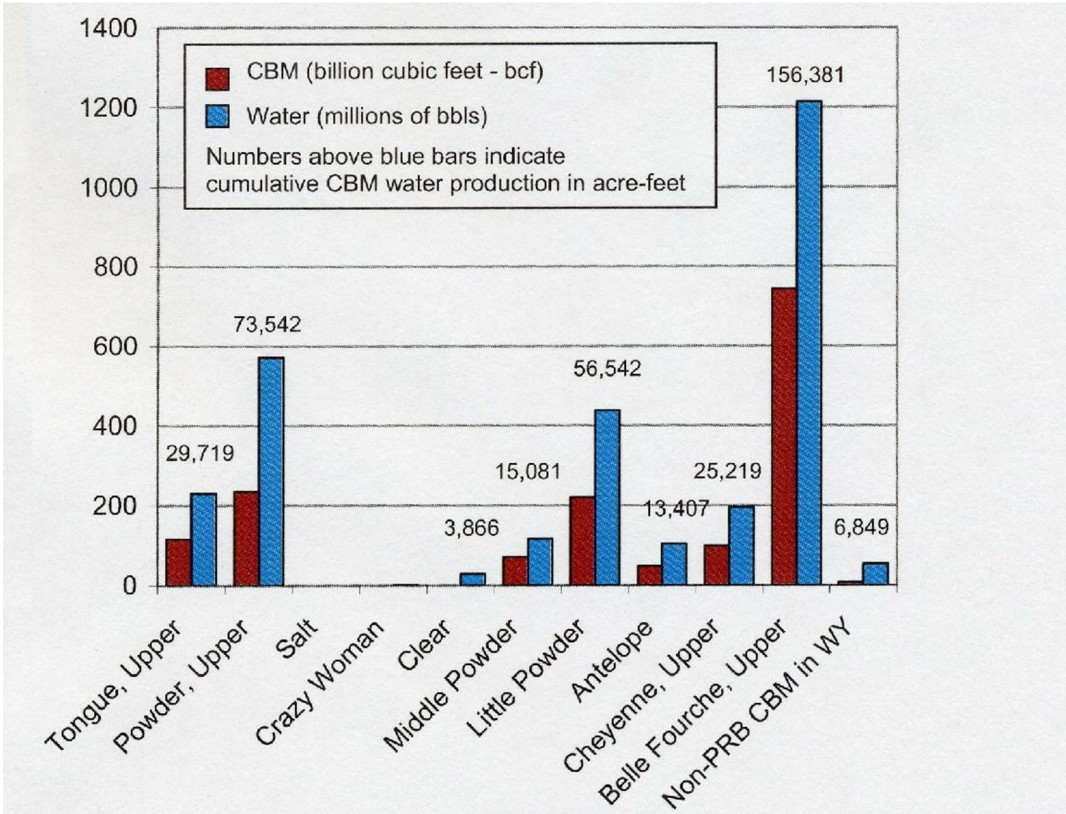

Data Source: Water Production from Coalbed Methane Development in Wyoming: A Summary of Quantity, Quality and Management Options (December 2005) Prepared by the Ruckelshaus Institute

**Figure 6-2**
**Permitted Coalbed Methane Wells as of December 31, 2004**

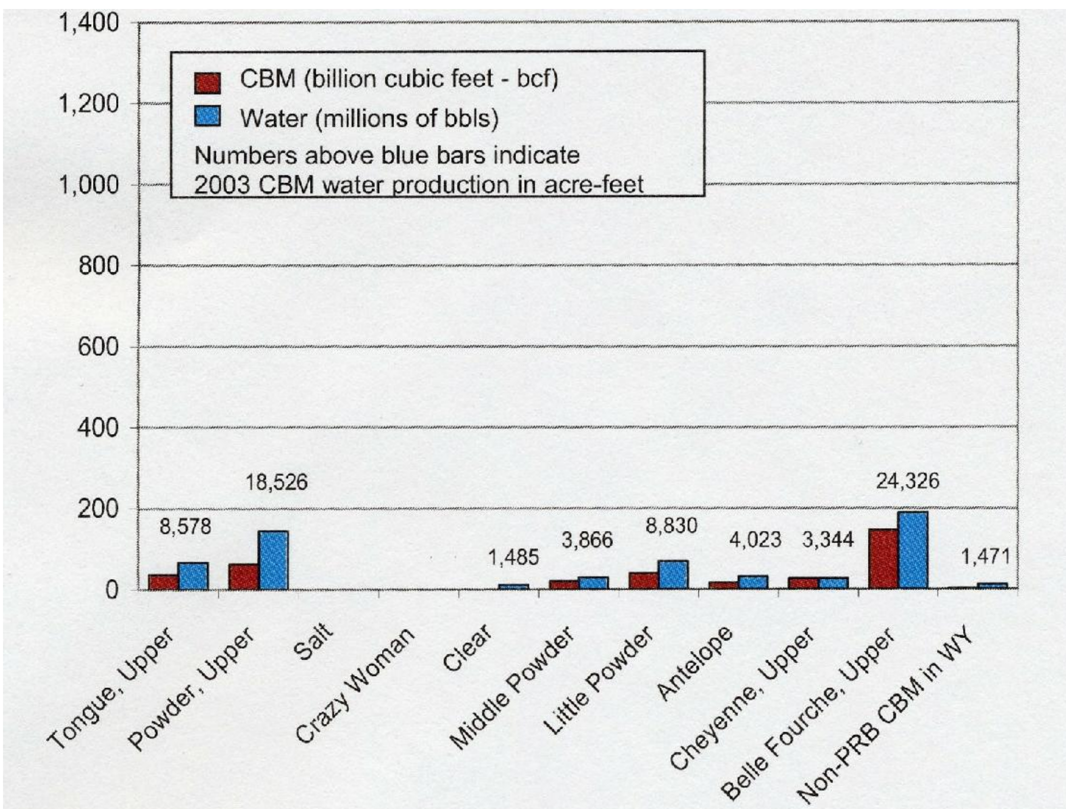



Data Source: Water Production from Coalbed Methane Development in Wyoming: A Summary of Quantity, Quality and Management Options (December 2005) Prepared by the Ruckelshaus Institute

**Figure 6-3**
**Coalbed Methane Wells & Production in the Powder River Coal Field**



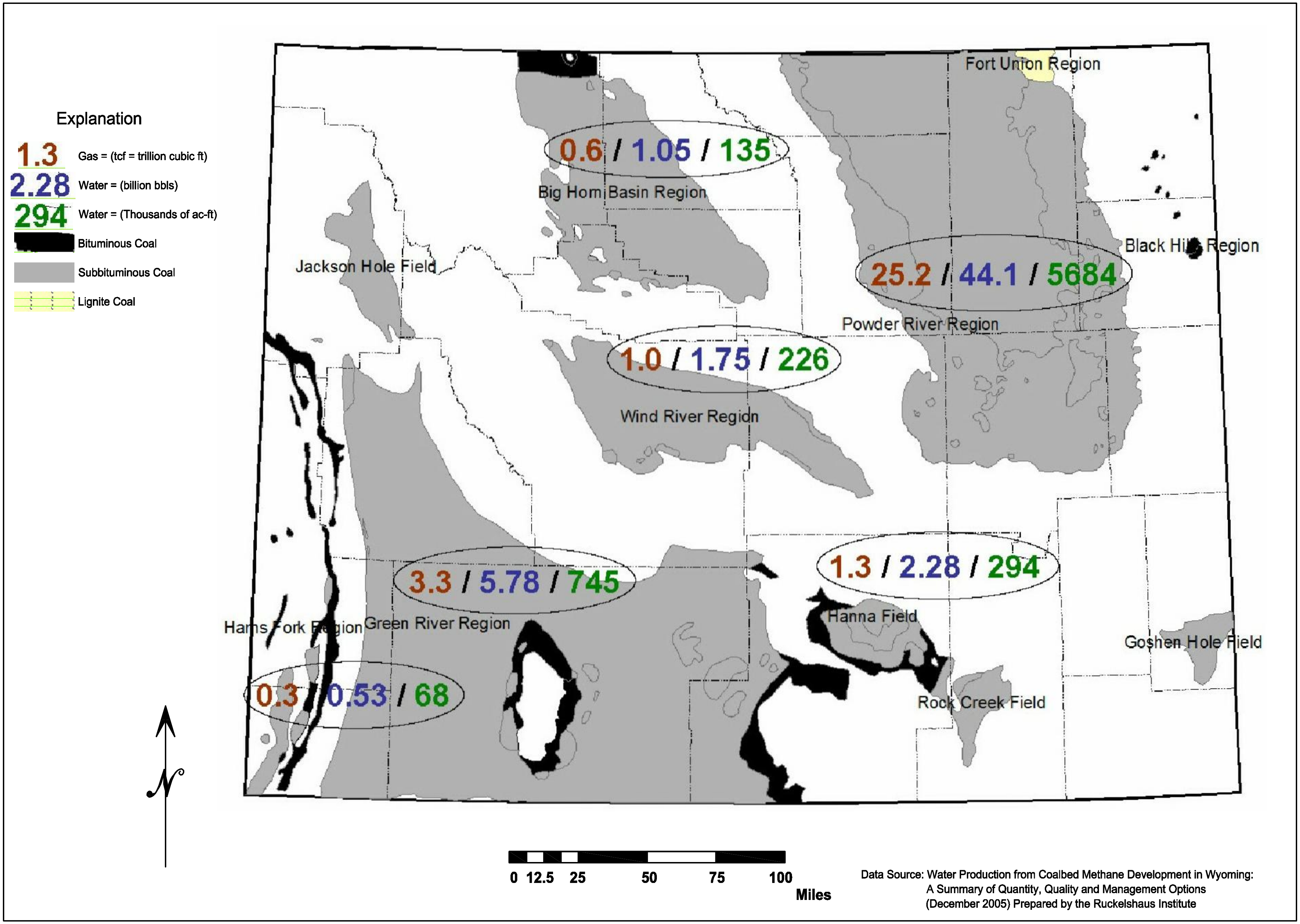

**Cumulative (1987 - Dec. 2004)**




**2003**

Data Source: Water Production from Coalbed Methane Development in Wyoming:
A Summary of Quantity, Quality and Management Options
(December 2005) Prepared by the Ruckelshaus Institute

**Figure 6-4**
**Coalbed Methane Gas & Water Production**




Data Source: Water Production from Coalbed Methane Development in Wyoming: A Summary of Quantity, Quality and Management Options (December 2005) Prepared by the Ruckelshaus Institute

**Figure 6-5**
**Projected Recoverable Coalbed Methane**

# 7.0 AVAILABILITY

This chapter presents estimates of the availability of surface water and groundwater for future uses.

## 7.1 SURFACE WATER

### 7.1.1 Introduction

The following subsections describe the analysis of existing surface water data, creation of spreadsheet-based surface water models, and use of the models' output to estimate water availability. The modeled results described herein denote physical availability over and above existing uses, which is to be distinguished from legal or permitted availability. As projects are proposed in the future, surface water physical availability will be reduced due to environmental and administrative requirements. However, physical availability is the important first step in assessing the viability of any future project. Lack of physical availability of water for a project is an obvious fatal flaw for any water development.

### 7.1.2 Methodology

The physical availability of surface water was determined through the construction and use of spreadsheet simulation models that calculate water availability based on the physical amount of water present at a specific node or location less historical diversions, compact requirements, and minimum flows. The determination of available surface water is broken down into the following seven components:

- Compilation of historic streamflow records.
- Study period selection.
- Data extension.
- Estimating natural flow at ungaged model nodes.
- Determining streamflows during wet, normal, and dry years.
- Spreadsheet model development and calibration.
- Determination of physically present surface water.

The *Guidelines for Development of Basin Plans* (WWDC, 2001) recommends that for the purposes of the river basin planning process, a hydrologic analysis be conducted for three periods using average dry year conditions, average normal year conditions, and average wet year conditions. Therefore, each hydrologic region in a basinwide model has three associated spreadsheet models representing those three hydrologic conditions. The gaged flows used in the spreadsheet model are developed by averaging recorded monthly streamflows for groups of years falling into those three hydrologic categories during a consistent period of record.

To determine the study period, historic streamflow records were analyzed for each basin. In the selection process, major events that would have affected streamflow were considered. These events were minimized to the extent possible, but it is impossible to find a period in which there were no significant events. Each of the river basin planning areas had a slightly different study period. The study periods used are shown below.

| | |
|---|---|
| Bear | 1971-1998 |
| Green | 1971-1998 |
| Northeast Wyoming | 1970-1999 |
| Platte | 1972-2001 |
| Powder/Tongue | 1970-1999 |
| Snake/Salt | 1971-2001 |
| Wind/Bighorn | 1973-2001 |

The periods selected from 1970 through 2001 contain extended periods of dry years including some of the driest years of record as well as periods of normal and wet hydrologic conditions throughout the river basin planning areas. These study periods also have the greatest abundance of recorded streamflow data and ditch diversion data and therefore require less data synthesis. A study period from the 1970 through 2001 time frame was therefore selected independently for each river basin planning area as appropriate for purposes of water availability modeling for the individual river basin plan.

A more detailed discussion and supporting documentation for the selection of the individual study periods and the modeling are provided in the "Surface Water Hydrology" technical memoranda for each of the river basin planning areas.

### 7.1.3 Surface Water Model

The WWDC has undertaken river basin planning efforts throughout Wyoming. The purpose of the statewide planning process is to provide decision-makers with current, defensible data to allow them to manage water resources for the benefit of all the state's citizens. Spreadsheet models were developed to determine average monthly streamflow in the basin during wet, normal, and dry years. The purpose of these models was to validate existing basin uses, assist in determining the timing and location of water physically available for future development, and help to assess impacts of future water supply alternatives.

The WWDC specified that the river basin models be consistent and use software available to the average citizen. Accordingly, Excel was selected as the software to support the spreadsheet modeling effort. The spreadsheet model developed for the Bear River, the first basin plan undertaken, became a template for subsequent river basin modeling, and new features were added as unique circumstances were encountered in the basins.

*Model Overview*

For six modeled river basin planning areas and subbasins, three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The Platte River Basin planning area was not modeled as information was available from litigation and negotiation. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data to identify the hydrologic conditions for each year in the study period.

A detailed description of the modeling effort for each of the six modeled river basin planning areas is contained in the hydrology technical memorandum for each of those basin planning areas.

*Model Structure and Components*

Each of the subbasin models is a workbook consisting of numerous individual pages (worksheets). Each worksheet is a component of the model and completes a specific task required for execution of the model. There are five basic types of worksheets:

- **Navigation Worksheets:** are Graphical User Interfaces (GUIs) containing buttons used to move within the workbook.
- **Input Worksheets:** are raw data entry worksheets (USGS gage data or headwater inflow data, diversion data, etc.).
- **Computation Worksheets**: compute various components of the model (gains/losses).
- **Reach/Node Worksheets:** calculate the water budget node by node.
- **Results Worksheets**: tabulate and present the model output.

Each river basin planning area was delineated into river or stream reaches and nodes. The choice of nodes must consider the objectives of the study and the available data. It also must contain all the water resource features that govern the operation of the basin.

*Stream Gage Data*

Monthly stream gage data were obtained from the Wyoming Water Resources Data System (WRDS) and the USGS for each of the stream gages used in the model. Linear regression techniques were used to estimate missing values for the many gages that had incomplete records. The Mixed Station Model developed by the USGS was used to perform the regression and data filling. Once the gages were filled in for the study period, monthly values for dry, normal, and wet conditions were averaged from the dry, normal, or wet years of the study period. The dry, normal, and wet years were determined on a subbasin level from indicator gages in each subbasin. The model uses estimated flow at ungaged headwater nodes as if they were gages.

Additional information on stream gage data and data extension is contained in the hydrology technical memorandum for each of the six modeled river basin planning areas.

*Diversion Data*

Surface water diversions are primarily for agricultural use. If actual diversion data existed for a modeled stream, that information was used in the modeling effort. However, because actual diversion records were unavailable in some basins, estimates of diversions were made, or the model simulated the depletion based on the consumptive portion of the diversion being taken from the stream. In river basin planning areas where this technique was used, the model treats this quantity as if it was the diverted amount and it is referred to as "diversion data," although it is a depletion quantity.

Data on the diversion data sheet are used to calculate ungaged reach gains and losses, and in some cases, inflow at ungaged headwater nodes. They are also used as the diversion demand in the Reach/Node worksheets.

*Reach Gain/Loss*

The models simulate major diversions and features of the basins, but minor water features such as small tributaries lacking historical records and diversions for small permitted acreages are not explicitly included. Some features are aggregated and modeled, while the effects of many others are lumped together using a modeling construct called "ungaged reach gains and losses." These ungaged gains and losses account for all water in the water budget that is not explicitly named.

### 7.1.4 Supply Estimates

An output worksheet in each spreadsheet model summarizes monthly flow at the downstream end of each reach and provides the basis of this analysis. In general, simulated flow at the reach terminus indicates how much water is physically present, but it may not fully reflect flow that is available for future appropriation. This apparently "available flow" may already be appropriated to a downstream user, may be allocated downstream to satisfy compact or decree obligations, may be satisfying an instream flow right, or may result from reservoir storage water being delivered to specific points of diversion downstream. In short, it is important to acknowledge these existing demands when determining developable flow.

To determine how much of the physical supply is actually developable for future uses, physical supply at a reach terminus must be reduced to provide for the following circumstances:

- assumed approval of pending instream flow right applications.
- deliveries of storage water.

The flow that is physically present and could be developed for future uses at each point is defined as the minimum of the physical supply value, adjusted to take into account the above-listed instream demands, and the adjusted physically present flow at all downstream reaches. In other words, if adjusted physical supply at the node is the limiting value, then all that water can be removed from the stream without impacting either instream demand at this location, or downstream appropriators. Thus, water available for future appropriation must be defined first at the most downstream point, with upstream availability calculated in stream order. These calculations were made on a monthly basis, and annual availability was computed as the sum of monthly available water. Calculating annual availability in this way can yield a different value than applying the same logic to annual flows for each reach. The summation of monthly values is more accurate, reflecting constraints of downstream use on a monthly basis.

The physically available supply adjusted for downstream demands and delivery of storage water is further subject to compact limitations. The limitation is on basinwide annual use, based on total annual flow at the state line. In some parts of the basin, the compact may be more limiting than the amount of water unappropriated within Wyoming. Furthermore, availability across the entire basin, once the compact is considered, may be less than the combined available supplies as defined by the spreadsheet analysis.

As virgin flow estimates were not prepared in the seven river basin plans, a comparison of present flows to current levels of depletion was made. Table 7-1 shows the flows that were estimated for the average or normal hydrologic condition. These flow estimates were reduced by the current depletions estimated in the seven river basin planning area plans. In the 1973 Framework Water Plan, depleted streamflow leaving Wyoming was estimated at 14,740,200 acre-feet. From Table 7-1, it can be seen that the depleted streamflow leaving Wyoming has diminished somewhat. The reduction in streamflow leaving the state can be attributed to increased consumptive use and possibly a drier study period. Direct comparison of the 1973 Framework Water Plan hydrology to the 1970 to 2001 hydrology was not done in the individual river basin plans.

**Table 7-1 Average Annual Streamflow and Uses - Normal Condition**

| Basin | State Line Outflow - Natural Conditions[1] | Depletions of Streamflow to Wyoming: Irrigation[2] | Municipal, Domestic, & Stock[2] | Industrial[2] | Reservoir Evaporation[2] | Total[2] | Depleted Streamflow Leaving Wyoming[3] | Wyoming's Remaining Share Under Compact |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | | | | | | | |
| GREAT BASIN | | | | | | | | |
| Bear River | 526,000 | 92,300 | 1,400 | 300 | 5,300 | 99,300 | 426,700 | 187,800 |
| COLORADO RIVER | | | | | | | | |
| Green River[4] | 2,616,500 | 401,000 | 20,900 | 66,300 | 121,300 | 609,500 | 2,007,000 | 221,300 |
| MISSOURI RIVER | | | | | | | | |
| Northeast Wyoming[5] | 240,500 | 69,000 | 0 | 0 | 23,500 | 92,500 | 148,000 | 9,800 |
| Platte River[6] | 1,307,400 | 477,300 | 19,300 | 70,300 | 213,800 | 780,700 | 526,700 | 0 |
| Powder/Tongue River | 982,600 | 184,000 | 12,300 | 0 | 11,300 | 207,600 | 775,000 | 248,100 |
| Wind/Bighorn River | 4,628,600 | 1,165,500 | 9,300 | 15,700 | 138,700 | 1,329,200 | 3,299,400 | 2,491,500 |
| Yellowstone River[7] | 3,149,600 | | | | | | 3,149,600 | 0 |
| COLUMBIA RIVER | | | | | | | | |
| Snake/Salt River[8] | 3,540,000 | 122,000 | 0 | 0 | 72,200 | 194,200 | 3,345,800 | 155,000 |
| **Total** | **16,991,200** | **2,511,100** | **63,200** | **152,600** | **586,100** | **3,313,000** | **13,678,200** | **3,313,500** |

[1] Estimates are based on outflow plus depletions from the current river basin plans.

[2] Depletion estimates are from the current river basin plans.

[3] Depleted flows are based on outflow estimates from the current river basin plans.

[4] Depletions for municipal, domestic, and stock include 14,400 acre-feet diverted to the N. Platte for City of Cheyenne use.

[5] Excludes the flows for the Little Missouri and Niobrara Rivers.

[6] The Platte River system is fully appropriated in that a water supply that is based on a water right with a current-day priority cannot be expected to provide a reliable supply due to water rights administation. Estimates exclude the flows and depletions from the Horse Creek and South Platte drainages.

[7] Drainage area is within Yellowstone National Park and includes estimates for the Madison, Gibbon, Firehole, and Gallatin Rivers.

[8] Excludes the flows for the Henrys Fork and Teton Rivers.

The methodology used in the basin studies to evaluate Wyoming's remaining share under the interstate compacts and decrees was coordinated through the Wyoming State Engineer's Office (SEO) and relies heavily on previous work performed by others on behalf of the State. A more detailed evaluation was beyond the scope of the river basin planning effort. The methodology employed provides estimates of Wyoming's allocation under each of the three hydrologic conditions (wet, normal, and dry years). With the exception of the Platte River Basin, the basin planning efforts determined the three hydrologic conditions. A detailed description of this work is contained in the hydrology technical memoranda associated with the individual plans.

### 7.1.5 Basin Supply Estimates

The following subsections contain basin planning area presentations of the physically available flows and legally available flows. Physically available flows were determined for all of the river basin planning areas except the Platte River. Legally available flows were not estimated for all of the river basin planning areas, therefore, Figures 7-1 through 7-7 present physically available flow. The planning area flows for all of the basins except the Platte River Basin are shown in Table 7-2. The flow estimates were prepared for three hydrologic conditions: wet, normal, and dry. More detailed discussions of hydrology for each of these six basins are contained in the basin plan final reports and technical memoranda.

*Bear River Basin*

The Bear River Basin planning area flows are shown in Table 7–2. The physically available flows and legally available flows were prepared for three hydrologic conditions, wet, normal, and dry. Physically available flows and the location of the estimated flows are presented on Figure 7-1.

*Green River Basin*

Table 7-2 indicates that there is significant physically available flow in the Green and Little Snake Rivers. Figure 7-2 shows the locations where flows were determined to physically exist for the Green River. Figure 7-3 shows the flows and their locations for the Little Snake River. During the Green River Basin study, estimates of legally available flow were not prepared.

*Northeast Wyoming River Basins*

Physically available flow estimates and the location of the flow estimates are displayed on Figure 7-4. Table 7-2 indicates that there is very limited legally available surface water in the Northeast Wyoming River Basin planning area. During the Northeast Wyoming study, estimates for legally available flows were prepared for only the Belle Fourche River and Redwater Creek. No flow estimates were prepared for the Little Missouri River and Niobrara River.

*Platte River Basin*

Flow estimates were not made for the Platte River Basin during the river basin planning effort. Hydrologic information was provided through the *Nebraska v Wyoming* lawsuit. In the framework planning effort, North Platte River flows were estimated for the three hydrologic conditions, wet, normal, and dry, based on USGS gaged flow data. The Platte River system is fully appropriated. In the Platte River system, there is very limited legally available surface water in the planning area under normal conditions. A water supply based on a current-day water right filing would be in priority and able to be utilized only during extremely wet hydrologic conditions due to water rights administration and therefore would be of little value.

*Powder/Tongue River Basin*

Physically available flow estimates and the location of the estimated flows are displayed on Figure 7-5. Table 7-2 indicates that there is considerable legally available flow in the Powder River and

Tongue River. During the Powder/Tongue Rivers Basin study, estimates of the legally available flows in the Little Powder River and the Little Bighorn River were not made. Legally available flows may exist in those drainages.

*Snake/Salt Rives Basin*

Physically available flow estimates and the location of the estimated flows are shown on Figure 7-6. During the Snake/Salt Rivers Basin study, no estimates of flows were made for the Teton and Henrys Fork Rivers. Physically available flows and legally available flows may exist in those drainages.

*Wind/Bighorn River Basin*

Flow estimates were prepared for the three hydrologic conditions, wet, normal and dry. The physically available flow estimates and the location of the estimated flows are presented on Figure 7-7. Table 7-2 shows that the Wind/Bighorn and Clarks Fork Rivers are among the most hydrologically prolific rivers in Wyoming. During the Wind/Bighorn River Basin study, model runs were made for conditions with the Tribal Futures Projects developed as well as without the development of the Tribal Futures Projects. These two scenarios do not affect the legally available flows as there is a decreed amount of water associated with the Tribal Futures Projects. In Table 7-2, the legally available flows shown for the Upper Wind, Little Wind, and Lower Wind Rivers include the Tribal Futures decreed water right. A more detailed discussion of this situation is contained in the Wind/Bighorn River Basin Plan final report and the associated technical memorandum.

**Table 7-2  Available Flows**

| Basin | Hydrologic Condition | | | | | |
|---|---|---|---|---|---|---|
| | Wet | | Normal | | Dry | |
| | Physically Available Flow | Legally Available Flow | Physically Available Flow | Legally Available Flow | Physically Available Flow | Legally Available Flow |
| | ac-ft per year | | | | | |
| **Bear River** | | | | | | |
| Upper Division | 360,000 | 325,000 | 176,000 | 142,000 | 37,000 | 27,000 |
| Central Division | 786,000 | 508,000 | 427,000 | 188,000 | 132,000 | 0 |
| **Green River** | | | | | | |
| Henrys Fork | 125,000 | NA | 60,000 | NA | 23,000 | NA |
| Lower Blacks Fork | 422,000 | NA | 229,000 | NA | 101,000 | NA |
| Lower Hams Fork | 186,000 | NA | 95,000 | NA | 48,000 | NA |
| Upper Blacks Fork | 247,000 | NA | 136,000 | NA | 54,000 | NA |
| Upper Little Snake River | 311,000 | NA | 211,000 | NA | 111,000 | NA |
| Lower Little Snake River | 665,000 | NA | 449,000 | NA | 189,000 | NA |
| Lower Green River | 1,924,000 | NA | 1,269,000 | NA | 620,000 | NA |
| Above Fontenelle Reservoir | 1,659,000 | NA | 1,073,000 | NA | 496,000 | NA |
| Upper Green River | 701,000 | NA | 464,000 | NA | 251,000 | NA |
| New Fork River | 776,000 | NA | 573,000 | NA | 301,000 | NA |
| Horn Creek | 93,000 | NA | 57,000 | NA | 24,000 | NA |
| Cottonwood Creek | 97,000 | NA | 50,000 | NA | 15,000 | NA |
| West Fork New Fork | 183,000 | NA | 122,000 | NA | 57,000 | NA |
| Pole Creek | 404,000 | NA | 282,000 | NA | 146,000 | NA |
| East Fork New Fork | 211,000 | NA | 119,000 | NA | 56,000 | NA |
| Piney Creek | 76,000 | NA | 42,000 | NA | 18,000 | NA |
| **Northeast Wyoming** | | | | | | |
| Upper Belle Fourche | 14,000 | NA | 4,000 | NA | 200 | NA |
| Middle Belle Fourche | 9,000 | NA | 3,500 | NA | 400 | NA |
| Lower Belle Fourche | 151,000 | 15,600 | 71,000 | 7,400 | 13,000 | 1,100 |
| Redwater Creek | 34,000 | 3,300 | 26,000 | 2,400 | 17,000 | 1,400 |
| Upper Beaver Creek | 11,000 | NA | 9,000 | NA | 5,000 | NA |
| Middle Beaver Creek | 17,000 | NA | 14,000 | NA | 9,000 | NA |
| Lower Beaver Creek | 30,000 | NA | 20,000 | NA | 14,000 | NA |
| Northern Tribs to Cheyenne River | 58,000 | NA | 13,000 | NA | 2,000 | NA |
| Southern Tribs to Cheyenne River | 45,000 | NA | 18,000 | NA | 3,000 | NA |
| Lower Cheyenne River | 103,000 | NA | 31,000 | NA | 5,000 | NA |
| Little Missouri River | NA | NA | NA | NA | NA | NA |
| Niobrara River | NA | NA | NA | NA | NA | NA |
| **Powder/Tongue River** | | | | | | |
| Little Bighorn | 152,000 | NA | 113,000 | NA | 81,000 | NA |
| Tongue River | 473,000 | 163,000 | 326,000 | 90,000 | 218,000 | 40,000 |
| Upper Clear Creek | 213,000 | NA | 124,000 | NA | 80,000 | NA |
| Lower Clear Creek (Powder River) | 547,000 | 211,500 | 324,000 | 131,000 | 194,000 | 74,300 |
| Upper Crazy Woman Creek | 49,000 | NA | 22,000 | NA | 6,000 | NA |
| Lower Crazy Woman Creek | 61,000 | NA | 31,000 | NA | 16,000 | NA |
| Upper Powder River | 230,000 | NA | 153,000 | NA | 91,000 | NA |
| South Fork Powder River | 44,000 | NA | 27,000 | NA | 13,000 | NA |
| Lower Powder River | 328,000 | NA | 195,000 | NA | 111,000 | NA |
| Little Powder River | 48,000 | NA | 12,000 | NA | 3,000 | NA |
| **Snake/Salt River** | | | | | | |
| Salt River | 694,000 | 31,000 | 458,000 | 22,000 | 216,000 | 12,000 |
| Snake River | 4,159,000 | 165,000 | 2,888,000 | 116,000 | 1,769,000 | 69,000 |
| Teton River | NA | NA | NA | NA | NA | NA |
| Henrys Fork | NA | NA | NA | NA | NA | NA |
| **Wind/Bighorn River** | | | | | | |
| Clarks Fork | 1,144,000 | 686,000 | 740,000 | 444,000 | 499,000 | 299,000 |
| Upper Wind River[1] | 471,000 | 355,000 | 250,000 | 150,000 | 75,000 | 70,000 |
| Little Wind River[1] | 137,000 | 137,000 | 88,000 | 88,000 | 27,000 | 27,000 |
| Lower Wind River[1] | 987,000 | 878,000 | 749,000 | 684,000 | 332,000 | 293,000 |
| Upper Bighorn River | 1,695,000 | NA | 1,303,000 | NA | 871,000 | NA |
| Owl Creek | 48,000 | NA | 28,000 | NA | 9,000 | NA |
| Nowood River | 425,000 | NA | 296,000 | NA | 249,000 | NA |
| Lower Bighorn River | 1,912,000 | NA | 1,568,000 | NA | 920,000 | NA |
| Greybull River | NA | NA | 108,000 | NA | 48,000 | NA |
| Shoshone River | 1,082,000 | NA | 748,000 | NA | 472,000 | NA |
| Bull Lake Creek | 162,000 | 112,000 | 108,000 | 71,000 | 14,000 | 14,000 |
| Dinwoody Creek | 64,000 | 57,000 | 40,000 | 37,000 | 6,000 | 6,000 |
| Middle Fork Popo Agie River | 166,000 | 166,000 | 108,000 | 108,000 | 61,000 | 61,000 |
| North Fork Little Wind River | 95,000 | 95,000 | 63,000 | 63,000 | 12,000 | 12,000 |
| Shell Creek | 57,000 | NA | 47,000 | NA | 19,000 | NA |

Note: NA - Information was not presented in the individual basin plans.
[1]Legally available flows include the development of the Tribal Futures Projects.

### 7.1.6 Future Supply Estimates

The most conservative estimate of water availability is the dry hydrologic condition depleted by the projected uses discussed in Chapter 6. In the river basin plans, the most likely projection scenario is the moderate or Mid Scenario. Table 7-3 shows the flow estimates resulting from the mid-level depletions and the dry hydrologic condition.

**Table 7-3 Average Annual Streamflow and Uses - Mid-Level Development - Dry Condition**

| Basin | State Line Outflow - Natural Conditions[1] | Future Depletions of Streamflow to Wyoming: Irrigation[2] | Municipal, Domestic, & Stock[2] | Industrial[2] | Reservoir Evaporation[2] | Total[2] | Depleted Streamflow Leaving Wyoming[3] | Wyoming's Remaining Share Under Compact |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | | | | | | | |
| GREAT BASIN | | | | | | | | |
| Bear River | 235,200 | 94,500 | 3,400 | 0 | 5,300 | 103,200 | 132,000 | 0 |
| COLORADO RIVER | | | | | | | | |
| Green River[4] | 1,614,500 | 423,000 | 30,800 | 106,400 | 121,300 | 681,500 | 933,000 | 150,200 |
| MISSOURI RIVER | | | | | | | | |
| Northeast Wyoming[5] | 145,300 | 72,800 | 0 | 0 | 23,500 | 96,300 | 49,000 | 2,500 |
| Platte River[6] | 1,110,800 | 484,600 | 27,100 | 61,300 | 213,800 | 786,800 | 324,000 | 0 |
| Powder/Tongue River | 733,300 | 194,000 | 15,000 | 17,000 | 11,300 | 237,300 | 496,000 | 248,100 |
| Wind/Bighorn River | 3,686,100 | 1,305,700 | 18,000 | 38,700 | 138,700 | 1,501,100 | 2,185,000 | 1,648,000 |
| Yellowstone River[7] | 2,374,000 | | | | | | 2,374,000 | 0 |
| COLUMBIA RIVER | | | | | | | | |
| Snake/Salt River[8] | 2,164,300 | 107,100 | 0 | 0 | 72,200 | 179,300 | 1,985,000 | 90,000 |
| **Total** | **12,063,500** | **2,681,700** | **94,300** | **223,400** | **586,100** | **3,585,500** | **8,478,000** | **2,138,800** |

[1] Estimates are based on outflow plus depletions from the current river basin plans.

[2] Depletion estimates are from the current river basin plans.

[3] Depleted flows are based on outflow estimates from the current river basin plans.

[4] Depletions for municipal, domestic, and stock include 22,700 acre-feet per year diverted to the N. Platte for City of Cheyenne use.

[5] Excludes the flows for the Little Missouri and Niobrara Rivers.

[6] The Platte River system is fully appropriated in that a water supply that is based on a water right with a current day priority cannot be expected to provide a reliable supply due to water rights administation. Estimates exclude the flows and depletions from the Horse Creek and South Platte drainages.

[7] Drainage area is within Yellowstone National Park and includes estimates for the Madison, Gibbon, Firehole, and Gallatin Rivers.

[8] Excludes the flows for the Henrys Fork and Teton Rivers.

Under the dry hydrologic condition, in the Bear River Basin, Northeast Wyoming River Basin, and the Platte River Basin, there is little if any legally available surface water.

## 7.2 GROUNDWATER

### 7.2.1 Background

The availability of groundwater is a function of the physical characteristics of the aquifer at the location of interest (see Chapter 4) and the value of the intended use. For example, an industrial use may be able to afford to drill deep wells, sustain large drawdowns, and treat groundwater of undesirable quality, whereas an irrigation use may be economical only where wells are shallow, production is high, and quality is adequate without treatment. Virtually any of the "major" aquifers described in Chapter 4 could provide useful groundwater supplies, given sufficient development value. The "minor" and "marginal" aquifers could provide modest supplies of good-quality groundwater at many locations. Successful groundwater development in the "major aquicludes" group will be dependent upon locally favorable conditions and minimal quantity and quality demands.

Development of groundwater in sufficient quantities and of sufficient quality to meet specific project goals will require site-specific hydrogeologic analyses. None of the aquifers discussed in Chapter 4 are universally productive; none are entirely free of water quality concerns. While the generalizations of this report can provide guidance on the location and potential of various aquifers, local evaluation programs are essential to development success.

The relationship between the groundwater and surface water portions of the overall water resource depends upon the location, depth, rate, volume, and use of the groundwater withdrawn, all in the context of the local and regional hydrogeologic environment. When a well is initially pumped, groundwater is removed from storage to create a cone of depression. That cone will grow deeper and broader as pumping continues until a balance is established between pumping from the aquifer and inflow to the aquifer from 1) adjacent water-bearing rocks and/or 2) surface water sources. The latter may include stream infiltration induced by pumping, interception of groundwater flow that would otherwise continue towards discharge at the surface, or production of groundwater that would otherwise be taken up and transpired by plants (a capture process known as "ET salvage").

### 7.2.2 Diversion Rates

In general, groundwater diversion rates of less than 5 gpm are widely, although not universally, available throughout Wyoming. Diversion rates in the 5 to 50 gpm range are likely obtainable from most of the areas of "major aquifers" shown on Figure 4-9. Diversion rates in excess of 50 gpm may require favorable local conditions of permeability. Rates on the order of 1,000 gpm are only routinely available from certain areas of productive alluvium (e.g., the Snake River plain) and from well-recharged and fractured occurrences of the major bedrock limestone aquifers. These assessments apply to instantaneous diversion rates, however, and may or may not represent the conditions necessary to sustain those rates over extended periods, when subject to the cumulative impacts of multiple wells, or when stream depletion is an issue.

### 7.2.3 Groundwater in Storage

The depth to the groundwater table is rarely more than a few hundred feet. Beneath that, water is stored in the pore space of the rocks to a depth where porosity falls effectively to zero, e.g., in the crystalline rocks known as "basement". In Wyoming's deepest basins, sedimentary rocks – sandstone, shale, limestone, etc. – extend to depths of 30,000 feet. Thus, there is a vast amount of groundwater in storage, although much of it is too expensive to develop – due to unfavorable permeability, depth, or quality – to represent a useful resource. Not surprisingly, calculations of the total volume of groundwater in storage generate impressively large values. For example, the 1973 Framework Water Plan estimated total bedrock-aquifer storage for the state of 3.1 billion acre-feet[1].

[1] Based on estimates that 10 percent of the total volume of sediments in each basin is "aquifer material" and 5 percent of that material is groundwater.

Calculations of groundwater storage in alluvial aquifers are somewhat more meaningful, as much of this water is reasonably assessable. The 1973 Framework Plan estimated alluvial aquifer storage for the state at 10.2 million acre-feet. Neither this nor the estimate of bedrock groundwater storage has been updated.

Groundwater in storage can be viewed as 1) a surface reservoir, from which water can be extracted repeatedly as it is subsequently refilled, or 2) a groundwater "mine", from which water can be extracted one time. The alluvial aquifer is most akin to a surface reservoir. It is filled either by streamflow infiltration or groundwater recharge that would otherwise proceed into the stream. Use of aquifer storage reduces streamflow, and that reduction continues until the reservoir is refilled. Where quantities of water in excess of contemporaneous streamflow are needed seasonally, the groundwater reservoir can be exercised to better align demands with supply by "evening out" surpluses and deficits. This process happens naturally across many of Wyoming's irrigated lands, as large springtime diversions generate return flows that sustain late-season streamflows.

Similarly, artificial aquifer storage and recovery (ASR) projects can be developed to deliberately recharge and draft groundwater reservoirs. Permitting requirements and land-use conflicts can be substantially less for groundwater reservoir projects than for surface reservoirs, evaporation losses are less, and water-treatment issues may be avoided. Although such projects are currently uncommon in Wyoming, there have been several studies of ASR in the Cheyenne area, and Laramie is currently investigating ASR as a technique for banking excess groundwater for later use.

More like a groundwater "mine" are aquifers for which surface connection is measured on the scale of decades or centuries. While this groundwater, too, will ultimately be replaced from surface sources, that replacement may be so diffuse and over such a long time period that it is effectively a nonrenewable resource. For example, a study of the Splitrock Aquifer south of the Sweetwater River currently being completed by the WWDC concludes that 200,000 acre-feet of groundwater can be removed over a 40-year period without meeting the Modified North Platte Decree criteria for "hydrological connection"[2].

At present, no statewide criteria have been promulgated for assessment of the interaction of groundwater with surface water[3], nor have estimates been developed of groundwater storage volumes available under "not connected" status. In general, the deeper and more distant from surface water features the groundwater is, the less is the likelihood of significant surface water connection.

The removal of groundwater from storage is indicated by a lowering of the groundwater table (or, in the case of a confined aquifer, by a decrease in pressure). Bedrock aquifers are generally deeper and more distant from streams than are alluvial aquifers and are more likely to experience groundwater level declines before production rates and recharge rates come into balance. Short-term fluctuations in groundwater levels may reflect seasonal variations in recharge and discharge, multi-season climate cycles, or deliberate drafting and recovery management. Long-term changes in groundwater levels indicate a deficit (or, in some cases, a surplus) of recharge relative to production. As groundwater-levels decline, users of the aquifer may experience difficulty in obtaining historical quantities of groundwater, and conflicts may develop.

Reports of groundwater level declines and conflicts are concentrated in the Platte and Powder

[2]The Modified North Platte Decree was negotiated to define "hydrological connection" as a stream depletion volume of 28 percent or more of the volume pumped over 40 years.

[3]In other states, criteria of 10 percent in 50 years, 1 percent in 100 years, etc. are used to regulate aquifer stream interactions.

River Basins. The Platte is home to all three of Wyoming's Groundwater Control Areas – Prairie Center, Platte County, and Laramie County – each precipitated by declining groundwater levels. See Figure 7-8. It has also been the basin of groundwater interference complaints/investigations near Saratoga, Bates Creek, Glenrock, Horseshoe Creek, Cottonwood Creek, Hawk Springs, and Laramie.

In the Powder River Basin, concerns with groundwater level declines are centered on the coalbed methane (CBM) industry. CBM production is inherently in conflict with groundwater levels as it depends on substantial drawdown to release the methane gas from the coal seams. For the same reason, CBM development cannot occur where permeabilities are high, so it is an industry focused on areas where groundwater supplies are not abundant to begin with. Short-term drawdowns in the Wasatch aquifer are projected by the BLM EIS to be 500-800 feet over much of the basin. Recovered water levels following CBM exhaustion are projected to remain 30 feet below original levels.

As CBM production spreads to other basins, it will target coal seams in the "sandstone" aquifers shown on Figure 4-9. Impacts to existing groundwater users in these areas remain to be seen. Because the coal seams are generally deeper than in the Powder River Basin, conflicts with existing users are likely to be less.

No significant areas of groundwater decline are reported for the Bear, Snake/Salt, or Green River Basins. In the Wind/Bighorn Basin, groundwater levels have dropped as a result of municipal and irrigation withdrawals in the Riverton and Hyattville areas, respectively.

### 7.2.4 Groundwater Recharge

A common approach to estimating the quantity of groundwater available for continuous development, as opposed to one-time extraction, is to estimate groundwater recharge. If no more water is taken from the groundwater reservoir than flows into the reservoir, no long-term decline will occur. Total groundwater recharge was estimated in several of the basin plans:

- 2 million ac-ft/yr for the Platte River Basin, based on recharge equal to 10 percent of precipitation.
- 50,000 ac-ft/yr for the Green River Basin, based on recharge equal to 10 percent of precipitation, but only for those areas where precipitation exceeds potential evapotranspiration.
- 1 million ac-ft/yr for the Snake/Salt River Basin, based on detailed estimates of recharge rates from the University of Wyoming groundwater vulnerability study (Wyoming Water Resources Center, 1998).
- 14,000 ac-ft/yr for the Bear River Basin, based on recharge equal to 2 percent of precipitation.

There is little consensus on detailed estimation of groundwater recharge rates, which are a complex function of the seasonal timing, duration, intensity, and type of precipitation; the infiltration characteristics of the soil; the hydraulic properties of the uppermost geologic materials; and the manner in which groundwater recharge moves within and between aquifers. Groundwater recharge is the source of "base flow" to streams. While matching groundwater consumption to recharge would prevent widespread groundwater level declines, it would also lead to dry streambeds for much of the year.

Where groundwater is closely connected with surface water, as in much of the alluvial aquifers, the locations and long-term availability of groundwater are effectively the same as for surface water. There may still be good reasons to develop groundwater. A municipality, for example, may choose to divert groundwater rather than the same quantity surface water, despite a depletive connection, to capture the substantial benefits of more stable chemistry, much reduced treatment requirements, higher winter temperatures, etc. Similarly, a decision on development of additional water supplies as groundwater or surface water may depend on the availability of project funding, which may vary by water source. Where surface flows are adequate to meet demands on average, but may be seasonally inadequate or may be compromised by short-term drought cycles, use of the alluvial groundwater reservoir may be useful to modulate variations in the availability of surface water resources over time.

The most abundant supply of undeveloped alluvial groundwater appears to be in the Snake/Salt Basin, particularly in the Snake River Aquifer in Teton County. Given the abundance of available surface water in that basin, conflicts with surface water are not expected to be a major constraint on groundwater development. In the Platte Basin, in contrast, surface water connection is addressed by the Modified North Platte Decree and the recently finalized Platte River Recovery Implementation Program (PRRIP), and presents a major limitation on future development. Maps have been developed of those portions of the Platte River Basin that, upon initial investigation, appear to produce depletions less than the “hydrologically connected’ criteria. In areas more closely associated with stream depletions, major additional development of groundwater in the Platte Basin is likely to come primarily through trade or replacement arrangements with respect to surface water.

In summary, the above approaches to estimate the amount of groundwater in storage and the total recharge to groundwater provide upper bounds on the possible supplies of mineable groundwater and sustainable groundwater production, respectively. As a practical matter, however, the available groundwater supply is substantially less.

### 7.2.5 Groundwater Quality

Most water uses have some sensitivity to water quality. Thus, groundwater availability also will be a function of how the quality from a particular aquifer and location aligns with the needs of a particular use. As explained in Chapter 4, natural groundwater quality is generally best closest to outcrop and deteriorates the longer groundwater has been in contact with aquifer minerals. This effect is weakest in the “major aquifers” of Figure 4-9 and strongest in the “minor” and “marginal” aquifers.

For the most part, Wyoming has been relatively free of widespread human impacts to groundwater quality. Beyond conflicts associated with relatively high concentrations of nitrates in water supply wells around Torrington, generally understood to result from application of crop fertilizer, groundwater contamination issues in Wyoming have largely been confined to local incidents of spills and leaks. These incidents have compromised the availability of groundwater in local areas but rarely have had widespread effects.

As discussed in Chapter 4, certain Wyoming aquifers are more susceptible to contamination than others. The alluvial aquifers are generally the most productive, but due to their relatively high permeabilities, exposure at the surface, and location along developed stream corridors, they are more subject to water quality impacts from surface uses.

### 7.2.6 Basin Summaries

Table 7-4 summarizes the general groundwater availability conclusions of the individual river basin plans. Only the “major” aquifers are addressed in Table 7-4.

**Table 7-4 Groundwater Availability Summary**

| Aquifer (Group) |
|---|
| **Bear River Basin** |
| Alluvial Aquifers |
| Local development potential, with surface water depletion |
| Other Aquifers |
| Highly localized potential for high yields and quality, depending on local geologic conditions; stream depletion concerns may apply |
| **Green River Basin** |
| Alluvial Aquifers |
| Local development potential, with surface water depletion |
| Major Aquifers - Sandstones |
| Coalbed methane production may provide groundwater |
| **Northeast Wyoming and Powder River Basin** |
| Madison Formation (Major Aquifers - Limestone) |
| Total recharge estimated at 75,000 ac-ft/yr |
| Potential well yields up to >1,000 gpm |
| Accessible depths around Black Hills |
| Water quality likely deteriorates with depth |
| Lance/Fox Hills (Major Aquifers - Sandstones) |
| Low to moderate yields |
| Potential high-fluoride issues |
| Fort Union / Wasatch Formations (Major Aquifers - Sandstones) |
| Coalbed methane groundwater production provides use opportunities and water level impacts |
| Alluvial Aquifers |
| Local development potential, with surface water depletion |
| **Platte River Basin** |
| Alluvial Aquifers |
| Development potential only with recognition of surface depletion |
| Ogalalla and Arikaree Formations (Major Aquifers - Sandstones) |
| Additional development potential in South Platte drainage, subject to Control Area limitations |
| North Platte development potential mainly in areas deemed "not hydrologically connected" |
| Casper Formation (Major Aquifers - Limestone) |
| Production highly dependent on local geologic conditions |
| Accessible depths along north and east slopes of Laramie Range |
| North Platte development potential mainly in areas deemed "not hydrologically connected" |

| Aquifer (Group) |
|---|
| **Snake/Salt River Basin** |
| Alluvial Aquifers |
| Yields up to 1,000 gpm potentially available, with surface water depletion |
| Highest availability along Snake River |
| Potential quality concerns with proliferation of septic systems |
| Salt Lake Formation (Major Aquifers - Sandstones) |
| High-yield wells highly dependent upon local geologic conditions |
| Other Aquifers |
| Highly localized potential for high yields and quality, depending on local geologic conditions |
| **Wind/Bighorn River Basin** |
| Alluvial Aquifers |
| Well yields 10 - 500 gpm |
| Surface water depletion issues |
| Wind River Formation (Major Aquifers - Sandstones) |
| Already heavily developed in some areas |
| Potential for high-capacity wells elsewhere |
| Groundwater quality variations may constrain use |
| Madison Formation (Major Aquifers - Limestone) |
| Potential for >1,000 gpm flowing wells |
| Production highly dependent on local geologic conditions |
| Accessible depths along west slope of Bighorn Mountains, northeast slopes of Wind River Mountains |
| Flathead Formation (mapped with Major Aquifers - Limestone) |
| Yield potential for >1000 gpm flowing wells highly dependent upon local geologic conditions |
| Accessible depths along west slope of Bighorn Mountains |

In general, groundwater availability is greatest for the alluvial aquifers of the state, with the understanding that connections with surface water will have to be addressed. The “major aquifers -

limestone" group has potential for development of high-yield, perhaps flowing, wells adjacent to most Wyoming mountain ranges, but these aquifers are highly dependent upon local geologic conditions to produce favorable conditions.

Table 7-5 shows SEO groundwater permits by type of use by river basin for the state. In addition, the table shows the 10-year growth rates of permit applications.

**Table 7-5 Groundwater Permits Summary**

| | Irrigation | | Rural Drinking Water | | Municipal | | Industrial | | CBM | |
|---|---|---|---|---|---|---|---|---|---|---|
| River Basin | Total Permits | 10-Yr Growth | Total Permits | 10-Yr Growth | Total Permits | 10-Yr Growth | Total Permits | 10-Yr Growth | Total Permits | 10-Yr Growth |
| Bear | 59 | 4.0% | 1,037 | 2.6% | 8 | 4.8% | 18 | 0.0% | 0 | 0.0% |
| Green | 90 | 2.3% | 7,193 | 3.9% | 34 | 1.6% | 262 | 1.9% | 798 | 53.5% |
| Northeast | 289 | 0.9% | 9,779 | 2.4% | 109 | 2.9% | 558 | 2.6% | 9,446 | 45.3% |
| Platte | 2,022 | 1.1% | 29,320 | 2.8% | 278 | 0.9% | 362 | 1.8% | 81 | |
| Powder/Tongue | 177 | 2.5% | 9,829 | 3.6% | 15 | 1.4% | 282 | 1.4% | 22,490 | 81.8% |
| Snake/Salt | 86 | 2.7% | 4,919 | 4.5% | 23 | 2.5% | 10 | 1.1% | 0 | 0.0% |
| Wind/Bighorn | 238 | 4.3% | 16,132 | 2.5% | 98 | 1.3% | 314 | 0.4% | 16 | |
| **Total** | **2,961** | **1.5%** | **78,209** | **3.0%** | **565** | **1.5%** | **1,806** | **1.7%** | **32,831** | **60.3%** |

Note: All wells with zero yields excluded; wells with "unknown" yields or no yield data included.

A more detailed discussion of the groundwater situation in the individual river basin planning areas is contained in the individual river basin plans and associated technical memoranda.

## 7.3 WATER CONSERVATION

### 7.3.1 Introduction

In general, the state has adequate water to serve the needs of its river basin residents. For the most part, water shortages are seasonal, and their effects can be magnified by drought conditions. Water conservation is any beneficial reduction in water losses, waste, or use.

Agricultural water consumption is the major water use sector in Wyoming. The Irrigation Association, an international organization that was started in 1949 and states that it is dedicated to "promoting water and soil conservation through proper water management," takes the following positions regarding long-range water conservation planning:

- Measure all water use.
- Price water so as to recognize its finite nature, provide financial incentives to users who conserve water, and provide financial penalties to users who waste water.
- Hold all water users responsible for protecting the quality of the water that they use.
- Create financial systems to reward users of efficient irrigation systems.
- Create national education programs regarding the "absolute necessity of supporting regulatory policies which reward conservation and efficient water use".
- Support water reclamation and reuse initiatives, particularly for irrigation, but also for municipal, industrial, and other water uses sectors.

- Increase support for developing new water sources, including new conveyance and storage systems and incorporating into development plans appropriate environmental concerns.
- Maintain water conservation planning as an ongoing program.
- Promote policies which allow for the lease, sale, or transfer of "established water rights" and/or the lease, sale, and transfer of water without jeopardizing established water rights, whenever possible. (Irrigation Association, 2005)

Water conservation in Wyoming involves all uses including agriculture, municipalities, industry, recreation, and environmental concerns. In the past, water conservation efforts were mainly focused on improving efficiency of agricultural water use. As communities within the state have grown and changed, there is a growing interest in flat water activities and streamflow-related recreation. Water conservation has different meaning at different times of the year and to different water users. Given Wyoming's climate and topography, storage of spring runoff must be included in consideration of water conservation for any water use sector (Tyrrell, 2004). The following is a discussion of water conservation activities and opportunities.

### 7.3.2 Agricultural Water Conservation

The largest water savings by quantity are generally realized by conservation in the agricultural sector, as it represents the largest use of water in the state. For this reason, much of the focus of water conservation is on irrigation practices. In order to determine what future conservation efforts will be effective, an inventory of existing facilities is necessary. Major items of interest in this inventory include conveyance facilities and irrigation methods.

A significant portion of water diverted for irrigation can be lost during conveyance to the field through seepage, deep percolation, phreatophytes, evaporation, and so forth. Water is typically diverted from the river or stream into a canal or ditch, which is generally of earth construction and unlined. The soils in many of the river basin valleys are predominantly gravelly loams as they were formed on the alluvium of the many rivers, streams, and washes that are present in the valleys. Water will quickly percolate through these granular soils. No extensive studies have evaluated ditch conveyance losses across the state.

The USBR and WWDC have worked on joint funded projects where the open canal and lateral system has been replaced with an enclosed gravity pressurized sprinkler system. The Sand Mesa project on the Midvale Irrigation District is an example.

Membrane liners have been used with good results on some of the large USBR canals around the state. Research has indicated that application of polyacrylamide (PAM) to the canal bottom and sides will reduce seepage losses and increase transmission efficiencies.

Irrigation methods also present an opportunity for water conservation. In Wyoming, historically flood irrigation was the most popular method used and still is very popular in spite of its low efficiency. Efficiency of flood irrigation has improved through the use of gated pipe and surge valves. Use of this technology has reduced water loss to seepage in laterals and to deep percolation that is not available to the crops.

Since the early 1970s many areas in Wyoming have converted to sprinkler irrigation. Utilization of hand lines or wheel lines has been replaced by use of center pivot systems. Sprinkler design and efficiency have also increased over time with the use of low energy consuming or low pressure application systems. For the most part, the conversion from flood to sprinkler irrigation has had a positive effect, as crop yields have increased considerably. Also, more acres of cropland can be irrigated late in the summer when there is less water available. However, some positive aspects of flood irrigation have been reduced with the conversion to sprinkler irrigation, such as groundwater recharge, reduction of peak runoff, and enhanced late season flow due to late season irrigation return flows.

### 7.3.3 Industrial Water Conservation

Industrial water use is very important as industry employs a significant percent of the state's work force and generates a large portion of the state's payroll. Conservation by industry differs by industrial sector.

In the case of cooling water, a means of conserving water is dry cooling. As with many of the other conservation measures, dry cooling comes at a cost both in construction and efficiency. In some sectors, reuse of water may be a conservation measure.

The other major industrial water use category is for process water. Conservation in an industrial process may be tied to major redesign of the particular industrial or manufacturing process. These changes are industrial sector-specific as well as individual plant-specific.

### 7.3.4 Municipal Water Conservation

Municipal water use is a significant use of water in the state following agricultural and industrial water use. Water conservation measures have been implemented by some of the municipalities in Wyoming; however, it has not been a major focus in all areas of the state.

Conservation measures generally consist of individual customer meters that track actual water use. Meters can also help determine if there are major losses in the distribution system through leaks. Many municipalities meter their public water systems, but some systems do not and have little or no incentive to conserve water. The expense of installing meters can be seen as prohibitive, and is unpopular politically. Also, some systems encourage water use during the winter months to prevent frozen pipes. Some systems are requiring meters on new hookups and considering phasing in metering for the existing population.

### 7.3.5 Recreational and Environmental Water Conservation

A growing amount of water use in the state is related to recreational and environmental uses. While these are generally nonconsumptive uses, water is still key to many of these activities. Various wetland and riparian enhancement projects have been conducted throughout the state over the years. While these projects do not necessarily conserve water, they do conserve or enhance habitat for fish, waterfowl, and other animals. Water utilized for wetlands may also be considered conservation of bird or fish habitat, although more water is used than if the wetland was not maintained. Also, the USBR has agreed to maintenance flows at some USBR dams in order to provide sufficient flow for fish during the winter months or other periods of aquatic concern.

Water storage can serve an important role in meeting these water needs by providing increased management of the available water supply for these uses. Storage can also serve to conserve water by meeting the needs of the resource while holding over surplus water for later use.

Fencing to keep cattle off of a stream bank can help reduce erosion, improve water quality, and maintain habitat. In these circumstances, an off-stream location for stock watering must be developed.

### 7.3.6 Conclusion

In order for conservation methods to be successfully implemented, there must often be an incentive or benefit for those involved. This incentive may be in various forms, such as increased crop yields, improved fishing, reduced costs, and so forth.

Reduction of conveyance losses and improvement of irrigation efficiency do not necessarily equate to less water used. In areas of deficit, conservation measures may result in the conserved water being applied to additional acres or providing a full supply of water throughout the season without a decrease in the water diverted. However, this improvement in efficiency will likely result in an increase in the crop quality and yield.

Prior to implementation of conservation improvements, the situation should be studied to see how conservation is addressing the issue and to make sure that the program will have the intended result.

Under the prior appropriation doctrine, water left in the stream is available to other users, and there is presently no mechanism whereby a diverter can capitalize on investment in conserving measures where the saving remains in the stream for use by other interests.

Water saved or water yield from conservation was not estimated in the river basin planning area studies. The amount of saved water or water yield, from conservation measures, is site-specific, and as was noted above, conservation measures may actually result in more water use rather than less.

## 7.4 REFERENCES

Irrigation Association, The. 2005. *Drought: A Handbook for Prevention and Action.* http://www.irrigation.org.

Tyrrell, P., Wyoming State Engineer. 2004. *Water Conservation and Wyoming Law: What Are Our Current Constraints?* In *Proceedings of the Wyoming Water Association 2004 Annual Educational Seminar and Meeting*. October 27-29, 2004. Casper, WY.

Wyoming Water Development Commission. 2001. *Guidelines for Development of Basin Plans.*

Wyoming Water Resources Center. University of Wyoming. 1998. *Wyoming Groundwater Vulnerability Assessment Handbook.*

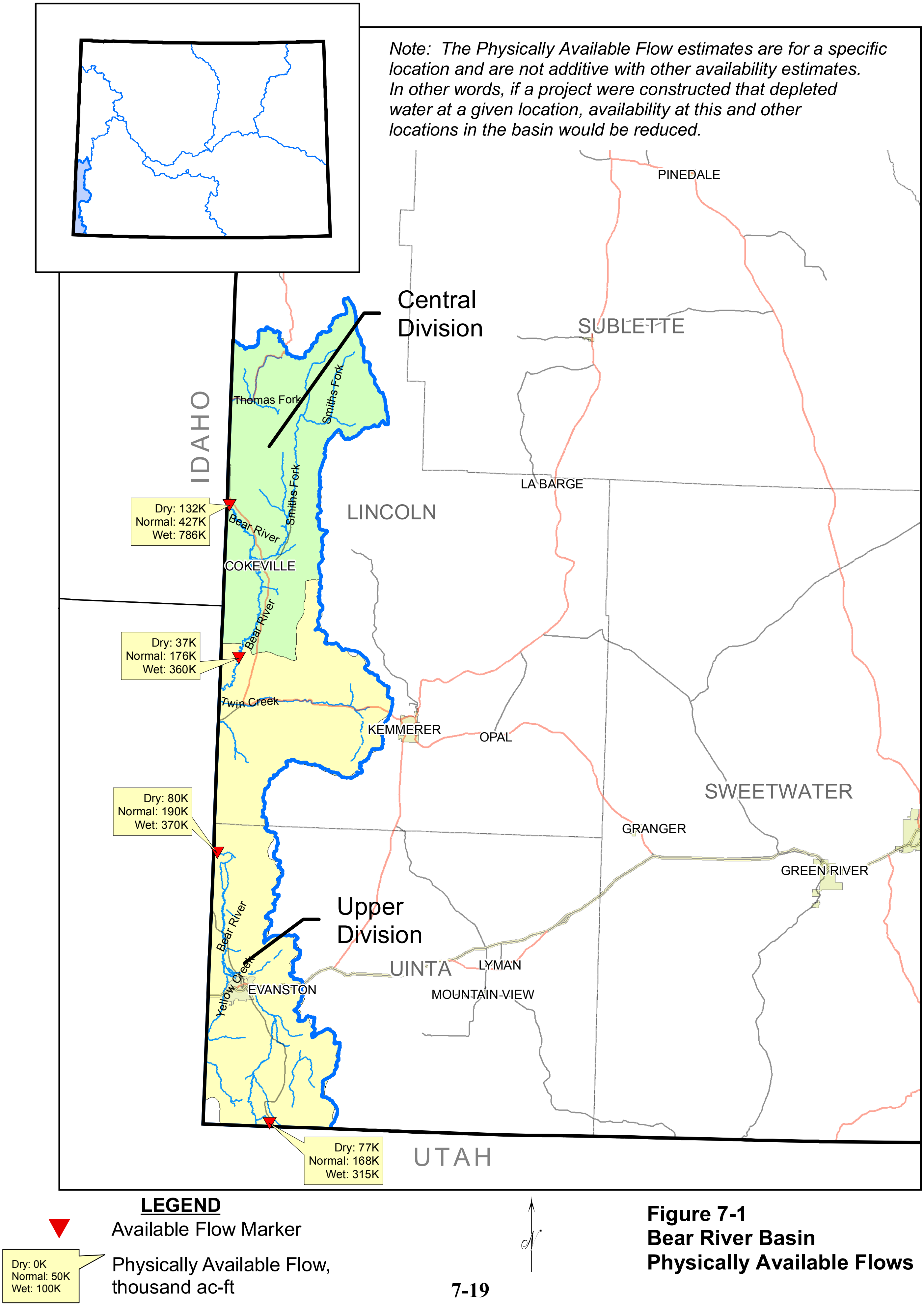



**Figure 7-1**
**Bear River Basin**
**Physically Available Flows**

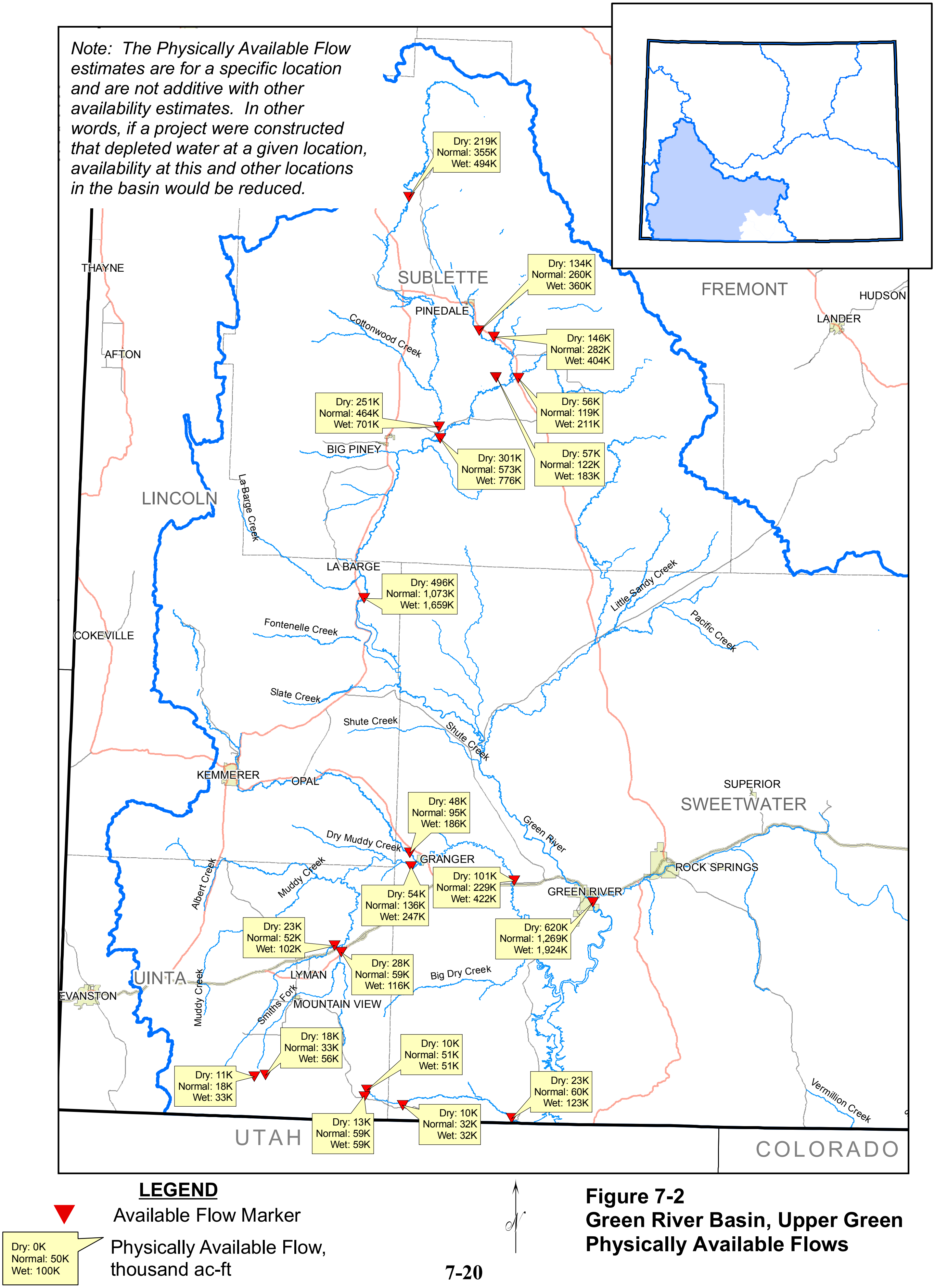
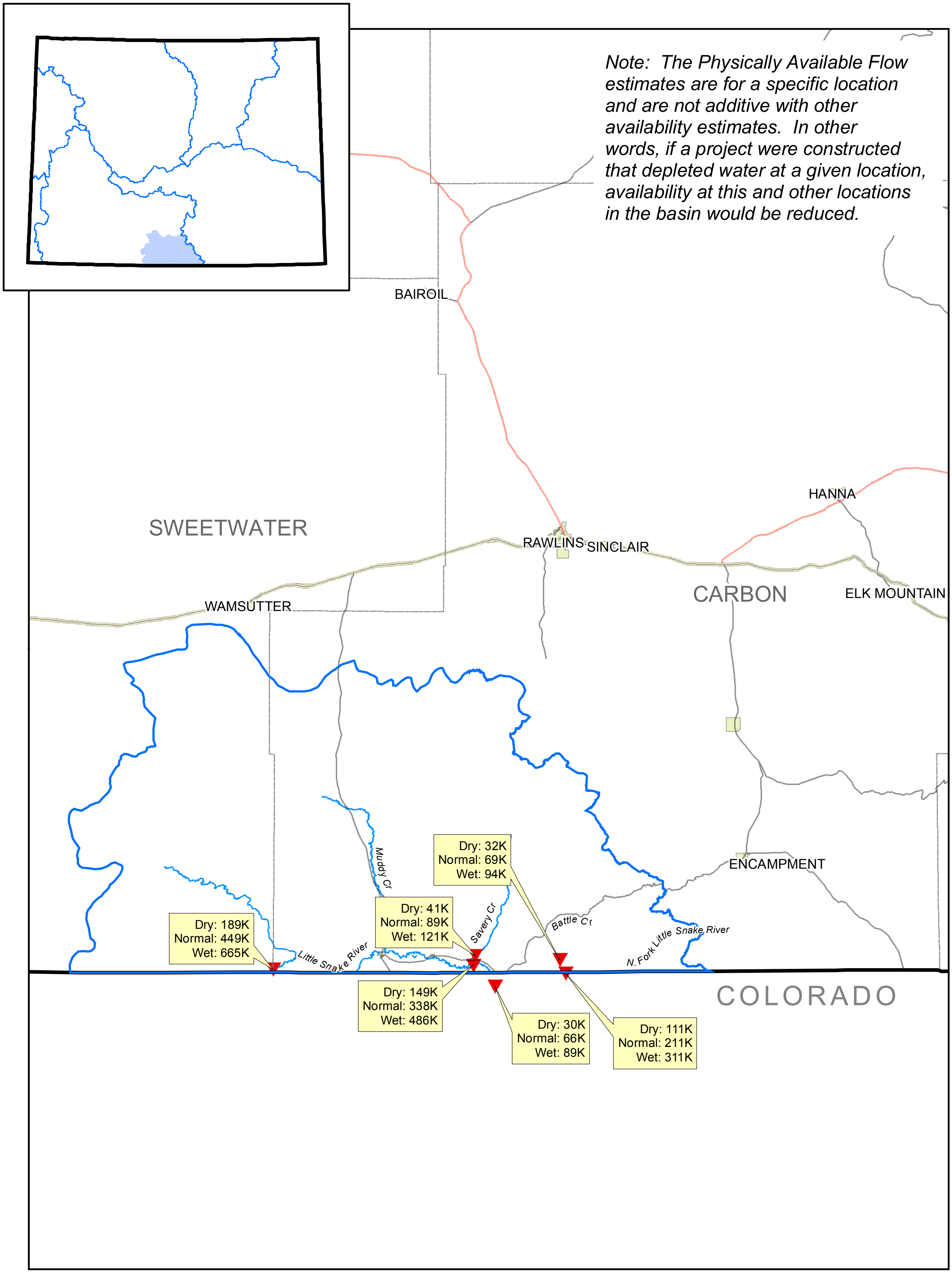



**Figure 7-2**
**Green River Basin, Upper Green Physically Available Flows**




**LEGEND**

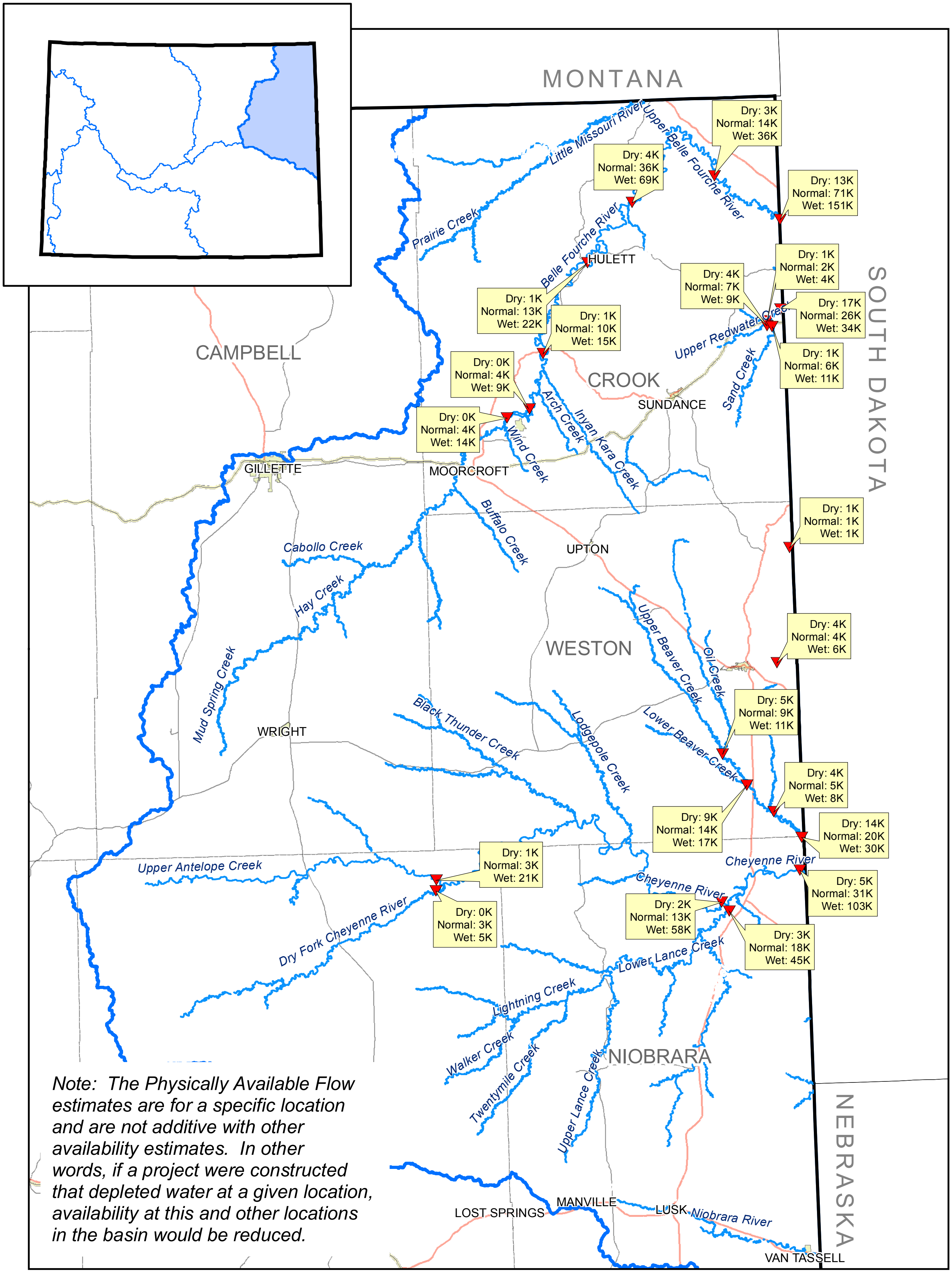
Available Flow Marker

| |
|---|
| Dry: 0K<br>Normal: 50K<br>Wet: 100K |

Physically Available Flow, thousand ac-ft

N

**Figure 7-3**
**Green River Basin, Little Snake River Physically Available Flows**



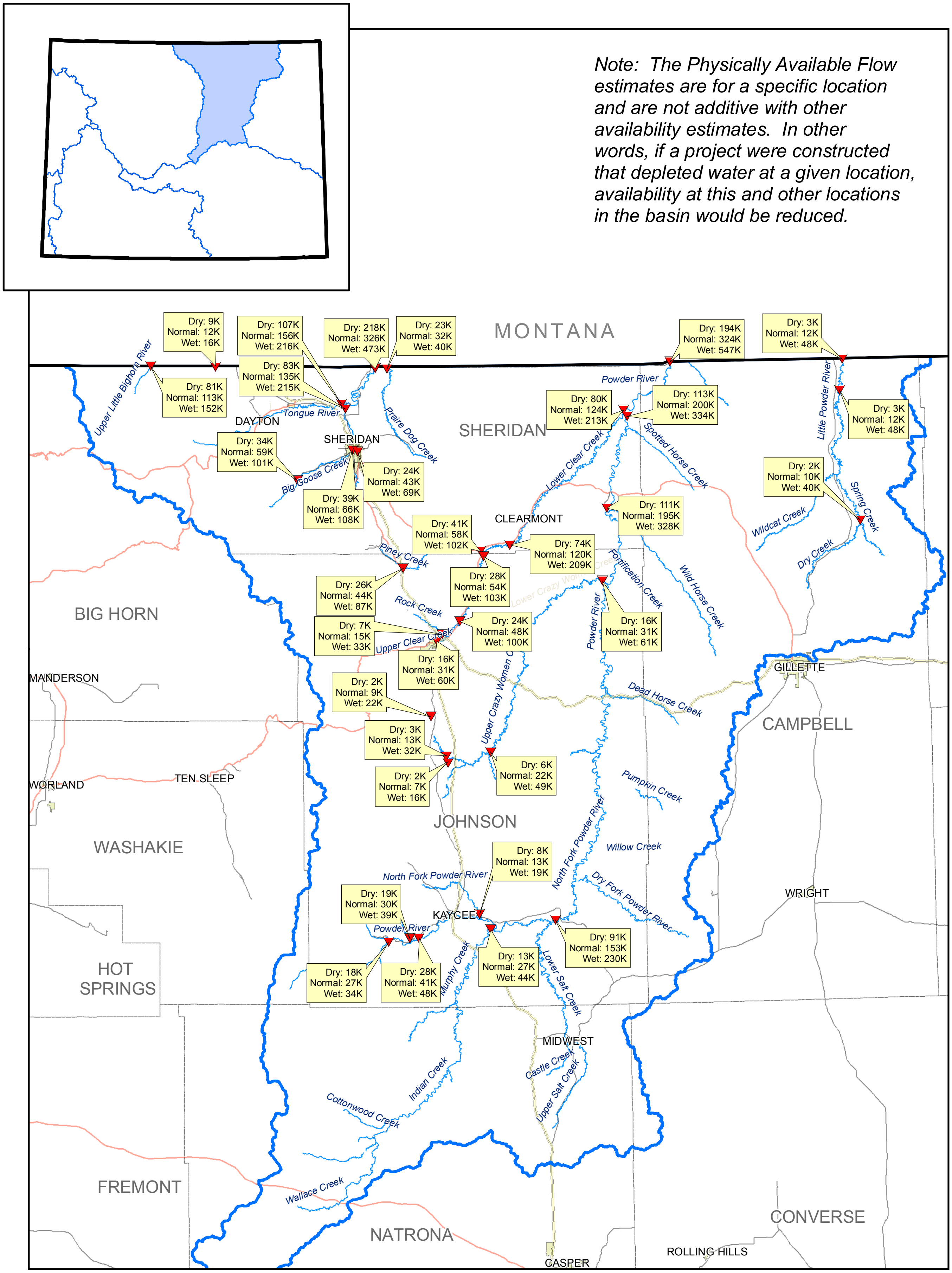

*Note: The Physically Available Flow estimates are for a specific location and are not additive with other availability estimates. In other words, if a project were constructed that depleted water at a given location, availability at this and other locations in the basin would be reduced.*

**LEGEND**

Available Flow Marker

Dry: 0K Normal: 50K Wet: 100K — Physically Available Flow, thousand ac-ft

**Figure 7-4**
**Northeast River Basin**
**Physically Available Flows**



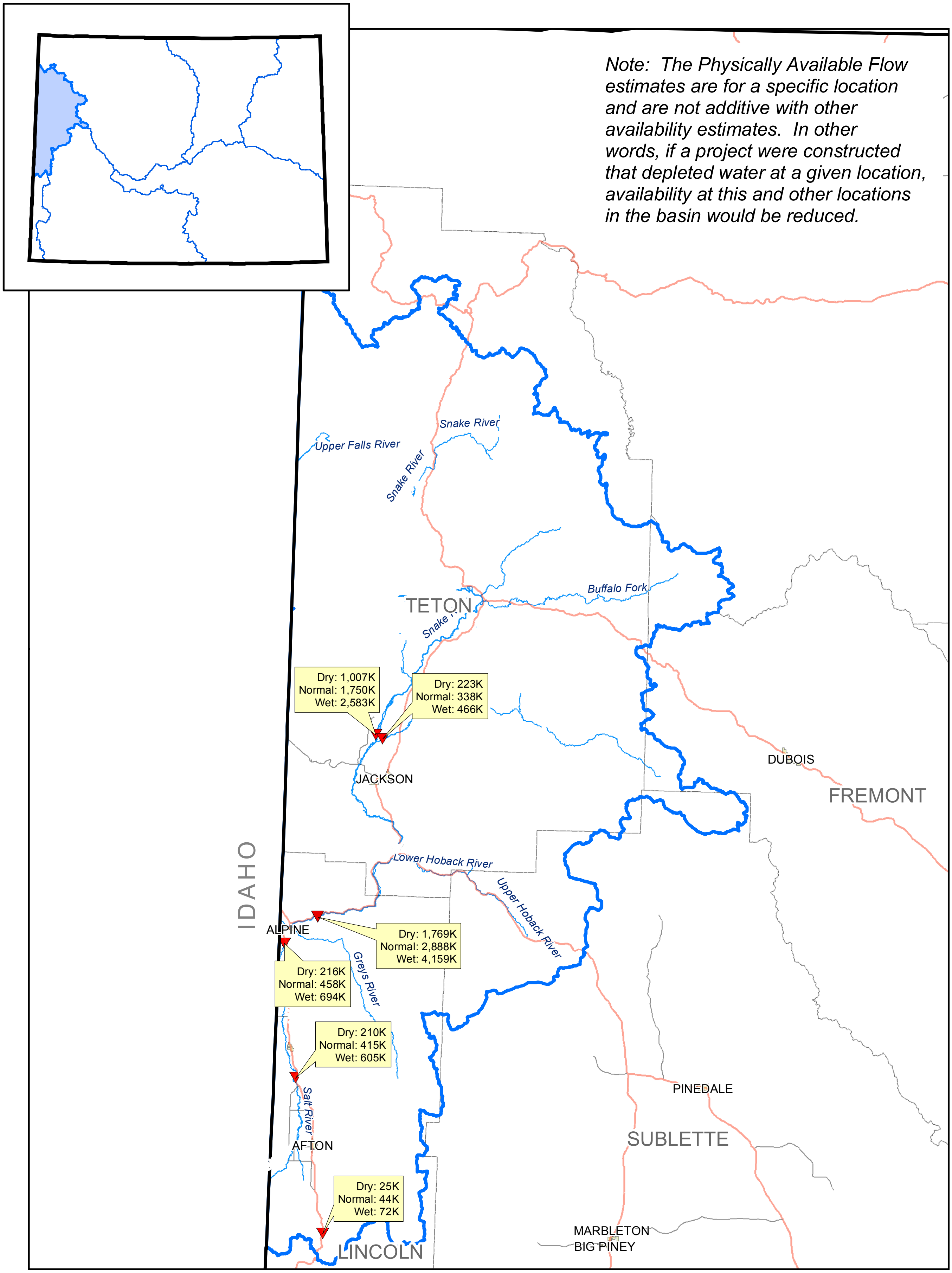

**LEGEND**

Available Flow Marker

Dry: 0K Normal: 50K Wet: 100K — Physically Available Flow, thousand ac-ft

N

**Figure 7-5**
**Powder/Tongue River Basin**
**Physically Available Flows**




**LEGEND**

Available Flow Marker

Dry: 0K
Normal: 50K
Wet: 100K

Physically Available Flow, thousand ac-ft

**Figure 7-6**
**Snake/Salt River Basin**
**Physically Available Flows**

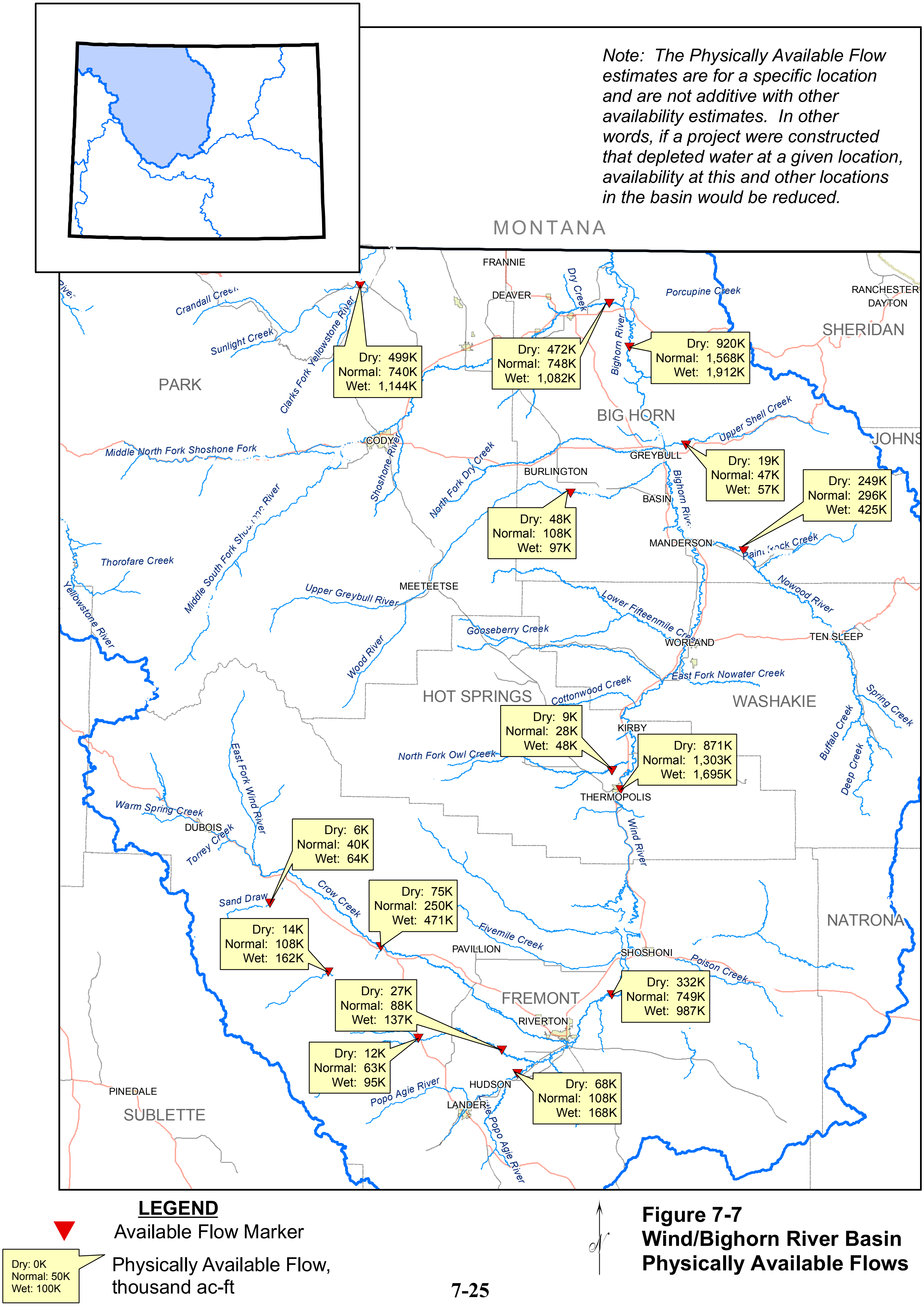



**Figure 7-7**
**Wind/Bighorn River Basin**
**Physically Available Flows**

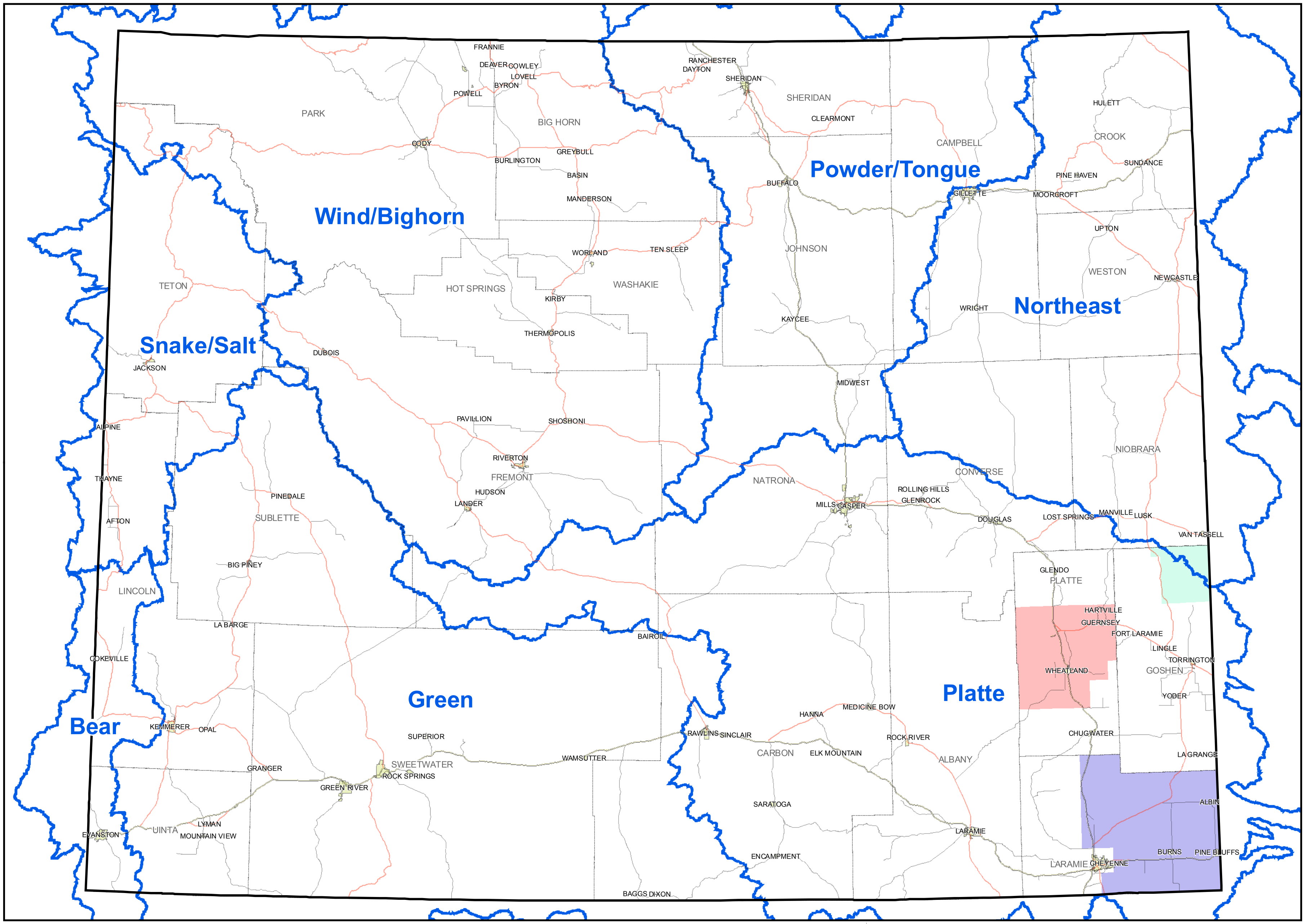
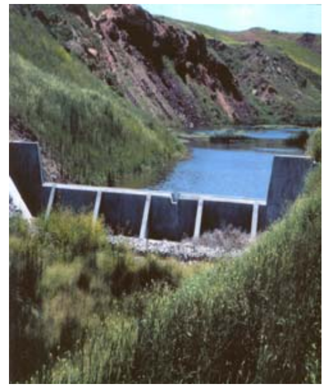



**Figure 7-8**
**Groundwater Control Areas**

# 8.0 OPPORTUNITIES

## 8.1 INTRODUCTION



Previous chapters of this report quantify water resources available for development and use and identify present and future water needs in the basins. The list of water use opportunities presented in this chapter is intended to be used by potential project sponsors and other organizations that need to develop a water supply to satisfy their specific needs.

Opportunities, for the most part, came from basic project planning. The opportunities were placed on a list and information on each opportunity was entered into a matrix for each of the river basin planning areas. The matrix allowed evaluation of a specific opportunity relative to similar or related opportunities. The methodology evaluates opportunities as to whether they are desirable, functional, and capable of receiving the support required for development.

The procedure used to complete this task consists of the following steps:

1. Use screening criteria developed in the basin plans to evaluate future water use opportunities.
2. Use a long-list of future water use opportunities developed in the basin plans.
3. Use a short-list of future water use opportunities developed in the basin plans.
4. Evaluate the opportunities on the short list.
5. Develop a Framework Scoring Matrix of advanced opportunities, specifically for the Framework Water Plan, where appropriate.

## 8.2 SCREENING CRITERIA FROM THE BASIN PLANS

The process of screening water use opportunities was conducted in a progressive manner in six of the seven basin plans. This process had not been performed for the Bear River Basin. The screening process was developed in the following manner unless noted in the individual basin discussions.

### 8.2.1 Long List of Future Water Use Opportunities

During preparation of the six basin plans (Bear River Basin excluded), long lists of future water use opportunities were initially prepared using information from published reports available for the planning area. The level of information and data available for the projects identified through the literature review varied from very sketchy to completed conceptual designs. Comments and suggestions received from members of the Basin Advisory Group (BAG) contributed to the development of the final version of the long list.

### 8.2.2 Short List of Future Water Use Opportunities

Generally, the next step in each basin was to prepare a ranked short list of opportunities. In this step, six criteria were evaluated to present an overall picture of the favorability of a project or opportunity. These criteria were evaluated using a matrix approach and those matrices have been included as various tables in this chapter. It should be noted that each basin used slightly different scoring methods. Therefore, the matrix scoring cannot be compared across basins. The following sections summarize the evaluation criteria.

*Water Availability*

This criterion reflects the general ability of a project to function given likely bypasses for prior rights and environmental uses. It is not a reflection of the relative size of a project.

*Financial Feasibility*

This criterion reflects the effects of the combination of technical feasibility (high or low construction cost) and economic use to which the water would be put (e.g., irrigation of native meadow versus cultivation of alfalfa or row crops). The intent of this ranking is to indicate the likely ability to afford the project or meet Wyoming Water Development Commission (WWDC) or other funding source criteria. A low number represents a project with a cost so high that it would be difficult to finance, whereas a high number represents a project that should more easily meet funding and repayment requirements.

*Public Acceptance*

This criterion reflects the extent to which a project will encounter or create public controversy (low number) versus a project that would likely engender broad public support (high number). For example, on-stream storage in environmentally sensitive areas would be very controversial, while off-channel storage in less sensitive areas would more likely be supported.

*Number of Sponsors/Beneficiaries/Participants*

Under this criterion, all other things being equal, a project serving a larger segment of the population would rank higher (higher number) than one serving only a few people (lower number).

*Legal/Institutional Concerns*

This criterion reflects the perceived relative ease (high number) or difficulty (low number) with which a project could be authorized and permitted under existing state and federal law.

*Environmental/Recreational Benefits*

This criterion reflects the net effect of positive environmental and recreational aspects of a project as offset, to the extent it can be determined, by potential negative impacts on these attributes.

### 8.2.3 Framework Scoring Matrix

A Framework Scoring Matrix was developed specifically for this Framework Water Plan to allow comparison of potential projects that had come into play since publication of the basin plans (Green, Northeast, Wind/Bighorn) and to evaluate opportunities in the Bear River that had not been previously ranked. This scoring matrix includes both monetary and non-monetary factors.

*Monetary Factors*

- **Size** – reservoir size in acre-feet.
- **Irrigated Acreage** – presently irrigated acreage.
- **2007 Total Project Costs** – project costs updated to 2007.
- **Unit Cost** – project costs divided by project size.
- **Sponsor's Cost** – cost per irrigated acre per year assuming WWDC financing (two-thirds grant, one-third loan at 4 percent for 20 years).
- **Comments**

*Non-monetary Factors*

- **Need –** project need based on shortages.
- **Water Availability** – availability of water.
- **Project Ability to Meet Need** – project location and size relative to needs.
- **Multiple Use Potential –** potential for recreation, flood control, water quality improvement, etc.
- **Geotechnical Feasibility** – preliminary geotechnical evaluation.
- **Land Ownership** – preliminary evaluation of landownership issues.
- **Cultural Resources** – preliminary evaluation of impacts.
- **Environmental Impacts** –preliminary evaluation of impacts on wetlands, riparian habitat, wildlife, etc.
- **Ability to Permit** – comparative evaluation of potential for successful project permitting.
- **Cost –** relative evaluation of project costs versus project benefits.
- **Total** – total of non-monetary factor scores.

Each of the non-monetary factors was assigned a weighted value that reflects the importance of that factor to project feasibility, and each potential project was assigned a score from 0 to 10 for each factor.

### 8.2.4 Agricultural Needs

Chapter 6 outlines the projected future water needs for the seven river basin planning areas in the state. Agriculture is the major water user in the state and exhibits the bulk of the seasonal shortage needs across the state.

The estimates of existing agricultural need used in the Framework Scoring Matrix were based upon full supply requirements. Full supply requirements were determined by applying the irrigation water requirement to the actual irrigated acreage. The water requirement derived from this calculation was compared to the historical diversions during dry years. The difference between the full supply requirement minus the historical diversion is the estimated shortage.

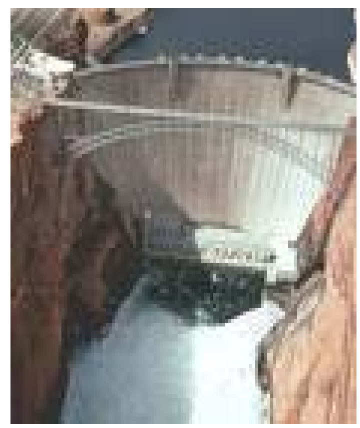
The results of the agricultural water use estimates were used as inputs to the water availability models prepared for the planning effort as discussed in Chapter 7. The modeling was used to determine the availability of excess flows for future development and also as a means of determining where there are needs for supplemental water supplies under existing conditions. The need for these supplemental supplies should be consistent with irrigators' perceptions of those needs. The diversion records during non-supply-limited conditions (wet years) were used in the planning area as a measure of the level of supply that irrigators have settled on, under existing conditions, as a balance between maximizing crop yields and conserving limited resources. This is defined here as the "full supply diversion requirement". The difference between the full supply diversion requirement and the dry year diversions was used to estimate need.

### 8.2.5 Potential Groundwater Development

Although there have been considerable hydrogeological investigations in the state, there have been few regional assessments of the annual recharge, storage, and sustained yield capability of the major aquifer systems in the state. Figure 4-9 shows the various aquifers and the basins where those aquifers occur. Groundwater development potential of the various aquifer systems is discussed in the groundwater section of Chapter 7.

## 8.3 BEAR RIVER BASIN

Future water use opportunities for the Bear River Basin are addressed in this section.



### 8.3.1 Physically Available Flows

The physically available flows at locations within the basin are provided in Table 7-2 and shown on Figure 7-1 in Chapter 7. The flows are indicated for dry, normal, and wet years in acre-feet per year. The available flows indicate that many of the tributaries have quite low flows in dry years, which usually results in potential for shortages.

### 8.3.2 Compact Limitations

The Bear River Compact of 1978 controls the split of water on the Bear River between Wyoming, Idaho, and Utah. The compact limitations are discussed in detail in Chapter 3. The legally available flows for the Upper and Central Divisions are summarized in Table 7-2 in Chapter 7. Compact provisions severely limit the available flow during dry years, particularly in the Central Basin.

### 8.3.3 Agricultural Needs

Almost every area of the Bear River Basin planning area can be considered water-short during dry years. The needs identified in the Basin Plan involved existing agricultural needs. Consequently, the opportunities are primarily focused on meeting those needs. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6. Table 8-1 indicates estimates of existing agricultural needs for the subbasins. The irrigated acres within those subbasins are also indicated.

**Table 8-1 Agricultural Needs, Bear River Basin**

| Subbasin | Irrigated Lands acres | Needs for Dry Hydrologic Condition ac-ft per year |
|---|---|---|
| Upper Division | 40,400 | 11,000 |
| Central Division | 23,500 | 12,000 |

### 8.3.4 Long and Short Lists of Future Water Use Opportunities

No specific long or short lists were developed for the Basin Plan.

### 8.3.5 Central Division Investigations

The Central Division of the Bear River extends from Pixley Dam to Stewart Dam in Idaho. Past investigations for storage have been confined to Smiths Fork Creek. The most recent study, *Cokeville Reservoir Level I Study* (Sunrise Engineers, Inc., 2004), analyzed six sites on the Smiths Fork: the Lower Teichert/Bagley site, Upper Teichert/Bagley site, Smiths Fork site, Ashby site, Ferney Glade site, and Tres Pass site. The alternatives were sized to meet irrigation shortages and varied in capacity depending upon the locations of the drainage. The six alternatives were evaluated for various criteria. Based on the evaluation, the Upper Teichert/Bagley site and the Smiths Fork site were advanced to preliminary design, cost estimate, and economic analyses.

These two sites, shown on Figure 8-1, were on-channel sites with significant environmental impacts, primarily to wetlands. The projects had no designated recreation pools, so potential multiple use was limited.

The potential for off-channel reservoirs to lessen environmental impacts was considered in the 2004 study, but no sites were pursued. A potential site on Muddy Creek could store significant amounts of water. The reservoir would be supplied from a seven-mile canal from the Smiths Fork. The site has minimal wetland and aquatic resources. Most site-specific data are unavailable. The site has been included in the secondary selection screening with data gaps indicated.

### 8.3.6 Upper Division Investigations

The Upper Division of the Bear River extends downstream to Pixley Dam. The shortages are located such that storage would be most effectively located in the upper reaches, primarily in Utah. A study was conducted in 1983 by Forsgren-Perkins Engineering for the WWDC. This study identified the West Fork Reservoir site as the most suitable for supplemental irrigation storage.

The West Fork Reservoir site was advanced to Level III-Phase I of Final Design by 1985. The site was investigated extensively, including geotechnical investigations, preliminary design, and development of cost estimates. The reservoir was sized at 12,000 acre-feet and was a single-purpose reservoir to be used for supplemental irrigation storage. The site is located approximately five miles into Utah.

The project did not advance to construction due to sponsor financial and legal concerns. The cost estimates of the project were updated to 2007 costs using United States Bureau of Reclamation (USBR) cost indices. The project has favorable financial potential. The project lacks some information.

The West Fork project has the best potential for storage development in the Upper Division. Missing data, primarily information on the ability to permit, should be acquired in order to advance the project. The potential for a multipurpose project should be investigated which could affect reservoir sizing. The project cost estimate should be updated and expanded to address the multipurpose concept.

### 8.3.7 Framework Scoring Matrix

To more fully evaluate the previously studied alternatives, a Framework Scoring Matrix was developed. The projects included in the matrix are the Upper Teichert/Bagley site, Smiths Fork site, Muddy Creek off-channel site from the Smiths Fork, and West Fork site. As shown on Tables 8-2 and 8-3, the matrix indicates the shortages of information or information gaps.

### 8.3.8 Recommendations

The following recommendations could result in storage projects to alleviate shortages in the Bear River Basin if sufficient interest is indicated by the BAG.

*Central Division*

Perform preliminary investigations and preliminary designs for a multipurpose storage project on the Muddy Creek site. Develop the information needed for the secondary selection scoring matrix including cost estimates and economics. The Muddy Creek Reservoir site has many data gaps but has the best potential for development. A Level I study would be needed to determine project feasibility.

*Upper Division*

Update the work previously performed on the West Fork site. Develop additional information to fill in data gaps indicated in the framework scoring matrix. This site was previously shown to have very economical cost per acre-foot of storage. A Level II study would be needed to determine project feasibility. A multipurpose storage project should be investigated.

**Table 8-2 Framework Scoring Matrix, Bear River Basin**

| Project | Storage | Irrigated Lands | Project Yield | 2007 Project Cost | Storage Cost | Sponsor Cost per Acre* | Sponsor Cost per Acre-Foot* | Comments |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | acres | ac-ft per year | $M | $ per ac-ft | $ per acre | $ per ac-ft | |
| Smiths Fork Res | 17,000 | 20,411 | 5,260 | 53.9 | 3,171 | 65 | 251 | Smiths Fork site. 125 acres wetlands impacted. |
| Upper Teichert Bagley Res | 14,000 | 20,411 | 4,233 | 47.5 | 3,393 | 57 | 275 | Smiths Fork site. 141 acres wetlands impacted. |
| Muddy Creek Res | 20,000 | 20,411 | NA | NA | NA | NA | NA | Smiths Fork off-channel site. Seven-mile canal required. |
| West Fork Res | 12,000 | 18,700 | NA | 24.0 | 2,000 | NA | NA | Located in Utah. 1985 updated costs. |

* Assumed WWDC Standard Funding Package of two-thirds grant and one-third loan at four percent interest rate.

**Table 8-3 Framework Selection Scoring, Nonmonetary Factors, Bear River Basin**

| Project | Need | Water Availability | Ability to Meet Need | Multiple Use Potential | Geotech Feasibility | Land Ownership | Cultural Resources | Environ. Impacts | Ability to Permit | Cost | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight:** | **20** | **10** | **10** | **10** | **10** | **10** | **10** | **20** | **20** | **20** | |
| Smiths Fork Res | 10 | 10 | 10 | 2 | 8 | 6 | 10 | 2 | 4 | 4 | 860 |
| Upper Teichert Bagley Res | 10 | 10 | 9 | 2 | 8 | 6 | 10 | 2 | 4 | 4 | 850 |
| Muddy Creek Res | 10 | 9 | 9 | 8 | NA | NA | NA | 8 | 8 | 4 | NA |
| West Fork Res | 10 | 10 | 10 | NA | 8 | 8 | NA | NA | NA | 9 | NA |

### 8.3.9 Future Groundwater Development

Current groundwater withdrawal estimates indicate that, on average, less than 3,000 acre-feet per year of groundwater is currently used in the Bear River Basin. The majority of this use is from the alluvial aquifer. Future development of this aquifer could provide additional water to meet increased demands; however, there are limitations and restrictions to additional depletions outlined in the Bear River Compact. These restrictions consider withdrawals from the alluvial aquifer similar to river withdrawals.

It is estimated that additional development in the bedrock aquifers up to 14,000 acre-feet per year would be sustainable. Well development in the bedrock aquifers needs to be studied in greater detail to determine the impact on Bear River flows and the extent to which compact restrictions may apply.

The current and projected groundwater use in the Bear River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

## 8.4 GREEN RIVER BASIN

Future water use opportunities in the Green River Basin are addressed in this section.

### 8.4.1 Physically Available Flows

The physically available flows for the subbasins of the Green River are summarized in Table 7-2 and shown on Figures 7-2 and 7-3 in Chapter 7. The available flows were developed for dry, normal, and wet hydrologic conditions. The available flows in the main stem of the Green River and in the major tributaries are relatively high even in dry years. The flows on some of the smaller tributaries indicate potential needs due to the relatively low flows in dry years.

### 8.4.2 Compact Limitations

Wyoming’s ability to develop and consumptively use water in the Green River Basin is primarily constrained by the two interstate Compacts, the Colorado River Compact and the Upper Colorado River Basin Compact. The compact limitations are discussed in detail in Chapter 3.

### 8.4.3 Agricultural Needs

Needs within the Green River Basin primarily occur on the tributaries. The needs identified in the Basin Plan involved existing agricultural shortages. Consequently, the opportunities are primarily focused on meeting those needs. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6.

Table 8-4 indicates estimates of existing agricultural needs for the subbasins. The irrigated acres within those subbasins are also indicated.

**Table 8-4 Agricultural Needs, Green River Basin Tributaries**

| Subbasin | Irrigated Lands | Needs for Dry Hyrdrologic Condition |
|---|---|---|
| | acres | ac-ft per year |
| Cottonwood Creek | 23,810 | 13,500 |
| Willow Creek | 25,595 | 12,150 |
| West Fork New Fork | | 7,200 |
| East Fork New Fork | 5,497 | 4,200 |
| Piney Creek | 38,691 | 18,700 |
| Hams Fork | 10,287 | 2,700 |
| Horse Creek | 17,372 | 3,900 |
| Beaver Creek | 9,660 | 3,900 |

### 8.4.4 Long List of Future Water Use Opportunities

The long list of opportunities developed in the Basin Plan for the Green River Basin included a total of 75 projects. Essentially all of the projects on the list were storage projects.

### 8.4.5 Short List of Future Water Use Opportunities

The long list was evaluated by the BAG to develop the short list of opportunities to consider. The short list was developed in the Basin Plan according to the following ordered set of priorities:

- Rehabilitation projects that preserve existing uses and economic dependencies.
- Projects that rectify existing demands/needs/shortages.
- Projects that meet projected future demands/needs/shortages.
- Transbasin diversions of water that enhance in-state uses.

The short list of future water use opportunities is shown in Table 8-5 and on Figures 8-2 and 8-3.

**Table 8-5 Evaluated Short List: Green River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] ac-ft | Project Evaluation Criteria[2] Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| ***Type 1*** | | **3** | **9** | **3** | **9** | **5** | **5** | |
| Eden Reservoir Rehabilitation | 6,300 c | 6 | 9 | 9 | 8 | 8 | 2 | 248 |
| Misc. Canal Rehab (Conservation) | unk | 9 | 7 | 8 | 6 | 6 | 2 | 208 |
| Middle Piney Reservoir | 4,201 c | 8 | 5 | 5 | 5 | 3 | 4 | 164 |
| Sixty Seven Enlargement (off ch) | 5,600 c | 5 | 5 | 6 | 4 | 6 | 2 | 154 |
| Grieve Reservoir | 4,860 y | 4 | 4 | 6 | 4 | 6 | 4 | 152 |
| ***Type 2*** | | **8** | **5** | **8** | **6** | **10** | **3** | |
| *Upper Green River* | | | | | | | | |
| Green River Supplemental Supply | 22,000 d | 7 | 6 | 6 | 8 | 5 | 2 | 238 |
| Sand Hill (off ch) | 14,100 c | 5 | 6 | 7 | 6 | 6 | 3 | 231 |
| Fontenelle Creek Narrows | 2,500 c | 6 | 5 | 6 | 4 | 6 | 5 | 220 |
| McNinch Wash (off ch) | 5,600 c | 5 | 5 | 7 | 4 | 6 | 3 | 214 |
| Snider Basin | 4,300 c | 6 | 6 | 5 | 5 | 5 | 5 | 213 |
| South Cottonwood | 6,000 c | 6 | 5 | 5 | 5 | 5 | 5 | 208 |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| North Piney Creek | 5,600 c | 6 | 2 | 5 | 5 | 5 | 5 | 193 |
| LaBarge Meadows | 4,800 c | 5 | 3 | 5 | 4 | 5 | 5 | 184 |
| Warren Bridge | 33,400 c | 8 | 5 | 2 | 8 | 1 | 4 | 175 |
| Fish Creek | 1,400 c | 3 | 5 | 5 | 2 | 5 | 4 | 163 |
| Green River Lakes Enl. | <250,000 c | 9 | 5 | 0 | 9 | 0 | 2 | 157 |
| ***Type 2*** | | **8** | **5** | **8** | **6** | **10** | **3** | |
| *New Fork River* | | | | | | | | |
| East Fork | 2,100 c | 7 | 5 | 5 | 5 | 5 | 5 | 216 |
| East Fork Gorge | unk | 7 | 5 | 5 | 5 | 5 | 5 | 216 |
| Boulder Lake Enl. | <120,000 c | 8 | 7 | 4 | 6 | 3 | 5 | 212 |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| Silver/Spring Creeks | 17,000 c | 5 | 5 | 5 | 4 | 5 | 5 | 194 |
| Burnt Lake Enl. | 15,570 c | 8 | 7 | 2 | 5 | 2 | 5 | 180 |
| Halfmoon Enl. | <95,000 c | 8 | 7 | 2 | 5 | 2 | 5 | 180 |
| East Fork No.1 | 4,700 c | 8 | 3 | 2 | 5 | 2 | 5 | 160 |
| *Big Sandy River* | | | | | | | | |
| Sander's Ranch (Leckie Ranch) | 60,000+ c | 7 | 5 | 5 | 6 | 5 | 5 | 222 |
| Groundwater Development | unk | 2 | 3 | 9 | 2 | 9 | 2 | 211 |
| *Black's Fork River* | | | | | | | | |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| *Little Snake River* | | | | | | | | |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| Lower Willow Creek | 2,700 y | 5 | 5 | 5 | 5 | 4 | 5 | 190 |
| Big Gulch | 5,250y | 3 | 6 | 5 | 4 | 5 | 5 | 183 |
| Upper Willow Creek (CO) | 1,500 y | 4 | 5 | 5 | 4 | 4 | 5 | 176 |
| Pot Hook | 6,700 y | 6 | 4 | 4 | 6 | 1 | 5 | 161 |
| Dutch Joe | 5,000 y | 4 | 6 | 5 | 5 | 2 | 3 | 161 |
| *Vermilion/Red Creek Basins* | | | | | | | | |

**Table 8-5 Evaluated Short List: Green River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| Storage Project | unk | 5 | 4 | 7 | 3 | 5 | 4 | 196 |
| | | | | | | | | |
| ***Type 3*** | | **8** | **5** | **8** | **6** | **10** | **3** | |
| *Green Below Fontenelle* | | | | | | | | |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| Eden Project Improvements (USBR) | 10,000 d | 6 | 5 | 6 | 6 | 2 | 2 | 183 |
| Seedskadee Project (USBR) | 86,000 d | 9 | 3 | 4 | 5 | 1 | 2 | 165 |
| *Upper Green River* | | | | | | | | |
| Green River Supplemental Supply | 22,000 d | 6 | 6 | 6 | 8 | 5 | 2 | 230 |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| East Side Project | 32,000 d | 6 | 5 | 4 | 4 | 3 | 3 | 168 |
| Kendall (Upper Kendall) | >100,000 c | 9 | 5 | 1 | 8 | 0 | 4 | 165 |
| Lower Kendall | >100,000 c | 9 | 5 | 1 | 8 | 0 | 4 | 165 |
| New Fork Narrows | >100,000 c | 9 | 4 | 1 | 5 | 0 | 4 | 142 |
| *Blacks Fork /Hams Fork Rivers* | | | | | | | | |
| Viva Naughton Enlargement | 36,000 c | 7 | 5 | 6 | 5 | 5 | 6 | 227 |
| Stateline Enlargement | unk | 6 | 5 | 6 | 7 | 4 | 5 | 218 |
| Meek's Cabin Enlargement | unk | 5 | 5 | 6 | 7 | 4 | 5 | 210 |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| *Little Snake River* | | | | | | | | |
| Groundwater Development | unk | 2 | 2 | 9 | 2 | 9 | 2 | 206 |
| Lower Willow Creek | 2,700 y | 5 | 5 | 5 | 5 | 4 | 5 | 190 |
| Upper Willow Creek (CO) | 1,500 y | 4 | 5 | 5 | 4 | 4 | 5 | 176 |
| Dolan Mesa Canal | 2,700 d | 5 | 3 | 5 | 3 | 4 | 4 | 165 |
| Savery-Pot Hook Project (USBR) | 5,000 y | 6 | 4 | 4 | 6 | 1 | 5 | 161 |
| ***Type 4*** | | **3** | **5** | **10** | **6** | **9** | **5** | |
| *Green Below Fontenelle* | | | | | | | | |
| Plains Reservoir (off ch) | <480,000 c | 9 | 3 | 3 | 3 | 1 | 4 | 119 |
| Lower Green Reservoir | <450,000 c | 9 | 2 | 2 | 2 | 1 | 3 | 93 |
| *Upper Green River* | | | | | | | | |
| Kendall (Upper Kendall) | >100,000 c | 9 | 4 | 0 | 7 | 0 | 3 | 104 |
| Lower Kendall | >100,000 c | 9 | 4 | 0 | 7 | 0 | 3 | 104 |
| New Fork Narrows | >100,000 c | 9 | 3 | 0 | 5 | 0 | 3 | 87 |

[1] y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

### 8.4.6 Supplemental Studies

Reservoir studies have been commissioned by the WWDC to supplement the information contained in the Basin Plan. These studies are summarized below.

*Green River Ground Water Recharge and Alternative Storage, Level I Project*

This study, performed by States West Water Resources Corporation (SWWRC, 2001) investigated the potential for groundwater recharge and potential storage sites in the Green River Basin. The study evaluated needs within the basin, which have been summarized earlier in this report. Screening of the short list projects resulted in seven storage projects being investigated in detail. These sites included the following projects, which are shown on Figure 8-2.

- Sand Hill Reservoir
- McNinch Reservoir
- East Fork River Reservoir
- East Fork Gorge Reservoir
- Church Reservoir
- Viva Naughton Enlargement
- Dempsey Basin Reservoir

Agricultural shortages within the Green River Basin are confined to the tributaries. The SWWRC (SWWRC, 2001) report identified projects to address shortages in the East Fork of the New Fork, Hams Fork, and the Piney Creek tributaries. The results of the secondary screening process indicate that agriculture probably cannot afford the projects as single-purpose reservoirs. The potential for developing these projects for multiple use should be considered. The Hams Fork projects, including the Viva Naughton Enlargement and Dempsey Basin off-channel storage project, are currently being studied as multipurpose projects.

*Middle Piney Reservoir Rehabilitation-Level II Study*

This study was commissioned by the WWDC in 2006. The objective of the study is to determine the rehabilitation improvements necessary to utilize approximately 4,200 acre-feet of existing storage. Dam safety issues presently preclude use of the storage.

*Upper Green River Storage Study*

This study was conducted by Kleinfelder, Inc. in 2007 to evaluate shortages and potential need in the Upper Green River Basin. The study evaluated the following potential reservoirs as shown on Figures 8-2 and 8-3.

- Lower Willow Creek Reservoir (Little Snake River Basin)
- Mickelson Creek Reservoir
- Horse Pasture Draw Reservoir
- Cow Gulch Reservoir

*Little Snake River Dams-Level II Study*

This study was conducted by Gannett Fleming in 2003 for the WWDC. Three potential storage sites were investigated: the Upper Willow Creek Dam and Reservoir, Upper Cottonwood Creek Reservoir, and Grieve Reservoir Rehabilitation. The study included subsurface investigations at the Upper Willow Creek site.

### 8.4.7 Framework Scoring Matrix

The sites investigated in the supplemental studies were evaluated utilizing the Framework Scoring Matrix developed for this Plan. The results are shown in Tables 8-6 and 8-7.

**Table 8-6 Framework Scoring Matrix, Green River Basin**

| | Storage | Irrigated Lands | Project Yield | 2007 Project Cost | Storage Cost | Sponsor Cost per Acre* | Sponsor Cost per Acre-Foot* | |
|---|---|---|---|---|---|---|---|---|
| **Project** | **ac-ft** | **acres** | **ac-ft per year** | **$M** | **$ per ac-ft** | **$ per acre** | **$ per ac-ft** | **Comments** |
| Middle Piney Rehab | 4,200 | NA | NA | NA | NA | NA | NA | Piney Creek drainage. |
| Horse Pasture Draw Res | 5,710 | 15,151 | 5,152 | 20.6 | 3,608 | 33 | 98 | North Horse Creek drainage off-channel site. |
| Sand Hill Res | 14,500 | 10,000 | 14,100 | 32.8 | 2,262 | 80 | 57 | Piney Creek drainage off-channel site would require 3-mile canal. |
| Church Res | 10,000 | 5,497 | 4,200 | 20.5 | 2,050 | 91 | 120 | East Fork drainage off-channel site would require 2-mile canal; water supply concerns. |
| Dempsey Basin Res | 24,000 | 10,287 | 10,700 | NA | NA | NA | NA | Off-channel site; Hams Fork drainage; critical cultural impacts. |
| Grieve Reservoir Rehabilitation | 400 | NA | 300 | 0.5 | 1,250 | NA | 41 | Little Snake drainage, off-channel. |
| Viva Naughton Enl | 24,000 | 10,287 | 10,700 | NA | NA | NA | NA | Hams Fork drainage; critical cultural impacts; large wetland impacts; multipurpose reservoir. |
| Mickelson Creek Res | 7,300 | 19,183 | 5,835 | 31.9 | 4,370 | 41 | 133 | South Cottonwood Creek drainage off-channel site. |
| Cow Gulch Res | 13,330 | 11,583 | 2,793 | 19.5 | 1,463 | 41 | 170 | Beaver Creek drainage off-channel site. |
| McNinch Res | 4,600 | 6,000 | 5,600 | 28.6 | 6,217 | 117 | 125 | Piney Creek drainage off-channel site would require 6-mile canal. |
| Lower Willow Creek Res | 23,190 | 10,011 | 5,943 | 45.1 | 1,945 | 110 | 185 | Willow Creek drainage. |
| East Fork Gorge Res | 1,900 | 5,497 | 1,900 | 30.7 | 16,158 | 137 | 395 | New Fork drainage. |
| East Fork River Res | 1,700 | 5,497 | 1,700 | 19.1 | 11,235 | 85 | 275 | New Fork drainage. |
| Upper Willow Creek | 10,000 | NA | 4,570 | 22.5 | 2,250 | NA | 121 | Little Snake drainage located in Colorado. |
| Upper Cottonwood Creek | 1,000 | NA | NA | 7.2 | 7,200 | NA | NA | Little Snake drainage. |

* Assumed WWDC Standard Funding Package of two-thirds grant and one-third loan at four percent interest rate.

**Table 8-7 Framework Selection Scoring, Nonmonetary Factors, Green River Basin**

| Project | Need | Water Availability | Ability to Meet Need | Multiple Use Potential | Geotech Feasibility | Land Ownership | Cultural Resources | Environ. Impacts | Ability to Permit | Cost | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight:** | **20** | **10** | **10** | **10** | **10** | **10** | **10** | **20** | **20** | **20** | |
| Middle Piney Reservoir Rehabilitation | 10 | 10 | 10 | 10 | 8 | 10 | 8 | 8 | 10 | 10 | 1,320 |
| Horse Pasture Draw Res | 10 | 8 | 8 | 4 | 6 | 5 | 8 | 8 | 8 | 6 | 1,030 |
| Sand Hill Off-Channel Res | 10 | 10 | 8 | 4 | 6 | 7 | 6 | 9 | 9 | 7 | 1,110 |
| Church-New Fork Reservoir | 10 | 4 | 10 | 4 | 6 | 9 | 8 | 8 | 9 | 8 | 1,110 |
| Dempsey Basin-Hams Fork Reservoir | 10 | 8 | 10 | 6 | NA | 5 | NA | NA | NA | NA | NA |
| Grieve Reservoir Rehabilitation | 8 | 10 | 8 | 2 | 8 | 6 | NA | NA | NA | 8 | NA |
| Viva Naughton-Hams Fork Enlargement | 10 | 8 | 10 | 8 | 8 | 10 | NA | NA | NA | NA | NA |
| Mickelson Creek Res | 10 | 6 | 5 | 4 | 6 | 7 | 8 | 8 | 8 | 5 | 980 |
| Cow Gulch Res | 10 | 6 | 8 | 4 | 6 | 7 | 6 | 6 | 6 | 5 | 910 |
| McNinch Wash Off-Channel Res | 4 | 10 | 4 | 4 | 6 | 7 | 5 | 8 | 8 | 5 | 860 |
| Lower Willow Creek Res | 10 | 8 | 4 | 4 | 6 | 8 | 8 | 4 | 4 | 4 | 820 |
| East Fork Gorge-New Fork Reservoir | 10 | 10 | 4 | 4 | 5 | 8 | 8 | 6 | 2 | 1 | 770 |
| East Fork New Fork Reservoir | 10 | 10 | 4 | 4 | 5 | 7 | 8 | 5 | 2 | 2 | 760 |
| Upper Willow Creek | 8 | 8 | 8 | 8 | 8 | 5 | NA | NA | NA | 7 | NA |
| Upper Cottonwood Creek | 4 | NA | NA | NA | 6 | NA | NA | NA | NA | 2 | NA |

### 8.4.8 Recommendations for Storage Opportunities

*Piney Creek Drainage and Tributaries*

Two projects that could meet most of the needs on the drainage have been identified in the Framework Scoring Matrix as the best alternatives.

Sand Hill Off-Channel Reservoir

This site is off-channel and would be supplied by a three-mile canal from Middle Piney and South Piney Creeks. The proposed storage was 14,500 acre-feet as a single-purpose reservoir for agriculture. This potential storage project had the third highest matrix score in the basin and relatively low cost per acre-foot of storage. A Level II study would be needed to determine the feasibility of this project. The potential for a multipurpose reservoir should be investigated.

Middle Piney Reservoir Rehabilitation

This rehabilitation project would allow storage of 4,200 acre-feet. This project had the highest score in the basin and will have a very low cost per acre-foot of storage. The Level II study currently in progress will develop the information necessary to determine project feasibility.

*East Fork of the New Fork Drainage (Church Off-Channel Reservoir)*

One project, the Church Reservoir off-channel site, has been identified as the best alternative to meet the needs on this drainage. This site would be supplied by a canal from tributaries of the East Fork River and could store a maximum of 10,000 acre-feet. This site is an alternate to the other two East Fork sites. This potential storage project had a high matrix score in the basin and reasonable costs per acre-foot of storage. This reservoir would need to be advanced with a Level II study. Geotechnical concerns and water supply concerns need to be addressed to determine project feasibility.

*Hams Fork Drainage*

Two projects are currently being investigated to meet the shortages on the Hams Fork. The Viva Naughton Reservoir Enlargement and the Dempsey Basin off-channel reservoir would meet needs of the irrigators, municipalities, and Naughton Power Plant. The current study will determine the best alternative to meet the needs. Cultural issues have been encountered at both sites. This project will be advanced with a Level II study in 2007 to determine the preferred alternative and project feasibility. The two sites were similar in scoring and cost, and either project would meet the needs of the drainage.

Viva Naughton Enlargement

This existing reservoir is located on the Hams Fork. A potential enlargement of 24,180 acre-feet has been proposed for agricultural, municipal, and industrial uses.

Dempsey Basin Reservoir

This site is an off-channel alternative to Viva Naughton and would be supplied by a canal from the Hams Fork upstream of Viva Naughton. A size of 24,180 acre-feet was proposed.

*Cottonwood Creek Drainage (Mickelson Creek Off-Channel Reservoir)*

One project, the Mickelson Creek Reservoir, has been identified as the best alternative to meet the needs in this drainage.

This potential storage project is off-channel and would require an approximately one-mile diversion canal from South Cottonwood Creek. The proposed storage capacity was 7,300 acre-feet. This project, although mid-range in scoring and cost, is the best alternative in the drainage. A Level II study would be needed to determine the feasibility of this project. The potential for a multipurpose reservoir should be investigated.

*Horse Creek Drainage (Horse Pasture Draw Off-Channel Reservoir)*

One project, the Horse Pasture Draw Reservoir, has been identified as the best alternative to meet the needs in this drainage. This potential storage project is off-channel and would require an approximately one-mile diversion canal from North Horse Creek. The proposed storage capacity was 5,710 acre-feet. This project is in the mid range in scoring and costs but is the best alternative in the drainage. A Level II study would be needed to determine the feasibility of this project. The potential for a multipurpose reservoir should be investigated.

*Beaver Creek Drainage (Cow Gulch Off-Channel Reservoir)*

One project, the Cow Gulch Reservoir, has been identified as the best alternative to meet the needs in this drainage. This potential storage project is off-channel and would require an approximate four and one-half mile canal to divert water from Middle Beaver Creek and South Beaver Creek. The proposed storage capacity was 13,330 acre-feet. This site was not highly rated but is the best alternative identified in the drainage. A Level II study would be needed to determine the feasibility of this project. The potential for a multipurpose reservoir should be investigated.

### 8.4.9 Future Groundwater Development

There is virtually no information on the overall groundwater basin water budget, such that major inflow and outflow components may be quantified. Accordingly, it is difficult to evaluate the Green River Basin’s safe, long-term yield for purposes of defining future groundwater development potential.

The basin has a total area of about 20,000 square miles (12.8 million acres). However, there are large areas of the basin in which potential evapotranspiration (ET) significantly exceeds average rainfall. For purposes of this analysis, it is assumed that recharge is effectively zero in areas where ET significantly exceeds rainfall. In the remaining parts of the Basin, mainly the mountain and foothills areas, rainfall exceeds potential (ET). These areas have been mapped and are estimated to have an area of approximately 925,000 acres. The average “surplus” rainfall (where annual rainfall exceeds annual ET) is assumed to be about 6 inches. It is also assumed that approximately 10 percent of the surplus rainfall recharges the groundwater system. This approach yields an estimate of about 50,000 acre-feet per year of groundwater recharge, which is considered to be an approximation of basin groundwater yield. These estimates neglect the potential for interbasin movement of groundwater. They also neglect the large quantity of groundwater in storage that could potentially be developed without experiencing significant basinwide impacts.

By comparison, the USGS (Martin, 1996; Glover, et al; 1998) estimates approximately 100,000 acre-feet per year of groundwater recharge by precipitation to the Tertiary-age rocks. For planning purposes, it is concluded that basin yield is on the order of between 50,000 and 100,000 acre-feet per year.

Currently, there is no evidence to suggest overdevelopment of the principal aquifer systems. It could be concluded that there is significant potential for additional development of these aquifer systems, with little risk of depleting this resource. However, the lack of overdevelopment actually means there is a smaller chance that aquifer storage and retrieval techniques will be successful.

There are many factors that may affect future development and availability of groundwater resources. In the case of the Quaternary-age alluvial aquifers, any future development of groundwater resources may be expected to have a direct and near-immediate impact on the adjacent rivers and streams within the alluvial system. Another factor is the potential development of groundwater associated with the coal bed methane (CBM) extraction industry.

The current and projected groundwater use in the Green River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

## 8.5 NORTHEAST WYOMING RIVER BASIN

Future water use opportunities for the Northeast Wyoming River Basin are addressed in this section.

### 8.5.1 Physically Available Flows

The physically available flows at locations within the subbasins of Northeast Wyoming are shown in Figure 7-4 and are summarized in Table 7-2 of Chapter 7. The available flows are indicated for dry, normal, and wet hydrologic conditions. As indicated by the figure and table, the estimated available flows are significantly lower in dry years than wet years in the Cheyenne River and Belle Fourche River subbasins. Available flows in the Redwater Creek and Beaver Creek subbasins vary to a much lesser degree from dry years to wet years. The needs in a basin are usually associated with low available flows in dry years.

### 8.5.2 Compact Limitations

Three interstate compacts have been negotiated by the States of Wyoming, Montana, North Dakota, and South Dakota for divisions of the waters of the Little Missouri River, Belle Fourche River, and Cheyenne River. Of these three compacts, only the Belle Fourche River Compact has been formally accepted by all interests. The provisions of this are discussed in Chapter 3 of this report. Wyoming’s apportionment of the Belle Fourche River under the three hydrologic conditions (wet, normal, and dry years) is summarized in Table 8-8.

**Table 8-8 Apportionment of Available Flow Per Belle Fourche River Compact**

| Hydrologic Condition | Average Annual Apportionment | | |
|---|---|---|---|
| | Belle Fourche River | Redwater Creek | Total |
| | ac-ft | | |
| Wet Years | 15,600 | 3,300 | 18,900 |
| Normal Years | 7,400 | 2,400 | 9,800 |
| Dry Years | 1,100 | 1,400 | 2,500 |

### 8.5.3 Agricultural Need

Almost every area of the Northeast Wyoming River Basin planning area can be considered water-short during dry years. The needs identified in the Basin Plan involved existing agricultural shortages. Consequently, the opportunities are primarily focused on meeting those needs. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6.

Table 8-9 includes estimates of existing agricultural needs in dry years and the irrigated acres for the subbasins.

**Table 8-9 Agricultural Needs, Northeast Wyoming River Basin**

| Subbasin | Irrigated Lands | Needs for Dry Hydrologic Condition |
|---|---|---|
| | acres | ac-ft per year |
| Upper Belle Fourche | 3,312 | 8,500 |
| Middle Belle Fourche | 9,011 | 19,600 |
| Lower Belle Fourche | 5,584 | 13,600 |
| Redwater Creek | 2,213 | 1,400 |
| Upper Beaver Creek | 669 | 1,200 |
| Middle Beaver Creek | 6,000 | 11,200 |
| Lower Beaver Creek | 3,561 | 6,800 |
| Northern Tribs to Cheyenne River | 7,958 | 22,100 |
| Southern Tribs to Cheyenne River | 12,736 | 37,200 |
| Lower Cheyenne River | 2,602 | 6,900 |
| Little Missouri River | 9,799 | 31,200 |
| Niobrara River | 847 | 1,300 |

### 8.5.4 Long List of Future Water Use Opportunities

The long list of future water use opportunities compiled in the Basin Plan comprised 14 projects. The opportunities were identified in the Belle Fourche River Basin and the Cheyenne River Basin. No opportunities were identified in the Little Missouri River Basin or the Niobrara River Basin. This list was reviewed by the BAG to produce the short list of water use opportunities.

### 8.5.5 Short List of Future Water Use Opportunities

Short lists of potential projects were developed in the Basin Plan for the Belle Fourche and Cheyenne River subbasins as shown in Tables 8-10 and 8-11. The short lists included four types of projects:

- **Type 1:** Rehabilitation projects that preserve existing uses.
- **Type 2:** Projects that rectify existing shortages consistent with the hierarchy of preferred uses established by the Wyoming statutes.
- **Type 3:** Projects that meet projected future demands consistent with the hierarchy of preferred uses established by the Wyoming statutes.
- **Type 4:** Projects that enhance uses in other Wyoming basins through trans-basin diversions.

The storage projects included in the short list are shown on Figure 8-4. No specific storage projects were identified in the Niobrara River, Little Missouri River, or the main stem of the Cheyenne River.

**Table 8-10 Evaluated Short List: Belle Fourche River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2*** | | **6** | **7** | **4** | **5** | **7** | **6** | |
| Inyan Kara Creek Reservoir | 1,000 c | 7 | 6 | 8 | 5 | 8 | 5 | 227 |
| Enl. Driskill No. 1 Reservoir | 2,800 c | 7 | 8 | 6 | 5 | 5 | 7 | 224 |
| Miller Creek Reservoir | 1,000 c | 6 | 6 | 8 | 5 | 8 | 5 | 221 |
| Lytle Creek Reservoir | 1,000 c | 6 | 6 | 8 | 5 | 8 | 5 | 221 |
| Blacktail Creek Reservoir | 1,000 c | 6 | 6 | 8 | 5 | 8 | 5 | 221 |
| Beaver Creek Reservoir | 1,000 c | 6 | 6 | 8 | 5 | 8 | 5 | 221 |
| Livingston Creek Reservoir | 955 c | 5 | 6 | 8 | 5 | 8 | 5 | 215 |
| ***Type 3*** | | **6** | **8** | **4** | **5** | **5** | **6** | |
| CBM Aquifer Storage and Retrieval | unk | 7 | 6 | 7 | 7 | 4 | 7 | 215 |
| Groundwater Development | unk | 6 | 5 | 8 | 4 | 7 | 5 | 193 |
| Trans-basin Diversions to Gillette | unk | 8 | 4 | 7 | 6 | 3 | 5 | 183 |
| ***Type 4 (None)*** | | | | | | | | |

[1]y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-11 Evaluated Short List: Cheyenne River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2*** | | **7** | **8** | **5** | **6** | **4** | **5** | |
| Beaver Creek Reservoir (north) | 7,775 c | 7 | 4 | 7 | 5 | 7 | 7 | 209 |
| Stockade Beaver Creek Reservoir | 6,100 c | 7 | 3 | 5 | 5 | 5 | 5 | 173 |
| ***Type 3*** | | **7** | **8** | **7** | **7** | **5** | **6** | |
| Beaver Creek Reservoir (south) | 15,000 y | 6 | 5 | 6 | 5 | 6 | 8 | 237 |
| Groundwater Development | unk | 5 | 6 | 5 | 5 | 7 | 5 | 218 |
| ***Type 4 (None)*** | | | | | | | | |

[1] y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

### 8.5.6 Supplemental Studies

Reservoir studies have been commissioned by the WWDC to supplement those contained in the basin plan. These studies are summarized below.

*Crook County Reservoirs and Water Management Study-Level I*

The WWDC commissioned a study entitled "Crook County Reservoirs and Water Management Study-Level I" (SEH, Inc., 2006). This study investigated potential reservoir projects located in Crook County in the Belle Fourche River and Redwater Creek subbasins. The study included the short list projects plus a site in the Redwater Creek subbasin. The sites investigated included the following, which are shown in Figure 8-4.

- Blacktail Creek Reservoir
- Oak Creek Reservoir
- Pine Creek Reservoir
- Miller Creek Reservoir
- Lower Inyan Kara Creek Reservoir
- Upper Inyan Kara Creek Reservoir
- Redwater Creek Reservoir

The study developed technical information, environmental data, and estimated costs of the reservoir sites.

*Crook County Reservoir Project-Level I*

The Lytle Creek Reservoir site was investigated in a separate study entitled "Crook County Reservoir Project – Level I," (ESA Consultants, 2006). This study investigated both technical and monetary effects and benefits for the site.

*Stockade Beaver Creek Reservoir-Level I*

This study, by Bearlodge Ltd, Inc. in 1986, evaluated recreation reservoir sites on Stockade Beaver Creek. The preferred storage site was located high in the drainage, would contain 520 acre-feet for recreational purposes, and is shown on Figure 8 -4.

*Beaver Creek Dam and Reservoir-Level I*

This study, by Bearlodge Ltd, Inc. in 1989, investigated recreation reservoir sites on Beaver Creek. Two alternative sites, the Upper and Lower Beaver Creek Reservoir sites, as shown on Figure 8-4, were identified and investigated with storage volumes of 8,000 acre-feet and 5,026 acre-feet, respectively. The potential reservoir sites were for recreational purposes.

*Beaver Creek Dam and Reservoir Project*

This study, by Bearlodge Ltd, Inc. in 1991, investigated the Upper Beaver Creek reservoir site identified as the preferred site in the 1989 study, as shown on Figure 8-4. Geotechnical drilling and exploration were performed on the site. Preliminary design and cost estimates were developed. The potential reservoir site was for recreational purposes.

### 8.5.7 Framework Scoring Matrix

The short list storage sites previously investigated in the Belle Fourche River, Redwater Creek, and Beaver Creek subbasins were comparatively analyzed using the Framework Scoring Matrix developed for the Framework Plan. The information is presented in Tables 8-12 and 8-13. The information developed in the Basin Plan and the specific reservoir studies was used for the matrix scoring. The reservoir projects have been arranged with the highest scoring projects listed first. The recommendations for storage opportunities were based on this information.

**Table 8-12 Framework Scoring Matrix, Northeast Wyoming River Basin Storage Opportunities**

| Project | Storage | Irrigated Lands | Project Yield | 2007 Project Cost | Storage Cost | Sponsor Cost per Acre* | Sponsor Cost per Acre-Foot | Comments |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | acres | ac-ft per year | $M | $ per ac-ft | $ per acre | $ per ac-ft | |
| Lower Beaver Creek Res | 5,000 | 3,561 | NA | 10.5 | 2,100 | 72 | NA | Beaver Creek site; studied as recreational reservoir |
| Blacktail Creek Res | 2,800 | 3,970 | NA | 17.1 | 6,107 | 106 | NA | Belle Fourche tributary |
| Lower Inyan Kara Res | 12,600 | 5,650 | NA | 29.3 | 2,325 | 127 | NA | Belle Fourche tributary |
| Upper Inyan Kara Res | 6,400 | 5,650 | NA | 13.3 | 2,078 | 51 | NA | Belle Fourche tributary |
| Lytle Creek Res | 2,800 | 5,130 | NA | 19.5 | 6,964 | 93 | NA | Belle Fourche tributary |
| Miller Creek Res | 500 | 5,650 | NA | 5.0 | 10,000 | 245 | NA | Belle Fourche tributary |
| Redwater Creek Res | 16,800 | 13,860 | NA | 31.8 | 1,893 | 56 | NA | Redwater Creek |
| Oak Creek Res | 3,100 | 571 | NA | 10.8 | 3,484 | 463 | NA | Belle Fourche tributary |
| Stockade-Beaver Res | 520 | NA | NA | 5.0 | 9,615 | NA | NA | Beaver Creek tributary; studied as recreational reservoir |
| Pine Creek Res | 1,900 | 1,420 | NA | 7.5 | 3,947 | 97 | NA | Belle Fourche tributary |

**Table 8-13 Framework Selection Scoring, Nonmonetary Factors, Northeast Wyoming River Basin Storage Opportunities**

| Project | Need | Water Availability | Ability to Meet Need | Multiple Use Potential | Geotech Feasibility | Land Ownership | Cultural Resources | Environ. Impacts | Ability to Permit | Cost | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weight** | **20** | **10** | **10** | **10** | **10** | **10** | **10** | **20** | **20** | **20** | |
| Lower Beaver Creek Res | 10 | 8 | 8 | 8 | 8 | 5 | 5 | 9 | 8 | 9 | 1,140 |
| Blacktail Creek Res (Belle Fourche) | 8 | 8 | 8 | 10 | 6 | 10 | 10 | 6 | 8 | 4 | 1,040 |
| Lower Inyan Kara Res (Belle Fourche) | 10 | 10 | 8 | 8 | 4 | 7 | 6 | 6 | 6 | 7 | 1,010 |
| Upper Inyan Kara Res (Belle Fourche) | 10 | 10 | 8 | 8 | 4 | 8 | 2 | 6 | 5 | 8 | 980 |
| Lytle Creek Res (Belle Fourche) | 8 | 8 | 8 | 10 | 8 | 8 | 2 | 6 | 6 | 4 | 920 |
| Miller Creek Res (Belle Fourche) | 8 | 6 | 6 | 8 | 5 | 8 | 6 | 8 | 6 | 4 | 910 |
| Redwater Creek Res | 10 | 10 | 4 | 8 | 4 | 2 | 4 | 3 | 4 | 8 | 820 |
| Oak Creek Res (Belle Fourche) | 4 | 8 | 2 | 8 | 6 | 6 | 10 | 4 | 5 | 5 | 760 |
| Stockade-Beaver Res | 10 | 4 | 4 | 4 | 8 | 5 | 5 | 4 | 6 | 2 | 740 |
| Pine Creek Res (Belle Fourche) | 6 | 6 | 4 | 8 | 4 | 8 | 4 | 2 | 2 | 5 | 640 |

### 8.5.8 Recommendations for Future Storage Opportunities

The storage opportunities in the Northeast Wyoming River Basin were developed in the Framework Scoring Matrix. The opportunities and recommendations for advancement are discussed for each subbasin. The storage sites are shown on Figure 8-4.

*Belle Fourche River Basin*

The projects that would be most beneficial to the basin would be multiple-use projects. Potential uses could include irrigation, recreation, fishery improvements, Keyhole Reservoir level improvements, flood control, and water quality improvement.

The following reservoir sites are the best opportunities for advancement for further study based on the Framework Scoring Matrix.

Upper or Lower Inyan Kara Reservoir Sites

The Upper and Lower Inyan Kara Reservoir sites were rated highly in the Belle Fourche River basin and had the lowest costs of development per acre-foot of storage. The Upper site could store a maximum of 6,400 acre-feet while the Lower site could store a maximum of 12,600 acre-feet. Reservoir yield was not developed for the sites. The compact limitations on the storage size (1,000 acre-feet) would have to be addressed. A multipurpose reservoir could benefit all of the uses indicated above. Issues of concern with these sites include reservoir yield, geotechnical feasibility, cultural and environmental issues, and compact considerations. A Level II study would need to be performed to determine project feasibility.

Smaller Reservoirs

The Blacktail Creek, Lytle Creek, Oak Creek, and Pine Creek Reservoir sites could be suitable for smaller multipurpose reservoirs. If the 1,000 acre-feet compact limitation is a limiting factor, several smaller reservoirs could be considered. The Blacktail Creek and Lytle Creek Reservoir sites were rated highly in the Framework Scoring Matrix, but the storage costs per acre-foot were relatively high. The Oak Creek and Pine Creek Reservoir sites were rated low in the Framework Scoring Matrix, but the storage costs per acre-foot were lower. Reservoir yields were not developed for the sites. Level II studies of the sites would be needed to determine reservoir feasibility. The Lytle Creek Reservoir alternative, which was studied in a separate Level I study, indicated considerable additional monetary benefits of multiple use.

*Beaver Creek Basin*

The Lower Beaver Creek Reservoir would be the project that could meet the most needs in the subbasin. This reservoir site was the highest rated project in the entire basin. The storage cost per acre-foot was one of the lowest in the basin for a 5,000 acre-foot reservoir. Issues of concern include reservoir yield, geotechnical feasibility, and environmental issues. Irrigation shortages, water quality benefits, flood control, and recreation benefits could be realized with the project. A Level II study would be needed to determine project feasibility.

*Cheyenne River Basin*

The Cheyenne River Basin was identified as having substantial irrigation needs, particularly on the northern and southern tributaries. No opportunities on the short list would meet these needs. If sufficient interest in the basin is indicated, a Level I study of potential storage sites could be initiated to determine if feasible projects could meet the shortages.

#### 8.5.9 Future Groundwater Development

The current and projected groundwater use in the Northeast Wyoming River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

#### 8.5.10 Coalbed Methane Waters

Substantial CBM development is occurring in Northeast Wyoming, particularly in the Belle Fourche subbasin. In view of the needs in this basin and others, the beneficial use of CBM discharge water should be considered. The subject of CBM waters is discussed in more detail in Chapter 6.

## 8.6 PLATTE RIVER BASIN

Future water use opportunities for the Platte River Basin are addressed in this section.

#### 8.6.1 Physically Available Flows

The surface water resources of the Platte River Basin are fully appropriated in that new water rights with current-day priorities could not be expected to be reliable in average or dry years due to the potential that they would be regulated through water rights administration to protect supplies with more senior priority dates.

#### 8.6.2 Institutional Limitations

Wyoming water law, the North Platte Decree, and the Platte River Recovery Implementation Program (PRRIP) limit future water development opportunities. Therefore, it is unlikely that there will be new projects that cause major new depletions to the system. The list of opportunities provided below is based on this premise.

#### 8.6.3 Needs

Existing agricultural needs were not quantified in the basin plan. However, the current and projected water demands for the agricultural, municipal, domestic, industrial, and recreational economic sectors were estimated. The information for the High, Mid, and Low Scenarios is presented in Chapter 6.

The projected future needs for all economic sectors, based on the Low, Mid, and High Scenarios, are summarized in Table 8-14. The table indicates the potential range of needs in the basin.

**Table 8-14 Platte River Basin Future Needs -All Sectors**

| Demand Scenario | Total Annual Demand | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Current 2005 Demands | | | | 2035 Demands | | | | Needs | | | |
| | Normal | | Max | | Normal | | Max | | Normal | | Max | |
| | Diversions | CU | Diversions | CU | Diversions | CU | Diversions | CU | Diversions | CU | Diversions | CU |
| | ac-ft per year | | | | | | | | | | | |
| High | 1,721,000 | 801,700 | 2,399,100 | 1,081,800 | 1,864,400 | 874,700 | 2,601,200 | 1,181,800 | 143,400 | 73,000 | 202,100 | 100,000 |
| Mid | 1,721,000 | 801,700 | 2,399,100 | 1,081,800 | 1,737,400 | 802,700 | 2,427,500 | 1,090,200 | 16,400 | 1,000 | 28,400 | 8,400 |
| Low | 1,720,900 | 801,500 | 2,399,100 | 1,081,800 | 1,681,900 | 770,500 | 2,362,100 | 1,053,700 | -39,000 | -31,000 | -37,000 | -28,100 |

### 8.6.4 Long List of Future Water Use Opportunities

The long list of future water use opportunities compiled in the Basin Plan comprised 21 categories of projects. This list was reviewed by the BAG to produce the short list of water use opportunities.

### 8.6.5 Revised Short List of Future Water Use Opportunities

The short list of opportunities developed in the Basin Plan was divided into structural and nonstructural opportunities. The short lists are in alphabetical order, and not in order of preference or importance.

Structural future water use opportunities include:

- CBM.
- Groundwater augmentation – non-hydrologically connected to North Platte River surface water.
- Improving agricultural irrigation system efficiencies.
- Modification of Pathfinder Dam and Reservoir.
- Regionalization of public water supply systems.
- Reuse alternatives--stormwater capture, storage, treatment, and management; irrigation with treated municipal wastewater; gray water irrigation; and municipal irrigation using untreated water.
- Snow fences.
- Transbasin diversions.
- Upper Laramie River reregulation reservoir opportunities.

Nonstructural future water use opportunities include:

- Drought response planning.
- Enhancing recreational use of water reservoirs.
- Glendo Reservoir--use of uncontracted water in Wyoming’s allocation to Glendo Reservoir storage.
- Increasing runoff from national forests based on modified U.S. Forest Service (USFS) policies and practices.
- Multipurpose flood control programs.
- Projects for which the maximum WWDC contribution is 50 percent of all project costs or $25,000, whichever is less.
- Projects that provide multiple benefits and have total estimated costs of not more than $100,000.
- Utilization of WWDC’s small water project program.
- Water banking.
- Water conservation.
- Water exchanges.
- Water right transfers.
- Weather modification.

### 8.6.6 Structural Future Water Use Opportunities

*Coalbed Methane Waters*

The development of CBM is discussed in Chapter 6. Minimal development has occurred in the North Platte River Basin. The largest development has occurred in the Powder River Basin. The potential importation of CBM groundwaters to the North Platte Basin should be studied. However, the reliability of the supply of CBM groundwaters may affect the feasibility of this alternate.

*Groundwater Augmentation*

Depending upon the type of groundwater use and desired quality and quantity, the aquifer systems have potential for future development in the South Platte subbasin. The future development potential within the South Platte subbasin is summarized below:

- The Quaternary Aquifer System has historically yielded large quantities of groundwater to wells in the South Platte subbasin, but its development potential is limited due to its areal extent, existing development, and Laramie County Control Area limitations.
- The Late Tertiary Aquifer System has been developed for irrigation, domestic, industrial, municipal, and stock supplies in the subbasin, and despite its current level of use, appears to have future development potential for additional supplies, dependent upon existing users and determinations by Laramie County Control Area management.
- The Late Paleozoic Aquifer System has been identified as a potential source for future groundwater development in the South Platte subbasin. Development of this aquifer system would require a site-specific hydrogeologic investigation prior to well drilling to assess development potential.

Areas of potential development of groundwater in the North Platte River Basin were identified in the “North Platte River Groundwater Assessment Study” initiated by the WWDC in 2002. This study identified 10 potential well sites to produce significant amounts of groundwater. High costs of development would probably limit the users to municipalities or industry. The WWDC funds development of groundwater at the request of sponsors.

The current and projected groundwater use in the Platte River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

Because of the relatively high water-demands of this most populous basin in the state, the Platte has been the subject of several large-scale studies of potential groundwater development. Specific exploration sites have been identified for the Casper Aquifer and related formations along both flanks of the Laramie Range, around the Hartville Uplift (near Guernsey), and along the Seminoe/Shirley Mountains. Exploration sites have also been identified for the North Park and Ogalalla Aquifers near Saratoga and Cheyenne, respectively.

*Improving Agricultural Irrigation Systems and Control Efficiencies*

The implementation of conservation measures to more efficiently use water offers the best potential for agriculture to address shortages in the basin. The measures that have been investigated include seepage controls, reregulation reservoirs, automated or remote controls, and evaporation reduction. Conservation projects have been encouraged and funded by the WWDC. The improvements can include both structural and operational measures. This concept should be continued and encouraged.

*Modification of Pathfinder Dam and Reservoir*

This project has the purpose of replacing 54,000 acre-feet of storage in Pathfinder Reservoir lost to sediment by increasing the height of the existing emergency spillway by 2.4 feet. The increased storage capacity would be separated into an Environmental Account and a Wyoming Account. Water accruing to the Environmental Account would be Wyoming's contribution to the PRRIP on behalf of its water users in the Platte River Basin. Water accruing to the Wyoming Account would be used as a supplemental municipal water supply and as replacement water to meet Wyoming's obligation for the pumping of wells in Goshen County as per the modified North Platte Decree.

The proposed project is currently being pursued by the State of Wyoming.

*Regionalization of Public Water Supply Systems*

The regionalization of public water supply systems has been encouraged by the State of Wyoming, and several projects have been funded by the WWDC. The systems optimize the availability of potable water and improve public health safety.

*Reuse Alternatives*

Municipalities have been investigating and implementing reuse of wastewater primarily for irrigation purposes. This practice can reduce demands on water treatment systems and reduce need for additional supply. Water right issues must be addressed for these systems because most wastewater flows cannot be reused. The WWDC has been supporting and funding projects for reuse.

*Snow Fences*

The use of snow fences to trap blowing snow for the purpose of increasing runoff is being investigated as a water resource management tool. The high percentage of blowing snow which sublimates makes this application potentially valuable. Research is ongoing by the Rocky Mountain Research Station, Laramie Forest Sciences Laboratory.

*Transbasin Diversions*

Transbasin diversions involve water transfers from water-rich basins to water-short basins. Two alternatives have been investigated for importation of water to the North Platte River Basin. The basins from which water might be transferred typically strongly oppose such transfers. Wyoming Statutes require mitigation for the basin from which water is taken. In addition, transbasin diversions should not occur unless all feasible water options have been exhausted in the basin that is to receive the water. As there are some other existing options in the North Platte River Basin, it would be premature to pursue transbasin alternatives. In addition, the existing demand presently does not warrant the very large investment that would be required to permit, construct, operate, and mitigate a transbasin diversion project. However, the following studies have been completed for transbasin diversion projects:

<u>Water Diversions from Wyoming's Green River Basin (WWDC)</u>

The WWDC staff performed a feasibility study of a transbasin diversion from the Green River Basin to the North Platte River Basin. The yield of the project was to be 50,000 acre-feet per year. Alternative diversion locations and routes from the Upper, Middle, and Lower Green River Basin were analyzed. The alternatives that were determined to be the most promising were:

- Middle Basin
  - Fontenelle to Sweetwater
  - Fontenelle to Seminoe
- Lower Basin
  - Green River to Seminoe
  - Green River to Platte River
  - Flaming Gorge to Seminoe
  - Flaming Gorge to Platte River

Project costs and costs of delivered water have not been completed. However, the total project costs will likely approach one billion dollars.

<u>Wind River Export Study – Level I (ECI, 2002)</u>

The purpose of the study was to assess the potential of exporting water from the Wind River Basin into adjacent basins to benefit the Wind River Indian Tribes. The tribal water rights have been estimated to yield approximately 36,000 acre-feet in dry years. The study investigated delivery of water to the North Platte River via the Sweetwater River.

Several issues need to be recognized. The conveyance of the water to potential users could involve substantial conveyance losses. Another aspect to consider is that the imported water could be used to extinction which could increase the effective yield of the system. Another consideration is that the Wind River Basin has substantial shortages and additional storage for the basin is being studied.

*<u>Upper Laramie River Reregulation Opportunities</u>*

The Laramie River is currently fully appropriated. Studies have identified storage sites within the Upper Laramie Basin. However, the primary value of the sites would be to reduce evaporation in existing reservoirs and help manage existing water more effectively. The reservoir alternatives have been found to be of marginal economic benefit because of high costs.

### 8.6.7 Nonstructural Future Water Use Opportunities

*<u>Drought Response Planning</u>*

The current Wyoming Drought Plan (revised January, 2003), contains a response plan. This plan was developed on the basis of information and similar plans from other states and agencies. The role of drought assessment and response as defined in the Wyoming Drought Plan is "to be proactive and to assist existing state, federal and local agencies to carry out their designated missions for assisting drought affected customer groups." (Micheli and Ostermann, 2003)

Drought response planning may be undertaken by individual farmers and ranchers as well as by governmental agencies. Planning by individuals may "focus on things that the manager can do to reduce risk (uncertain consequences) associated with climatic variability." (Thurow and Taylor, 1999)

For example, operators could consider transferring their most senior water rights to their most productive lands in order to receive the most benefit from a short water supply. The transfers would have to be approved by the Wyoming Board of Control and there are costs associated with the preparation of the necessary petitions; however, such transfers could prove valuable during a drought.

*Enhanced Recreational Use of Water Reservoirs*

Recreational use of water resources comprises a significant portion of Basin tourism. Enhancement of recreational use could interfere with agricultural and municipal uses.

*Glendo Reservoir*

Wyoming is allocated 15,000 acre-feet of Glendo storage water. Approximately 4,400 acre-feet are under a long-term contract with the USBR. Presently, the remaining 10,600 acre-feet are typically marketed by the USBR through temporary use agreements. The WWDC is considering purchasing the 10,600 acre-feet to make it more readily available for priority purposes in Wyoming.

*Increasing Runoff from National Forests*

This concept would involve intensive and selective forest harvest to enhance water runoff. The management of the National Forests for maximization of runoff is a very controversial issue. The actual increase in runoff due to intensive forest harvest is also not clearly documented.

*Multipurpose Flood Control Programs*

The concept of this opportunity is to develop multipurpose projects which include flood control. The concept of development of new storage projects on the North Platte system is greatly complicated by the lack of water availability.

*Water Banking*

Water banking is an institutionalized process designed to facilitate transfer of developed water to new uses. Wyoming has the least active water market of all prior-appropriation states. Other states have found the concept to be an important water management tool. The State of Wyoming should investigate the concept to determine potential benefits to the state.

*Water Conservation*

This concept relates to all water use opportunities. Previous discussion in Chapter 7 emphasized agricultural conservation and municipal conservation. Conservation of water in all areas of usage will help stretch the available supplies. All water users should practice conservation.

*Water Exchanges*

Water exchanges can be implemented through temporary use agreements approved by the State Engineer's Office (SEO). These temporary use agreements provide the opportunity for dry year leasing whereby a municipality or industry could pay an irrigator not to produce a crop during a dry year and transfer the historic consumptive use to meet their demands through a temporary use agreement. Presently, temporary use agreements have a term of only two years. While the agreements are renewable, the water should be placed back on the land at least once in every five-year period.

*Water Right Transfers*

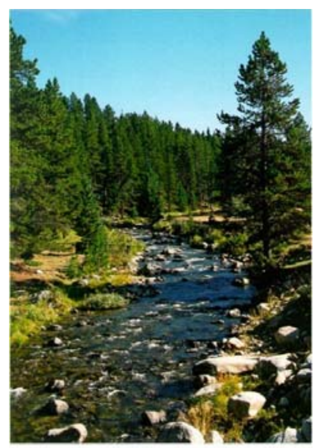
Water right transfers have typically involved transferring agricultural water rights to municipal or industrial uses. However, transfers can occur between all types of uses. Only the historic consumptive use resulting from the implementation of the water right can be transferred to other uses. Transfers must be approved by the Wyoming Board of Control. The transfers are not financially supported by the WWDC.

*Weather Modification*

The WWDC has sponsored a pilot project for five years to study the effects of cloud seeding. The results of the study should identify the benefits of the program. If the results confirm the predicted increase in snowfall, the weather modification program could be a large benefit to the North Platte River Basin.

## 8.7 POWDER/TONGUE RIVER BASIN

Future water use opportunities for the Powder/Tongue River Basin are addressed in this section.



### 8.7.1 Physically Available Flows

The physically available flows are summarized in Table 7-2 and shown on Figure 7-5 in Chapter 7. The flows are estimated for dry, normal, and wet hydrologic conditions. The lower portions of the Tongue River and Powder River Basin have substantial available flows in dry years. The upper portions of the Basins typically have dry year available flows substantially lower than wet year flows.

### 8.7.2 Compact Limitations

The Yellowstone River Compact of 1950 governs the allocation of the waters in the Powder River and Tongue River between the states of Montana and Wyoming. The compact restrictions are discussed in detail in Chapter 3. The unappropriated or unused total divertible flow of the Tongue River, Powder River, and Little Powder River, after needs for supplemental supply for existing rights are met, is allocated to Wyoming and Montana as follows:

- Tongue River: 40 percent to Wyoming, 60 percent to Montana
- Powder River and Little Powder River: 42 percent to Wyoming, 58 percent to Montana

To represent the wide range of possible interpretations, two estimates were made of Wyoming's remaining allocation of Tongue River water per the Yellowstone River Compact (a conservative estimate and a liberal estimate) as summarized in Table 8-15.

**Table 8-15 Remaining Allocation of Available Flow per Yellowstone River Compact**

| Hydrologic Condition | Tongue River Basin | | Powder River Basin |
|---|---|---|---|
| | Conservative Estimate | Liberal Estimate | |
| | ac-ft | | |
| Wet Years | 163,000 | 189,000 | 211,500 |
| Normal Years | 90,000 | 117,000 | 131,100 |
| Dry Years | 40,000 | 67,000 | 74,300 |

### 8.7.3 Agricultural Needs

Almost every tributary area of the Powder/Tongue Basin planning area can be considered water-short during dry years. The needs identified in the Basin Plan involved existing agricultural shortages. Consequently, the opportunities are primarily focused on meeting those needs. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6.

Table 8-16 indicates estimates of existing agricultural needs for the subbasins in dry years. The irrigated acres within those subbasins are also indicated.

**Table 8-16 Agricultural Needs, Powder/Tongue River Basin**

| Subbasin | Irrigated Lands | Needs for Dry Hydrologic Condition |
|---|---|---|
| | acres | ac-ft per year |
| Little Bighorn | 1,781 | 3,100 |
| Tongue River | 62,760 | 113,600 |
| Upper Clear Creek | 39,176 | 78,400 |
| Lower Clear Creek (Powder River) | 7,174 | 14,700 |
| Upper Crazy Woman Creek | 12,324 | 15,200 |
| Lower Crazy Woman Creek | 1,418 | 4,000 |
| Upper Powder River | 18,107 | 39,900 |
| South Fork Powder River | 2,103 | 4,000 |
| Lower Powder River | 6,440 | 21,100 |
| Little Powder River | 9,873 | 27,600 |

### 8.7.4 Long List of Future Water Use Opportunities

The long list of water use opportunities compiled in the Basin Plan comprised 54 projects. Opportunities were identified in all five of the sub-basins. This list was reviewed by the BAG to produce the short list of water use opportunities.

### 8.7.5 Short List of Future Water Use Opportunities

The long list was evaluated, and the short lists for each subbasin were developed in the Basin Plan as shown in Tables 8-17 through 8-22. The short lists were broken down into the following four types:

- **Type 1**: Rehabilitation projects that preserve existing uses.
- **Type 2:** Projects that rectify existing shortages consistent with the hierarchy of preferred uses established by the Wyoming statutes.
- **Type 3**: Projects that meet projected future demands consistent with the hierarchy of preferred uses established by the Wyoming statutes.
- **Type 4**: Projects that enhance uses in other Wyoming basins through trans-basin diversions.

The storage projects included in the short list are shown on Figure 8-5.

**Table 8-17 Evaluated Short List: Little Bighorn River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2 (None)*** | | | | | | | | |
| ***Type 3*** | | **6** | **5** | **6** | **5** | **8** | **6** | |
| BEPC Sunrise Project | 82,110 c | 6 | 7 | 7 | 5 | 5 | 6 | 214 |
| Little Bighorn River Export System | 29,600 y | 8 | 7 | 6 | 7 | 3 | 5 | 208 |
| Groundwater Development | unk | 5 | 6 | 8 | 4 | 7 | 4 | 208 |
| Half Ounce Reservoir | 10,000 y | 8 | 6 | 4 | 5 | 5 | 3 | 185 |
| Twin Creek Reservoir | 38,588 c | 8 | 6 | 4 | 4 | 4 | 4 | 178 |
| Fuller No. 1 Reservoir | 22,829 c | 4 | 3 | 5 | 4 | 5 | 5 | 159 |
| Fuller No. 2 Reservoir | 1,549 c | 4 | 3 | 5 | 4 | 5 | 4 | 153 |
| ***Type 4 (None)*** | | | | | | | | |

[1]y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-18 Evaluated Short List: Tongue River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1*** | | | | | | | | |
| Misc. Canal Rehab (Conservation) | unk | Not ranked, only one project of this type | | | | | | |
| ***Type 2*** | | | | | | | | |
| Sheridan Canal System | 68,500 y | Not ranked, only one project of this type | | | | | | |
| ***Type 3*** | | **6** | **8** | **6** | **7** | **6** | **6** | |
| Upper State Line Reservoir | 75,000 y | 8 | 6 | 7 | 7 | 6 | 7 | 265 |
| Lower State Line Reservoir | 88,000 y | 8 | 6 | 7 | 7 | 6 | 7 | 265 |
| Jones Draw Reservoir | 2,500 y | 5 | 5 | 8 | 8 | 7 | 4 | 240 |
| West Fork Reservoir | 2,500 y | 5 | 5 | 8 | 8 | 7 | 4 | 240 |
| Prairie Dog Reservoir | 20,000 y | 6 | 4 | 7 | 4 | 6 | 6 | 210 |
| Rockwood Reservoir | 93,000 y | 7 | 7 | 4 | 5 | 3 | 5 | 205 |
| Groundwater Development | unk | 4 | 4 | 9 | 4 | 6 | 4 | 198 |
| North Fork Reservoir | 21,600 y | 7 | 5 | 5 | 4 | 3 | 5 | 188 |
| South Fork Reservoir | 13,200 y | 7 | 5 | 5 | 4 | 3 | 5 | 188 |
| Shutts Flats Reservoir | 7,600 y | 7 | 4 | 5 | 4 | 3 | 5 | 180 |
| ***Type 4 (None)*** | | | | | | | | |

[1] y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-19 Evaluated Short List: Clear Creek Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] ac-ft | Project Evaluation Criteria[2] Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2 (None)*** | | | | | | | | |
| ***Type 3*** | | **6** | **8** | **6** | **7** | **6** | **6** | |
| Lake DeSmet Enlargements | 239,243 c | 8 | 9 | 7 | 5 | 7 | 4 | 263 |
| Lower Clear Creek Reservoir | 30,300 y | 8 | 5 | 6 | 6 | 6 | 7 | 244 |
| B.C.L. Company Reservoir | 29,300 c | 7 | 5 | 6 | 6 | 6 | 7 | 238 |
| Tex Ellis Reservoir | 17,100 y | 7 | 4 | 7 | 6 | 7 | 6 | 236 |
| Tie Hack Reservoir Enlargement | 7,500 c | 4 | 5 | 7 | 8 | 4 | 7 | 228 |
| Groundwater Development | unk | 4 | 3 | 7 | 3 | 6 | 5 | 177 |
| Little Sour Dough Reservoir | 1,642 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| Camp Comfort Reservoir | 11,640 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| South Rock Creek Reservoir | 13,300 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| Triangle Park Reservoir | 3,000 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| Canyon Reservoir | 5,000 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| South Clear Creek Reservoir | 5,000 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| Lynx Park Reservoir | 10,700 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| Sour Dough Creek Reservoir | 4,500 c | 4 | 3 | 4 | 3 | 3 | 4 | 135 |
| ***Type 4 (None)*** | | | | | | | | |

[1]y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-20 Evaluated Short List: Crazy Woman Creek Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2*** | | **6** | **7** | **5** | **6** | **4** | **3** | |
| Hazelton Watershed Site "B" | 3,000 acres | 5 | 7 | 5 | 7 | 4 | 4 | 174 |
| Doyle Creek Reservoir | 3,000 acres | 5 | 7 | 5 | 7 | 4 | 4 | 174 |
| Hazelton Watershed Site "A" | 1,580 acres | 7 | 5 | 6 | 5 | 3 | 3 | 158 |
| ***Type 3*** | | **6** | **8** | **5** | **6** | **5** | **6** | |
| Crazy Woman Reservoir | 10,500 y | 7 | 6 | 6 | 6 | 5 | 5 | 211 |
| Lower Crazy Woman Reservoir | 67,200 y | 7 | 4 | 6 | 7 | 4 | 6 | 202 |
| North Fork Crazy Woman Reservoir | 2,759 c | 6 | 5 | 5 | 4 | 6 | 4 | 179 |
| Enl. Negro Creek Reservoir | 13,900 c | 7 | 5 | 5 | 5 | 3 | 4 | 176 |
| Groundwater Development | unk | 4 | 3 | 7 | 3 | 6 | 5 | 161 |
| ***Type 4 (None)*** | | | | | | | | |

[1]y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-21 Evaluated Short List: Powder River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2*** | | **6** | **7** | **5** | **6** | **4** | **3** | |
| Morgareidge No. 7 Reservoir | 4,600 acres | 5 | 6 | 5 | 7 | 4 | 4 | 167 |
| Red Fork Powder River Reservoir | unk | 4 | 4 | 5 | 6 | 4 | 4 | 141 |
| ***Type 3*** | | **6** | **8** | **5** | **6** | **5** | **6** | |
| Moorhead Reservoir | 35,000 y | 8 | 7 | 7 | 6 | 5 | 6 | 236 |
| Buffalo Creek Reservoir | unk | 8 | 3 | 7 | 6 | 7 | 6 | 214 |
| Pumpkin Reservoir | 60,000 y | 6 | 6 | 6 | 6 | 6 | 5 | 210 |
| Clarks Fork Exchange | 99,700 c | 8 | 6 | 6 | 5 | 3 | 6 | 207 |
| Bass Industrial Reservoir | 123,380 c | 6 | 6 | 6 | 5 | 5 | 5 | 199 |
| Arvada Reservoir | 35,000 y | 6 | 6 | 6 | 5 | 5 | 5 | 199 |
| Middle Fork Powder River Reservoir | 27,000 y | 5 | 5 | 5 | 6 | 7 | 5 | 196 |
| Fence Creek Reservoir | 106,700 c | 7 | 4 | 7 | 5 | 6 | 4 | 193 |
| Fortification Creek Reservoir | 63,300 y | 5 | 4 | 7 | 6 | 6 | 4 | 187 |
| Gibbs Reservoir | 10,800 y | 6 | 5 | 6 | 4 | 5 | 5 | 185 |
| Groundwater Development | unk | 3 | 3 | 7 | 3 | 6 | 5 | 155 |
| ***Type 4 (None)*** | | | | | | | | |

[1] y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

**Table 8-22 Evaluated Short List: Little Powder River Basin**

| Project Type[3] | Est. Yield, Capacity, or Depletion[1] | Project Evaluation Criteria[2] | | | | | | TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| ***Type 1 (None)*** | | | | | | | | |
| ***Type 2 (None)*** | | | | | | | | |
| ***Type 3*** | | **6** | **8** | **4** | **5** | **4** | **6** | |
| Coal Mine Reclamation Reservoirs | unk | 5 | 7 | 8 | 6 | 6 | 8 | 220 |
| Groundwater Development | unk | 6 | 5 | 7 | 4 | 7 | 5 | 182 |
| ***Type 4 (None)*** | | | | | | | | |

[1] y = yield, c = capacity, d = depletion, unk = unknown

[2] Each criterion has a different weighting for each type of project; 10 is most important, 1 is least important. Weighting factors are shown in bold.

Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable.

Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score.

[3] Type 1: Rehabilitation projects that preserve existing uses

Type 2: Projects that rectify existing shortages

Type 3: Projects that meet projected future demands

Type 4: Projects that enhance uses in other Wyoming basins

### 8.7.6 Recommendations for Storage Opportunities

The opportunities for future water use in the Powder/Tongue River Basin were primarily storage reservoirs as shown in Figure 8-5. The opportunities and recommendations for advancement are discussed for each subbasin.

*Little Bighorn River Basin*

The needs in this subbasin, which are not very great, occur in the Pass Creek subdrainage. The short-listed storage site for this drainage, Twin Creek Reservoir, is located below most of the irrigated lands near the state line. This storage site had a relatively low score on the short list.

*Tongue River Basin*

The indicated needs, which are very significant, occur in the middle portions of Tongue River, Goose Creek, and Prairie Dog Creek, and their tributaries. The short-listed storage sites higher in the drainages are primarily located in the Bighorn National Forest. These sites include North Fork, Shutts Flats, South Fork, Rockwood, and West Fork Reservoirs. These reservoir sites were the lowest ranked sites on the short list.

Three of the reservoir sites (Upper State Line, Lower State Line, and Prairie Dog) are located near the state line. The ability of these lower reservoirs to meet the identified needs has not been evaluated. The location of the reservoirs would require exchanges to serve the irrigated lands.

The storage projects on the short list were identified in the "Tongue River-Level I Report" produced for the WWDC in 1985. This study was of a very preliminary nature and has numerous data gaps. To address the needs in the Tongue River subbasin, a Level I study to review the short-listed projects and additional projects would be needed. The demand on several existing reservoirs in the National Forest is dropping due to the development of subdivisions. Water marketing is going on and will likely continue.

*Clear Creek Basin*

The needs in the Clear Creek Basin, which are very significant, occur primarily in the upper basin portion above Lake DeSmet. Short-listed sites in the upper basin are located primarily in the National Forest. Sour Dough Creek Reservoir, Lynx Park Reservoir, South Clear Creek Reservoir, Canyon Reservoir, Triangle Park Reservoir, South Rock Creek Reservoir, Camp Comfort Reservoir, Little Sour Dough Reservoir, and Tie Hack Reservoir Enlargement are all located on Bighorn National Forest lands. Of the sites, only the Tie Hack Reservoir Enlargement had a reasonably good score. All these sites have questionable water supply due to the overappropriated condition of the basin.

If sufficient interest is present in this drainage, a Level I study should be pursued to evaluate the potential sites. Alternative sites outside of the forest lands including off-channel sites should be considered.

*Crazy Woman Creek Basin*

The needs were identified primarily in the upper portions of Crazy Woman Creek. To be effective, storage would need to be located relatively high on the upper tributaries of the North Fork, Middle Fork, and the South Fork. Three short-listed sites are located in these areas: Doyle Creek

Reservoir, North Fork Crazy Woman Reservoir, and Negro Creek Reservoir Enlargement. These three reservoir sites did not score very well on the short list evaluation.

If sufficient interest is present in this drainage, a Level I study should be pursued to evaluate the potential sites. Off-channel sites should also be investigated.

*Powder River Basin*

The needs were identified primarily in the upper portions of the Powder River Basin. Storage would be most effectively located in the North Fork, Middle Fork, and the South Fork of the Powder River. Four sites were short-listed that are located in this area: Morgareidge No. 7 Reservoir, Buffalo Creek Reservoir, Middle Fork Powder River Reservoir, and Red Fork Powder River Reservoir. The highest rated reservoir site was the Buffalo Creek Reservoir of unknown size. The Middle Fork of the Powder River site has been extensively studied and is a technically feasible reservoir site. However, opposition to the project has stymied development. The Morgareidge No. 7 Reservoir on Beaver Creek was not rated very high, nor was the Red Fork Powder River Reservoir.

If sufficient interest is present in this drainage, a Level I study should be pursued to evaluate the potential sites. Off-channel sites should also be considered.

*Little Powder River Basin*

No specific projects were identified.

#### 8.7.7 Future Groundwater Development

The aquifer system descriptions provided in Section 8.2.5, Potential Groundwater Development, apply to the Powder/Tongue River Basin. The current and projected groundwater use in the Powder/Tongue River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

#### 8.7.8 Coalbed Methane Waters

The Powder River Basin has experienced rapid growth of CBM development. To date, the development has not occurred in the areas of identified need. However, the potential for beneficial use of CBM discharge waters should be considered. The subject of CBM water is discussed in more detail in Chapter 6.

## 8.8 SNAKE/SALT RIVER BASIN

Future water use opportunities for the Snake/Salt River Basin are addressed in this section.

#### 8.8.1 Physically Available Flows

The physically available flows are shown at significant locations within the Snake and Salt Rivers on Figure 7-6 in Chapter 7. The irrigated acreages are summarized in Table 8-23. As indicated in Table 8-24, the Snake/Salt River Basin has very significant physically available flows, which are not legally available.

**Table 8-23 Irrigated Acreage, Snake/Salt River Basin**

| Subbasin | Irrigated Lands acres |
|---|---|
| Salt River | 65,584 |
| Snake River | 33,487 |

**Table 8-24 Available Flows, Snake/Salt River Basin**

| Subbasin | Hydrologic Condition | Physically Available Flow | Legally Available Flow |
|---|---|---|---|
| | | ac-ft per year | |
| Salt River | Dry | 216,000 | 12,000 |
| | Normal | 458,000 | 22,000 |
| | Wet | 694,000 | 31,000 |
| Snake River | Dry | 1,769,000 | 69,000 |
| | Normal | 2,888,000 | 116,000 |
| | Wet | 4,159,000 | 165,000 |

### 8.8.2 Compact Limitations

The Snake River Compact of 1949 limits Wyoming to diversions of 4 percent of the Wyoming-Idaho state line flows as discussed in detail in Chapter 3. The compact limits the legally available flow to the estimated quantities shown in Table 8-24. This severely limits the amount of flow that Wyoming can develop.

### 8.8.3 Agricultural Needs

No existing needs were quantified in the Snake/Salt River Basin Plan. However, there are indications of late season irrigation shortages, particularly in the Salt River Basin tributaries. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6.

### 8.8.4 Long List of Future Use Opportunities

The long list of future water use opportunities compiled in the Basin Plan comprised 50 projects. The opportunities were identified in the Snake River Basin and the Salt River Basin. This list was reviewed by the BAG to produce the short list of water use opportunities.

### 8.8.5 Short Lists of Future Water Use Opportunities

The short lists were produced for the Salt River and Snake River subbasins as shown in Figure 8-6 and Tables 8-25 and 8-26. The short lists include opportunities in agriculture, domestic/municipal, environmental, recreational, and industrial projects.

**Table 8-25 Evaluated Short List: Salt River Basin**

| Project Type | Project Evaluation Criteria | | | | | | TOTAL SCORE[1] |
|---|---|---|---|---|---|---|---|
| | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| **Agricultural** | | | | | | | |
| Cottonwood Lake Enl. | 8 | 6.5 | 7.5 | 7.5 | 5.5 | 6 | 41 |
| Strawberry Reservoir Enl. | 8 | 7 | 6.5 | 5.5 | 5.5 | 6.5 | 39 |
| Swift Creek Reservoir Enl. & Rehab. | 8 | 5.5 | 7 | 6.5 | 5 | 6.5 | 38.5 |
| Route Runoff/Groundwater Augmentation | 9 | 6 | 7 | 4.5 | 7.5 | 4.5 | 38.5 |
| Dry Creek Reservoir | 8 | 5 | 6 | 6 | 3.5 | 5 | 33.5 |
| Salt River Reservoir (headwaters) | 8 | 5.5 | 5.5 | 6.5 | 3.5 | 4 | 33 |
| Willow Creek Reservoir | 8 | 6 | 5.5 | 5.5 | 3.5 | 4 | 32.5 |
| Crow Creek Reservoir | 8 | 5.5 | 5 | 5 | 3.5 | 4 | 31 |
| Green Canyon Reservoir | 8 | 5.5 | 5.5 | 4 | 3.5 | 3.5 | 30 |
| Stump Creek Reservoir | 8 | 5.5 | 5 | 4 | 3.5 | 4 | 30 |
| Cedar Creek Reservoir | 8 | 5 | 5 | 4 | 3.5 | 3.5 | 29 |
| Stewart Creek Reservoir | 8 | 5 | 5 | 4 | 3.5 | 3.5 | 29 |
| **Domestic/Municipal** | | | | | | | |
| Additional Community Water Sources | 8.5 | 8 | 8 | 7.5 | 7.5 | 5 | 44.5 |
| Meter Community Water Systems | 8.5 | 6 | 5.5 | 6.5 | 8.5 | 4 | 39 |
| **Environmental** | | | | | | | |
| Alpine Wetlands (Greys River Area) | 7.5 | 7 | 6.5 | 5 | 7 | 4 | 37 |
| Riparian River Banks Rehab. | 7.5 | 4.5 | 5 | 4 | 7 | 4.5 | 32.5 |
| Additional Wetlands | 7 | 5.5 | 6.5 | 4 | 5 | 4 | 32 |
| River Morphology Rehab. | 7.5 | 4 | 5 | 4 | 6 | 4.5 | 31 |
| **Recreational** | | | | | | | |
| Salt River above Narrows Reservoir | 8.5 | 6 | 6.5 | 5.5 | 4.5 | 7.5 | 38.5 |
| Cloud Seeding Operations | 8 | 4.5 | 3.5 | 3.5 | 6 | 6.5 | 32 |
| **Industrial** | | | | | | | |
| Promote Water Bottling Opportunities | 9 | 8 | 8 | 6 | 7 | 4 | 42 |
| Facilities on Existing Irrigation Systems | 7.5 | 6 | 8 | 6 | 5.5 | 4.5 | 37.5 |
| Low Head/Open Channel Hydro Projects | 7 | 4.5 | 6 | 4.5 | 4 | 4 | 30 |

[1] The total score is the sum of the individual scores. No weighting factors were used.

**Table 8-26 Evaluated Short List: Snake River Basin**

| Project Type | Project Evaluation Criteria | | | | | | TOTAL SCORE[1] |
|---|---|---|---|---|---|---|---|
| | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | |
| **Agricultural** | | | | | | | |
| Spring Gulch Irrigation System Sprinkler | 8 | 5 | 5 | 4 | 5 | 3 | 30 |
| South Park Irrigation System Sprinkler | 8 | 5 | 5 | 2 | 5 | 3 | 28 |
| Cottonwood Creek Reservoir (Gros Ventre) | 5 | 2 | 2 | 3 | 2 | 6 | 20 |
| **Domestic/Municipal** | | | | | | | |
| Additional Community Water Sources | 8 | 8 | 8 | 8 | 8 | 8 | 48 |
| Fire Protection Wells in Outlying Areas | 8 | 8 | 8 | 8 | 8 | 6 | 46 |
| Improve Winter Flood Control in Jackson | 7 | 8 | 6 | 9 | 8 | 7 | 45 |
| Meter Community Water Systems | 8 | 5 | 5 | 8 | 8 | 5 | 39 |
| **Environmental** | | | | | | | |
| Improve Water Quality of Surface Runoff from Developed Areas | 8 | 7 | 8 | 7 | 8 | 5 | 43 |
| Riparian River Banks Rehab. | 8 | 6 | 7 | 7 | 6 | 6 | 40 |
| Additional Wetlands | 8 | 7 | 8 | 6 | 5 | 5 | 39 |
| Transfer Grand Teton National Park Water Rights to Instream Flow | 8 | 7 | 6 | 7 | 4 | 6 | 38 |
| Increase Flows in West Bank Spring Creeks | 7 | 5 | 6 | 6 | 4 | 6 | 34 |
| River Morphology Rehab. | 8 | 2 | 2 | 4 | 2 | 6 | 24 |
| **Recreational** | | | | | | | |
| Snowmaking Operations | 8 | 8 | 6 | 8 | 8 | 6 | 44 |
| Make Aesthetic Ponds a Beneficial Use by SEO | 8 | 6 | 6 | 6 | 5 | 6 | 37 |
| Cloud Seeding Operations | 2 | 4 | 3 | 2 | 2 | 7 | 20 |
| **Industrial** | | | | | | | |
| Promote Water Bottling Opportunities | 9 | 8 | 8 | 7 | 6 | 2 | 40 |

[1] The total score is the sum of the individual scores. No weighting factors were used.

*Agricultural Opportunities*

The short list for the Salt River subbasin includes 11 storage projects which are primarily located on tributaries of the Salt River. Of these sites, seven are located on the Bridger-Teton National Forest. The WWDC currently has a Level I study being conducted for the Cottonwood Lake Enlargement. As indicated previously, the shortages or needs for the alternative sites were not specifically quantified. The available water supply for the affected tributaries was quantified.

In the Snake River subbasin, conversion of flood irrigation to sprinkler systems has normally been funded by other state agencies. Cottonwood Creek Reservoir on the Gros Ventre was the only short-listed storage site.

Domestic/Municipal Opportunities

Development of additional water sources for municipal needs can be studied and funded by the WWDC. These WWDC studies are normally on an individual community request basis. The State of Wyoming has storage water available in Palisades Reservoir for potential development. Metering of community water systems is normally funded by other state agencies. Flood control, is normally a secondary benefit of storage projects as proposed for the Jackson area of the Snake River subbasin.

Environmental Opportunities

The potential environmental opportunities on the short list for the Salt River subbasin included improvement of wetlands, riparian areas, and stream stability. The WWDC has been funding watershed management plans which consider these opportunities as well as other opportunities. Most of the environmental opportunities on the short list for the Snake River subbasin would fall within a watershed management plan.

Recreational Opportunities

Recreational opportunities are normally incorporated into multipurpose storage projects as previously discussed. WWDC-funded projects can incorporate recreational opportunities.

Industrial Opportunities

The State of Wyoming has storage water available in Palisades Reservoir for potential development. Industrial opportunities are normally supported by the local entities.

### 8.8.6 Recommendations for Opportunities

If sufficient interest is indicated in the basins by the BAG, the following recommendations could advance the short list projects.

*Salt River Subbasin*

A basinwide study of supplemental irrigation needs and the best projects to meet those needs would be the most efficient way to advance the opportunities. The potential multiuse projects that most effectively benefit the basin could be determined. Projects that benefit irrigation, municipal needs, recreation, and environment would have the best potential for implementation.

A Level I study of potential multipurpose storage projects in this subbasin would be needed to advance potential projects. The information needed to advance project opportunities would include need, water availability, ability to meet needs, multiuse potential, geotechnical feasibility, landownership issues, cultural resource impacts, environmental impacts, ability to permit, estimated costs, and economics. Watershed management opportunities could be incorporated in potential projects.

*Snake River Subbasin*

Watershed management plans would be the most beneficial opportunity in this subbasin. These plans could incorporate the more diverse opportunities in this basin.

### 8.8.7 Future Groundwater Development

As a practical matter, the availability of groundwater is a local and project-specific function of competing users, water quality needs, economics, and legal constraints. Nonetheless, a few general conclusions can be made:

- The availability of groundwater across the Snake River alluvial deposits is physically limited only by the flow of the Snake River itself (3 million acre-ft per year). Aquifer permeability is sufficient, in most areas, to support production rates on the order of 1,000 gpm from individual wells. It is unlikely that groundwater development from this aquifer will impact surface flows sufficiently to trigger concerns about the volume of the combined water resource over any reasonable planning horizon. "Local water supplies are, in most cases, readily available through groundwater development. While each water supply system presents unique hydrogeologic and engineering concerns, the need for long-distance conveyance of water from areas of supply to areas of use is relatively unlikely" (Jorgensen et al., 1999). A more likely constraint on groundwater development in this area is the incremental deterioration of groundwater quality that accompanies the establishment of increasing domestic, municipal, commercial, and other uses.
- In Star Valley, the alluvial aquifer is much less thick than along the Snake River and is above the groundwater table in many areas. Successful well development across the valley floor has been primarily based on the highly variable Salt Lake Formation. Development experience with this formation demonstrates that high-volume wells are possible, but that careful, site-specific exploration is necessary and that groundwater of adequate quantity and quality may not be available at all sites.
- Springs issuing from bedrock units on the east side of Star Valley have been extensively developed and, with adequate safeguards with respect to water quality, can be expected to continue.
- Bedrock aquifers in upland areas provide a full spectrum of groundwater development potential, from low permeability and low quality to highly productive aquifers with good water quality. Due to the complexities of the study area bedrock geology, these conditions are quite site-specific and can change dramatically over short distances. Detailed, site-specific evaluations and exploratory drilling should be anticipated in areas where groundwater is anticipated from these units.

The current and projected groundwater use in the Snake/Salt River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

## 8.9 WIND/BIGHORN RIVER BASIN

Future water use opportunities for the Wind/Bighorn River Basin are addressed in this section.

### 8.9.1 Physically Available Flows

The physically available flows are summarized in Table 7-2 and shown on Figure 7-7 in Chapter 7. The flows are estimated for dry, normal, and wet hydrologic conditions. The information indicates that the Upper Wind River and its tributaries, including the Little Wind River and Owl Creek, have very low dry year available flows in comparison to wet years. The needs in a basin usually are associated with the low available flows in dry years.

### 8.9.2 Compact Limitations

Within the Wind River, Clarks Fork, and Bighorn Basins, surface water usage and flow are regulated by the Yellowstone River Compact of 1950, the general adjudication of all rights to use water in the Bighorn River system, and the State of Wyoming in the District Court, Fifth Judicial District, Civil Case No. 4993. The compact limitations are discussed in detail in Chapter 3. The unappropriated waters in the tributaries, after meeting existing water rights (1950) and supplemental supply for existing rights, as measured at gages near the confluence, are allocated as follows:

- Bighorn: 80 percent Wyoming, 20 percent Montana
- Clarks Fork: 60 percent Wyoming, 40 percent Montana

The compact's effects on available flows are shown in Table 7-2 in Chapter 7.

### 8.9.3 Agricultural Needs

Significant areas of the Wind/Bighorn River Basin planning area can be considered water-short during dry years. The needs identified in the Basin Plan involved existing agricultural needs. Consequently, the opportunities are primarily focused on meeting those needs. The projected diversions and consumptive use for high, mid, and low planning scenarios are presented in Tables 6-2 and 6-3 in Chapter 6.

Table 8-27 indicates estimates of existing agricultural shortages for the subbasins. The irrigated acres within those subbasins are also indicated.

**Table 8-27 Agricultural Needs, Wind/Bighorn River Basin**

| Subbasin | Irrigated Lands acres | Needs for Dry Hydrologic Condition ac-ft per year |
|---|---|---|
| Clarks Fork | 18,299 | 30,000 |
| Upper Wind River | 138,863 | 193,000 |
| Little Wind River | 45,536 | 98,000 |
| Lower Wind River | 12,919 | 21,000 |
| Upper Bighorn River | 63,150 | 12,000 |
| Owl Creek | 17,839 | 40,000 |
| Nowood River | 21,725 | 7,000 |
| Lower Bighorn River | 25,862 | 27,000 |
| Greybull River | 98,046 | 29,000 |
| Shoshone River | 158,187 | 29,000 |
| Bull Creek | NA | 193,000 |
| Dinwoody Creek | NA | 193,000 |
| Middle Fork Popo Agie River | NA | 22,000 |
| North Fork Little Wind River | NA | NA |
| Shell Creek | NA | 1,000 |

### 8.9.4 Long List of Future Water Use Opportunities

The long list of future water use opportunities compiled in the Basin Plan comprised approximately 300 projects. This list was reviewed by the BAG to produce the short list of water use opportunities.

### 8.9.5 Short List of Future Water Use Opportunities

The short list of future water opportunities is summarized in Table 8-28. The ratings of the projects are summarized in Table 8-29.

**Table 8-28 Short List of Future Projects, Wind/Bighorn River Basin**

| Project Type | Name | Description | Location |
|---|---|---|---|
| **MUNICIPAL** | | | |
| New Source | Paleozoic Well Field | Construct Deep Aquifer Supply | Regionalization: Lander/Hudson/Riverton |
| | Paleozoic Well Field | Construct Deep Aquifer Supply | Regionalization: Wind River Reservation |
| | Paleozoic Well Field | Construct Deep Aquifer Supply | Regionalization: Hot Springs County |
| Distribution/Storage Opportunities | Bighorn Regional Joint Powers Board | Storage Tanks/Redundant Transmission | HotSprings/Washakie County |
| | Tensleep/Hyattville | Storage Tanks/Transmission | Washakie County |
| Conjunctive Use | Aquifer Storage and Retrieval | Alluvial Aquifer Augmentation | Upper Wind River/Riverton Area |
| Water Management | Ground Water Control District | Administration of Future Development | Riverton Area |
| | Ground Water Control District | Administration of Future Development | Paintrock Anticline and Hyattville |
| Water Conservation | Leak Detection | Municipal Survey and Repair of Leaks | Basinwide |
| | Reuse of Grey Water Nonpotable Water | Irrigation of Parks/Cemeteries | Basinwide |
| **AGRICULTURAL** | | | |
| New Source | None | | |
| Storage Opportunities | Bull Lake Enlargement | Reservoir Enlargement | Big Wind River |
| | Dinwoody Lake Enlargement | Reservoir Enlargement | Big Wind River |
| | Steamboat | New Reservoir | Big Wind River |
| | Ray Lake | Reservoir Enlargement | Little Wind River |
| | Little Popo Agie Off-Channel Site 5 | New Reservoir | Little Popo Agie |
| | Pumpkin Draw | New Reservoir | Owl Creek |
| | Neff Park (Popo Agie Study) | New Reservoir | Popo Agie |
| | Lake Creek | New Reservoir | Clarks Fork |
| | Moraine Creek No. 1 | New Reservoir | Shell Creek |
| Distribution | Popo Agie Master Plan | Ditch Headgate and Diversion Improvements | Popo Agie Basin |
| | Kirby Creek Watershed | Stock Reservoirs | Kirby Creek Basin |
| New Lands | Riverton East | Construct New Diversions/Ditches | Wind River Basin |
| | Westside | Construct New Diversions/Ditches | Bighorn Basin |
| Water Conservation | Midvale/LeClair | Ditch Linings/Conveyance Improvements | Wind River Basin |
| | Riverton Valley | Ditch Linings/Conveyance Improvements | Wind River Basin |
| | Wind River Irrigation Project | Ditch Linings/Conveyance Improvements | Wind River Basin |
| Basin Transfer | Clarks Fork to Greybull Drainage | Storage and Pipeline | Clarks Fork to Bighorn Basin |
| **ENVIRONMENTAL** | | | |
| | Instream Flows | Admin Minimum Flows | Wind and Bighorn Basin |
| | Minimum Reservoir Pools | Admin Reservoir Releases | Wind and Bighorn Basin |
| | Watershed/Habitat Improv. | Water Quality Impaired Streams | Bighorn Basin |
| **CULTURAL/RELIGIOUS** | | | |
| | Water Use by Tribes | Coordinated Reservoir Releases | Wind and Bighorn Basin |

**Table 8-29 Evaluated Short List: Wind/Bighorn River Basin**

| Project Type | Project Evaluation Criteria | | | | | | | TOTAL SCORE (AVG)[1] | Framework Total Score[2] |
|---|---|---|---|---|---|---|---|---|---|
| | Need | Water Availability | Financial Feasibility | Public Acceptance | No. of Sponsors/ Beneficiaries | Legal/ Institutional | Environmental/ Recreation Benefits | | |
| ***Weighting*** | **8** | **7** | **7** | **6** | **6** | **5** | **7** | | |
| **Municipal** | | | | | | | | | |
| *Groundwater Development* | | | | | | | | | |
| Madison Aquifer (Lander) | 6 | 7 | 6 | 7 | 10 | 5 | 5 | 6.6 | 301 |
| Madison Aquifer (Southern Bighorn Basin) | 5 | 7 | 8 | 8 | 10 | 7 | 5 | 7.1 | 323 |
| *Distribution/Storage Opportunities* | | | | | | | | | |
| Big Horn Regional Joint Powers Board | 4 | 7 | 8 | 8 | 10 | 7 | 5 | 7.0 | 315 |
| Town of Tensleep Regionalization | 8 | 8 | 6 | 5 | 6 | 7 | 5 | 6.4 | 298 |
| *Conjunctive Use* | | | | | | | | | |
| Recharge of Alluvial System Along Upper Wind River | 7 | 8 | 5 | 5 | 4 | 4 | 7 | 5.7 | 270 |
| *Water Conservation* | | | | | | | | | |
| Leak Detection Program | 7 | 8 | 5 | 5 | 5 | 9 | 5 | 6.3 | 287 |
| Reclaimed Water for Irrigation | 6 | 7 | 3 | 4 | 5 | 5 | 5 | 5.0 | 232 |
| **Agricultural** | | | | | | | | | |
| *New Source (none)* | | | | | | | | | |
| *Storage Opportunities* | | | | | | | | | |
| Bull Lake Dam Enlargement - 48,000 AF (Bighorn) | 5 | 7.3 | 10 | 3 | 10 | 3 | 6 | 6.3 | 296 |
| Dinwoody Lake Enlargement - 82,580 AF (Bighorn) | 5.5 | 4.3 | 9.7 | 3 | 10 | 3 | 6 | 6.0 | 277 |
| Steamboat - 36,000 AF (Bighorn) | 5 | 8.5 | 9.9 | 3 | 10 | 3 | 6 | 6.5 | 304 |
| Wind River East Fork No. 1 - 103,000 AF | 5.9 | 1.9 | 9.2 | 3 | 10 | 3 | 6 | 5.6 | 260 |
| Little Wind River North Fork No. 3 | 9.1 | 4.7 | 8.4 | 3 | 0 | 3 | 6 | 4.9 | 240 |
| Ray Lake Enlargement - 41,650 AF (Little Wind) | 9.1 | 2.1 | 8.4 | 5 | 10 | 6 | 7 | 6.8 | 315 |
| Moraine Creek No. 1 - 1,150 AF (Shell Cr) | 5 | 10 | 8.4 | 5 | 0 | 6 | 7 | 5.9 | 278 |
| Pumpkin Draw - 2,000 AF (Owl Cr) | 5 | 10 | 8.4 | 5 | 4.7 | 6 | 7 | 6.6 | 306 |
| Lake Creek - 5,100 AF (Clarks Fork) | 0 | 5.3 | 8.4 | 5 | 0 | 6 | 7 | 4.5 | 205 |
| *Distribution* | | | | | | | | | |
| Popo Agie River Master Plan | 7 | 5 | 8 | 7 | 7 | 6 | 7 | 6.7 | 310 |
| Kirby Creek Master Plan | 7 | 5 | 5 | 7 | 5 | 7 | 8 | 6.3 | 289 |
| *New Lands* | | | | | | | | | |
| Westside Irrigation Project | 8 | 6 | 6 | 7 | 9 | 5 | 5 | 6.6 | 304 |
| Riverton East | 8 | 5 | 6 | 7 | 9 | 5 | 5 | 6.4 | 297 |
| *Water Conservation* | | | | | | | | | |
| Line Ditches to Reduce Seepage Loss | 8 | 8 | 5 | 8 | 5 | 5 | 4 | 6.1 | 286 |

**Table 8-29  Evaluated Short List:  Wind/Bighorn River Basin**

| | Project Evaluation Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Project Type** | **Need** | **Water Availability** | **Financial Feasibility** | **Public Acceptance** | **No. of Sponsors/ Beneficiaries** | **Legal/ Institutional** | **Environmental/ Recreation Benefits** | **TOTAL SCORE (AVG)[1]** | **Framework Total Score[2]** |
| Change from Open Ditch to Pipeline | 8 | 8 | 5 | 8 | 5 | 5 | 4 | 6.1 | 286 |
| Midvale Irrigation District | 8 | 8 | 7 | 8 | 6 | 5 | 4 | 6.6 | 306 |
| LeClair Laterals | 8 | 8 | 7 | 8 | 6 | 5 | 4 | 6.6 | 306 |
| Riverton Valley Crossings | 8 | 8 | 6 | 8 | 6 | 5 | 4 | 6.4 | 299 |
| More Efficient Irrigation Systems | 8 | 8 | 5 | 8 | 5 | 5 | 4 | 6.1 | 286 |
| Low Head Sprinklers | 8 | 8 | 5 | 8 | 5 | 5 | 4 | 6.1 | 286 |
| *Basin Transfer* | | | | | | | | | |
| Clarks Fork to Shoshone River Pipeline | 2 | 10 | 4 | 5 | 6 | 6 | 5 | 5.4 | 245 |
| Wood River to Gooseberry Cr Storage in Sunshine Reservoir and Pipeline | 5 | 6 | 4 | 5 | 6 | 6 | 5 | 5.3 | 241 |
| Wood River to Cottonwood/Grass Cr Storage in Sunshine Reservoir and Pipeline | 5 | 6 | 4 | 5 | 6 | 6 | 5 | 5.3 | 241 |
| **Environmental** | | | | | | | | | |
| *Environmental/Recreation* | | | | | | | | | |
| Instream or Minimum Flows | 7 | 3 | 8 | 7 | 10 | 7 | 8 | 7.1 | 326 |
| Minimum Reservoir Pool | 7 | 3 | 8 | 7 | 10 | 7 | 8 | 7.1 | 326 |
| River Restoration/Habitat Improvement | 6 | 9 | 6 | 7 | 4 | 7 | 7 | 6.6 | 303 |
| **Cultural/Religious** | | | | | | | | | |
| *Cultural/Religious Management* | | | | | | | | | |
| Coordinated Releases for Cultural Purposes | 8 | 8 | 7 | 6 | 6 | 8 | 7 | 7.1 | 330 |
| Coordinated Releases for Religious Purposes | 8 | 8 | 7 | 6 | 6 | 8 | 7 | 7.1 | 330 |

[1] This score is the average of the individual scores.

[2] This value is the sum of individual scores multiplied by the weighting factors.  This is unique to the Framework Water Plan and was calculated to create a more uniform scoring system among the basins.

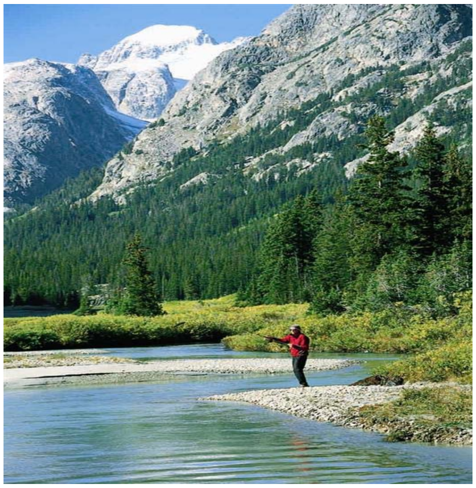
### 8.9.6 Supplemental Studies

Other studies have been conducted within the Wind/Bighorn River Basin. Brief summaries of these studies follow.

*Upper Wind River Storage Project – Level I Study*

The purpose of this study (SEH, Inc., 2001) was to evaluate alternate sites for additional and/or new storage. The study was confined to the Upper Wind River. Approximately 150 storage sites were evaluated and rated. Five sites were advanced to conceptual design: Bull Lake Enlargement, Little Wind River North Fork No. 3, Dinwoody Lake Enlargement, Wind River East Fork No. 1, and Steamboat. The information from this study was the primary resource in developing the framework scoring matrix.

*Popo Agie River Watershed Study – Level I Study*



This purpose of this study (Anderson Consulting Engineers, Inc., 2003) was to evaluate and describe the Popo Agie River watershed and develop a watershed management plan. One of the tasks was to identify and preliminarily investigate potential storage sites. Eighteen sites were identified and investigated. One site, Neff Park on Sawmill Creek, a tributary of Middle Popo Agie River, was placed on the short list. This site would have a capacity of 6,440 acre-feet.

*Crowheart Area/Dinwoody Canal System – Level I Study*

The purpose of this study (Nelson Engineering, 2005) was to evaluate the Dinwoody Canal system and investigate the feasibility of the enlargement of Dinwoody Lake. The Dinwoody Lake Enlargement portion of the study involved boring one exploratory hole to a depth of 90 feet. The boring confirmed the existence of glacial till to a very significant depth in the foundation. A conceptual cost estimate was developed for a reservoir enlargement to store an additional 39,300 acre-feet.

*Kirby Area Water Supply – Level I Study*

The purpose of this study (Anderson Consulting Engineers, Inc., 2005) was to evaluate the potential to divert, store, and put to beneficial use winter releases from Boysen Reservoir. Sixteen reservoir sites were initially identified for evaluation and screening. Three sites were identified and studied further. These were the Freeman Draw Reservoir on the Bighorn River with a 100,000 acre-foot capacity; the Fifteenmile Creek Reservoir with a 98,000 acre-foot capacity; and the Nowater Creek Reservoir with a 104,000 acre-foot capacity. The sites on Fifteenmile Creek and Nowater Creek would require supply from the Bighorn River.

The study determined and confirmed that there are no shortages on the Bighorn River below the reservoir sites. Shortages below Boysen Reservoir are on the tributaries which could not be served by these reservoirs.

*Cottonwood/Grass Creek Watershed Management Plan – Level I Study*

This study, currently under development, has the purpose to assess, describe, and inventory the watershed and then to develop a management and rehabilitation plan for the watershed. One of the tasks in the study is to assess water storage needs and potential alternative reservoir sites to meet the needs.

*Owl Creek Master Plan*

The purpose of this study (SEH, Inc., 2005) was to assess, describe, and inventory the watershed and then to develop a management and rehabilitation plan for the watershed. One of the tasks was to identify and evaluate reservoir sites. Five reservoir sites were identified as having the best potential to meet shortages within the basin. These five sites were recommended for future study. A study is currently in progress to analyze the alternative storage sites in detail.

*Wind River Export Study – Level I*

The purpose of this study (ECI, 2002) was to assess the potential of exporting water from the Wind River Basin into adjacent basins to benefit the Wind River Indian Tribes. The study identified the best potential for sale of the water to be the Colorado Front Range. The system investigated would deliver 54,300 acre-feet per year to potential customers. The study also investigated delivery of water to the North Platte River via the Sweetwater River. The compact issues concerning transbasin exportation would have to be considered.

*Ray Lake Enlargement – Level II Study*

The purpose of this study (Gannett Fleming, 2005) was to assess the safety of dams issues with the existing structure and evaluate the potential to enlarge the reservoir to provide water to areas of existing shortage within the Little Wind River drainage. The rehabilitation of the existing dam to meet safety of dams criteria was feasible as was enlargement of the reservoir. However, enlargement may require realignment of the dam. The project is pending action by the sponsors.

### 8.9.7 Framework Scoring Matrix

The short list reservoir sites investigated in the referenced studies were evaluated utilizing the Framework Scoring Matrix developed for the Framework Plan. The results are shown in Tables 8-30 and 8-31. The information developed in the Basin Plan and the specific reservoir studies was utilized for the matrix scoring. The reservoir projects have been arranged with the highest scoring projects listed first. The recommendations for storage opportunities were based on this information.

**Table 8-30 Framework Scoring Matrix, Wind/Bighorn River Basin**

| Project | Storage | Irrigated Lands | Project Yield | 2007 Project Cost | Storage Cost | Sponsor Cost per Acre* | Sponsor Cost per Acre-Foot* | Comments |
|---|---|---|---|---|---|---|---|---|
| | ac-ft | acres | ac-ft per year | $M | $ per ac-ft | $ per acre | $ per ac-ft | |
| Steamboat Off-Channel Reservoir | 44,800 | 138,863 | 40,000 | 56.7 | 1,266 | 10 | 35 | Tribal lands; estimated yield |
| Bull Lake Enlargement | 48,300 | 138,863 | 30,000 | 42.7 | 884 | 8 | 35 | Tribal and USBR lands; estimated yield |
| Ray Lake Enlargement | 27,000 | 13,691 | 11,000 | 53.5 | 1,981 | 96 | 119 | Tribal lands; resevoir includes 10,000 AF recreation pool; supply limitations |
| Dinwoody Lake Enlargement | 39,300 | 138,863 | 25,000 | 40.4 | 1,028 | 7 | 40 | Estimated yield |
| North Fork Little Wind River No. 3 Reservoir | 38,600 | 45,536 | 25,000 | 88.3 | 2,288 | 48 | 87 | Tribal lands; estimated yield |
| Wind River East Fork No. 1 Reservoir | 70,600 | NA | 12,000 | 94.4 | 1,338 | NA | 193 | Tribal lands; estimated yield |
| Neff Park - Sawmill Creek | 6,440 | NA | 4,000 | 13.5 | 2,096 | NA | 83 | Middle Popo Agie drainage; located on USFS lands; estimated yield |

* Assumed WWDC Standard Funding Package of two-thirds grant and one-third loan at four percent interest rate.

**Table 8-31 Framework Selection Scoring, Non-Monetary Factors, Wind/Bighorn River Basin**

| Project | Need | Water Availability | Ability to Meet Need | Multiple Use Potential | Geotech Feasibility | Land Ownership | Cultural Resources | Environ. Impacts | Ability to Permit | Cost | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight: | 20 | 10 | 10 | 10 | 10 | 10 | 10 | 20 | 20 | 20 | |
| Steamboat Off-Channel Reservoir | 10 | 10 | 10 | 6 | 8 | 6 | 6 | 10 | 9 | 8 | 1,200 |
| Bull Lake Enlargement | 10 | 8 | 10 | 6 | 8 | 4 | 4 | 8 | 9 | 8 | 1,100 |
| Ray Lake Enlargement | 10 | 5 | 8 | 8 | 8 | 4 | 8 | 8 | 10 | 4 | 1,050 |
| Dinwoody Lake Enlargement | 10 | 8 | 10 | 6 | 6 | 4 | 0 | 8 | 8 | 8 | 1,020 |
| North Fork Little Wind River No. 3 Reservoir | 10 | 7 | 8 | 6 | 6 | 6 | 5 | 8 | 8 | 4 | 980 |
| Wind River East Fork No. 1 Reservoir | 10 | 5 | 10 | 6 | 7 | 0 | 5 | 4 | 2 | 2 | 690 |
| Neff Park - Sawmill Creek | 10 | 6 | 4 | 10 | NA | 2 | NA | NA | NA | 4 | NA |

### 8.9.8 Recommendations for Storage Opportunities

The reservoir storage opportunities for the Wind/Bighorn River Basin are summarized by subbasin below and the sites are shown on Figure 8-7.

*Upper Wind River*

The Upper Wind River has significant needs under most hydrologic conditions. The projects identified as having the most potential for alleviating these needs include:

- Steamboat Off-Channel Reservoir: An approximately 55-foot high dam would impound approximately 45,000 acre-feet with an estimated annual yield of 40,000 acre-feet. The reservoir would be supplied with a nine-mile canal from the Wind River.
- Bull Lake Enlargement: Bull Lake is an existing USBR reservoir. Raising the dam 22 feet would increase storage by 48,300 acre-feet with an estimated average annual yield of 30,000 acre-feet.
- Dinwoody Lake Enlargement: Dinwoody Lake is an existing reservoir. Raising the dam 90 feet would increase storage by 39,300 acre-feet with an estimated average annual yield of 25,000 acre-feet.

The Steamboat Off-Channel Reservoir was the highest rated storage project with a relatively low cost per acre-foot of storage. The Bull Lake Enlargement was the second highest rated project with the lowest cost per acre-foot of storage. The Dinwoody Lake Enlargement was the fourth highest rated project with the second lowest cost per acre-foot of storage.

To advance these projects, a Level II study would be needed to determine feasibility. No single project would yield adequate water to meet the previously identified needs in the Upper Wind River Basin. Consequently, a Level II study should include all three potential projects to determine the best solution for the basin.

*Little Wind River*

The Little Wind River has significant identified needs. The projects identified as having the most potential for alleviating the needs are:

- Ray Lake Enlargement: The Ray Lake Enlargement was investigated with a Level II study in 2005. An enlargement of 27,000 acre-feet would have an estimated annual yield of 11,000 acre-feet. The existing Ray Lake is an off-channel reservoir.
- North Fork Little Wind River No. 3 Reservoir: This proposed reservoir would have a storage capacity of 38,600 acre-feet with an estimated annual yield of 25,000 acre-feet.

The Ray Lake Enlargement was the higher rated project in the Little Wind River Basin with the lower cost per acre-foot of storage. This project is well advanced for design and construction. The North Fork Little Wind No. 3 Reservoir was the next highest rated project. The North Fork Little Wind No. 3 Reservoir project would need to be advanced to a Level II study to determine feasibility. The Ray Lake Enlargement project will not meet all of the needs in the Little Wind River Basin.

*Clarks Fork*

The Clarks Fork has identified needs. The only project identified in the short list, the Lake Creek Reservoir Project, would store 5,100 acre-feet. To advance this project, a Level I study would be needed.

*Bighorn River*

The Bighorn River has minimal needs. Storage water is available from Boysen Reservoir. The Kirby Area Water Supply Level I study identified three alternative reservoir sites for analysis, conceptual designs, and cost estimates. This study confirmed the lack of needs below Boysen Reservoir. No storage sites for the Bighorn River were on the short list.

*Greybull River*

The Greybull River has relatively small shortages. The construction of the Greybull Valley Project, which included the Roach Gulch Reservoir has alleviated most of the shortages. No storage sites for the Greybull River were included on the short list.

*Shoshone River*

The Shoshone River has relatively small needs. No storage sites for the Shoshone River were included on the short list. The State of Wyoming owns water in the Buffalo Bill Enlargement, which is presently enhancing recreation benefits, and water is available for sale for future municipal and industrial demands.

*Owl Creek*

The Owl Creek drainage has significant identified needs. A Level I study, "Master Plan for Owl Creek Basin" (SEH, Inc., 2005), identified five alternative sites that showed promise for meeting the needs. In 2006, a Level II project was commissioned to investigate the alternate storage opportunities.

### 8.9.9 Future Groundwater Development

While numerous hydrogeological investigations have been conducted in the planning area, there have been few, if any, regional assessments of the annual recharge, storage, and sustained yield capability of the major aquifers. General conclusions regarding the groundwater development potential of several of the major aquifers are summarized below.

- Subaquifers in the Quaternary Aquifer may have local development potential. Depending upon local hydrogeologic conditions, individual well yields may typically range from 10 to 500 gpm. Water quality and susceptibility to surface water sources of contamination must be addressed.
- The Wind River Aquifer is already heavily developed within the Wind River Basin, but opportunities for additional groundwater development and installation of high-capacity wells may be possible in areas not currently developed. Local water quality conditions may constrain development in the planning area.

- The Madison Aquifer likely has the most development potential for high-yield wells. Yields of up to 14,000 gpm have been encountered historically under flowing artesian conditions. However, declines in local hydraulic head and large variations in the fracture and karst permeability of this system will necessitate site-specific investigations to be conducted prior to drilling. Drilling depths and water quality will also constrain development at specific locations within the planning area.
- The Flathead Sandstone is another viable high-yielding aquifer in areas where the formation can be drilled at reasonable depths. This aquifer generally has large artesian pressures, and it has produced large artesian flows of up to 3,000 gpm. As with the Madison Aquifer, drilling depths and water quality will constrain development at many locations throughout the basin.

The current and projected groundwater use in the Wind/Bighorn River Basin is summarized in Table 6-15 in Chapter 6. The projections were developed for Low, Mid, and High Scenarios. The municipal and domestic groundwater projections are summarized in Table 6-8.

## 8.10 REFERENCES

Gannett Fleming, Inc. 2005. *Ray Lake Enlargement, Level II Final Report.*

Sunrise Engineers, Inc. 2004. *Cokeville Reservoir Level I Study.*

States West Water Resources Corporation. 2001. *Green River Ground Water Recharge and Alternative Storage, Level I Project.*

Kleinfelder, Inc. 2007. *Upper Green River Storage Study.*

States West Water Resources Corporation. 2001. *Green River Ground Water Recharge and Alternative Storage – Level I Project.*

Glover, K.C., Naftz, D.L., and Martin, L.J. 1998. *Geohydrology of Tertiary Rocks in the Upper Colorado River Basin, Colorado, Utah, and Wyoming, excluding the San Juan Basin.*

Martin, L.J. 1996. *Geohydrology of Tertiary Rocks in the Green River Structural Basin in Wyoming, Utah, and Colorado.*

SEH, Inc. 2006. *Crook County Reservoirs and Water Management Study – Level I.*

ESA Consultants. 2006. *Crook County Reservoir Project – Level I.*

ECI. 2002. *Wind River Export Study – Level I.*

Micheli, R. and Ostermann, T. 2003. *Wyoming Drought Plan.*

Thurow, T.S., and Taylor, C.A. 1999. *Viewpoint – The Role of Drought in Range Management.*

Jorgensen Engineering and Land Surveying. 1999. *Teton County Water Supply Master Plan, Level I.*

SEH, Inc. 2001. *Upper Wind River Storage Project – Level I Study.*

Anderson Consulting Engineers, Inc. 2003. *Popo Agie River Watershed Study – Level I Study.*

Nelson Engineering. 2005. *Crowheart Area/Dinwoody Canal System – Level I Study.*

Anderson Consulting Engineers, Inc. 2005. *Kirby Area Water Supply – Level I Study.*

SEH, Inc. 2005. *Owl Creek Master Plan.*

ECI. 2002. *Wind River Export Study – Level I.*

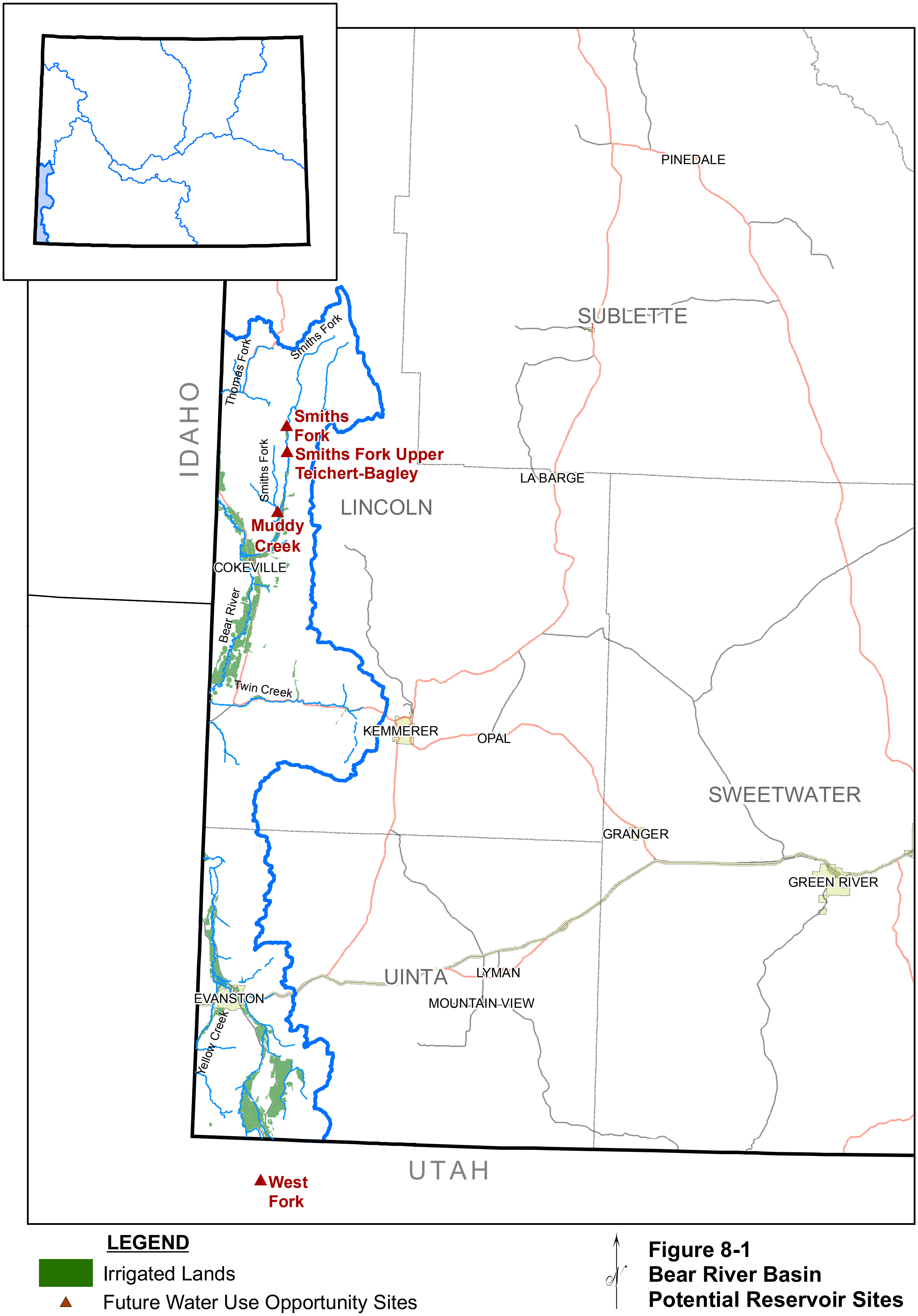



**Figure 8-1**
**Bear River Basin**
**Potential Reservoir Sites**

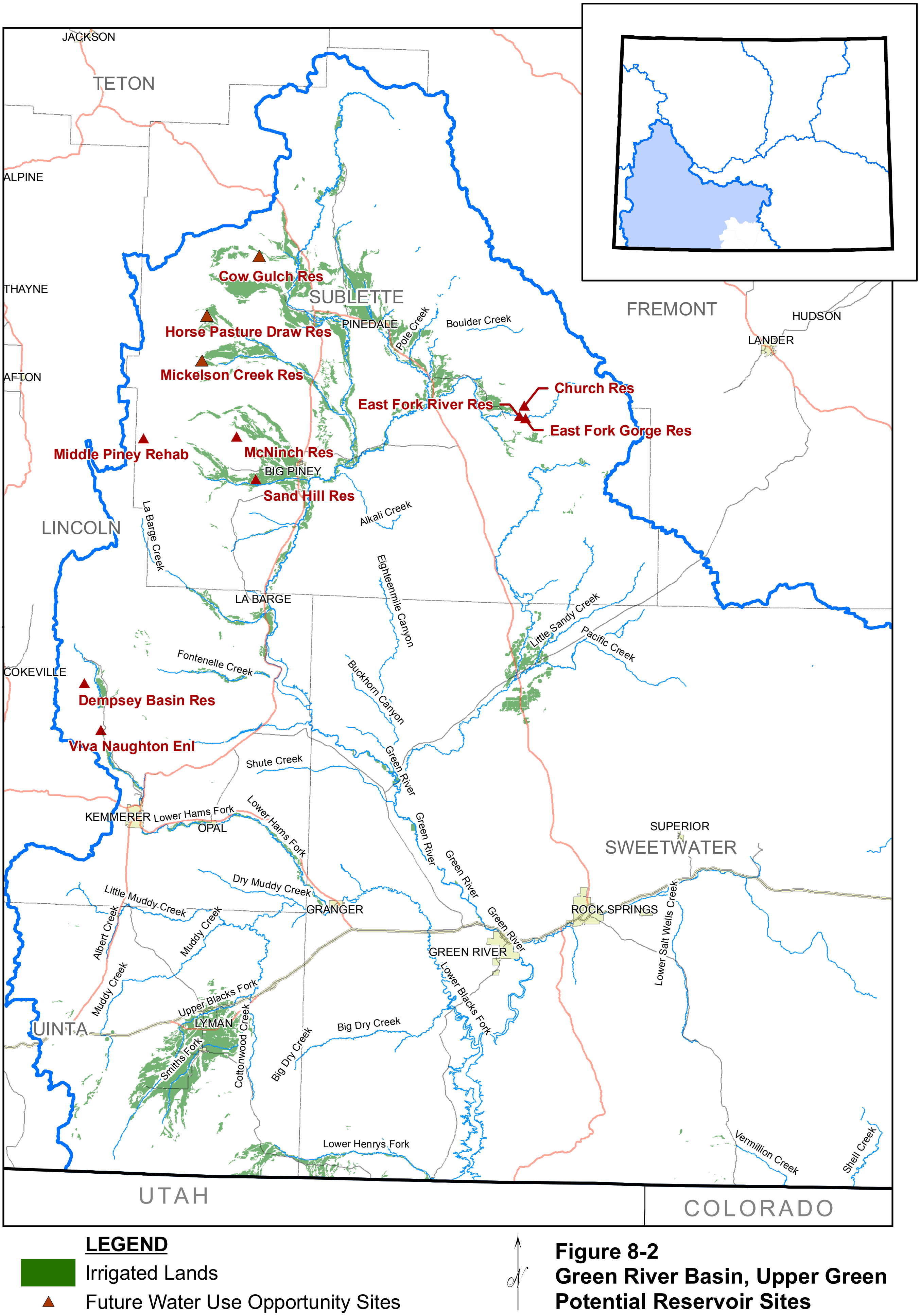



**Figure 8-2**
**Green River Basin, Upper Green Potential Reservoir Sites**

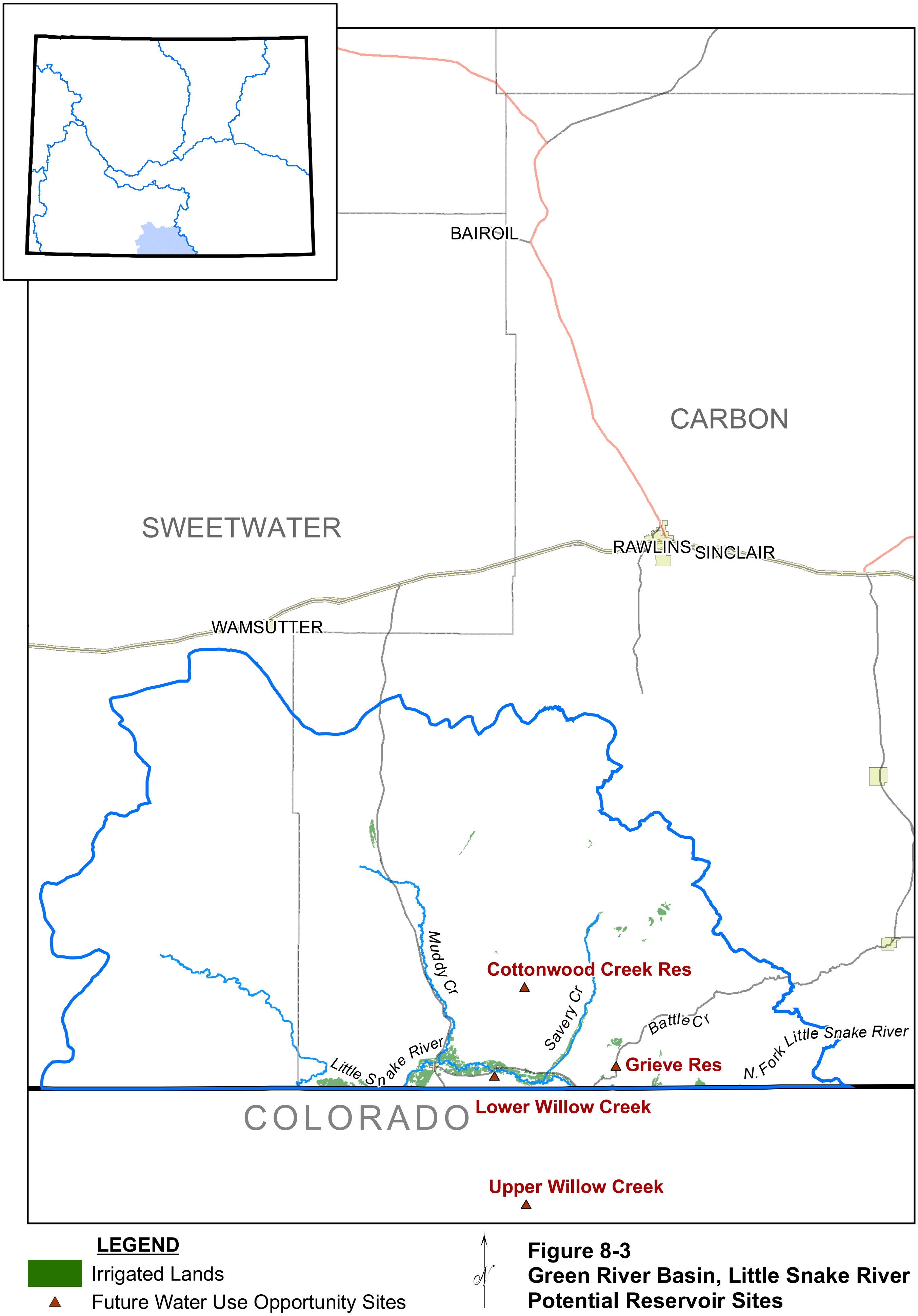
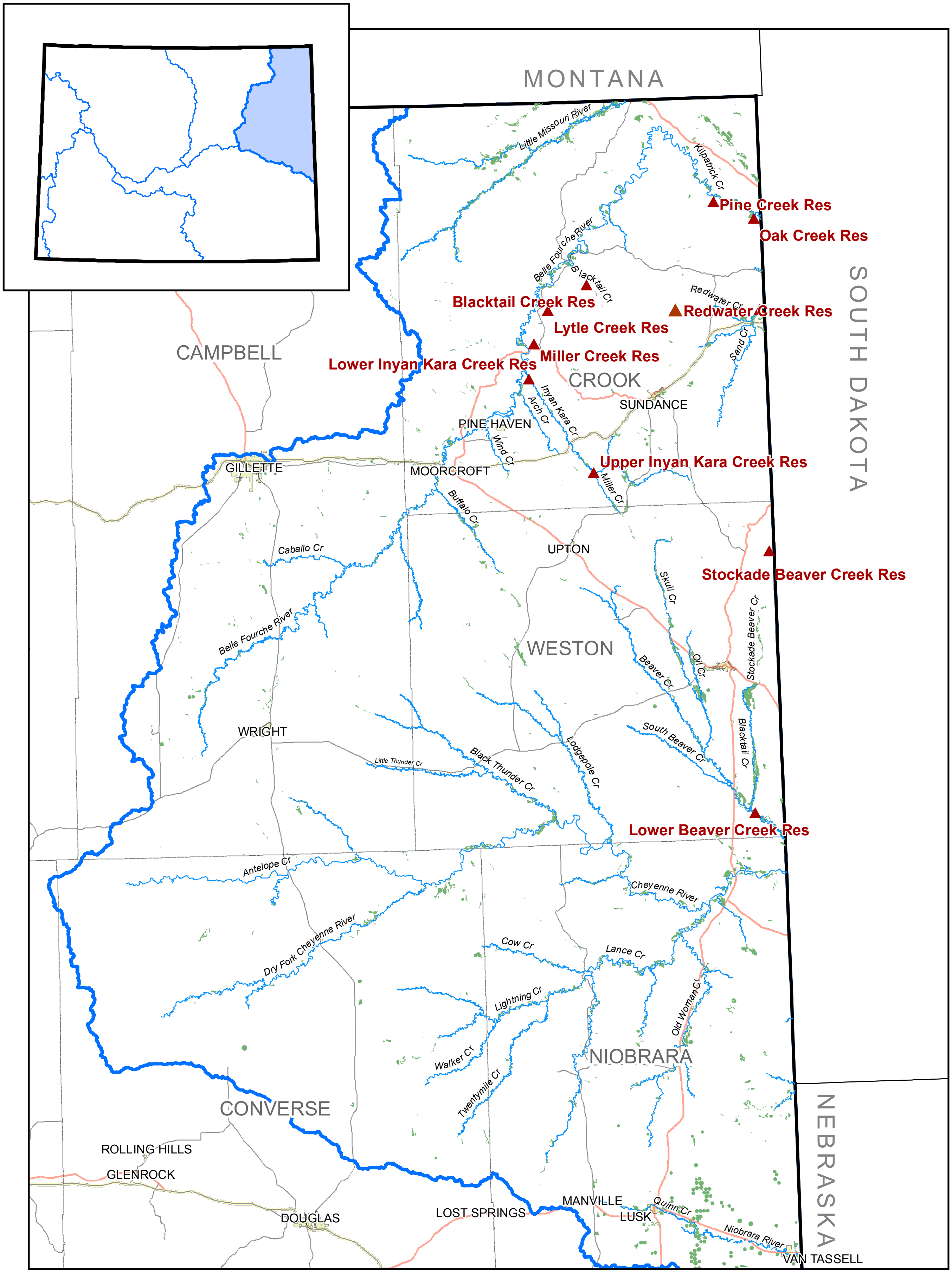



**Figure 8-3**
**Green River Basin, Little Snake River Potential Reservoir Sites**

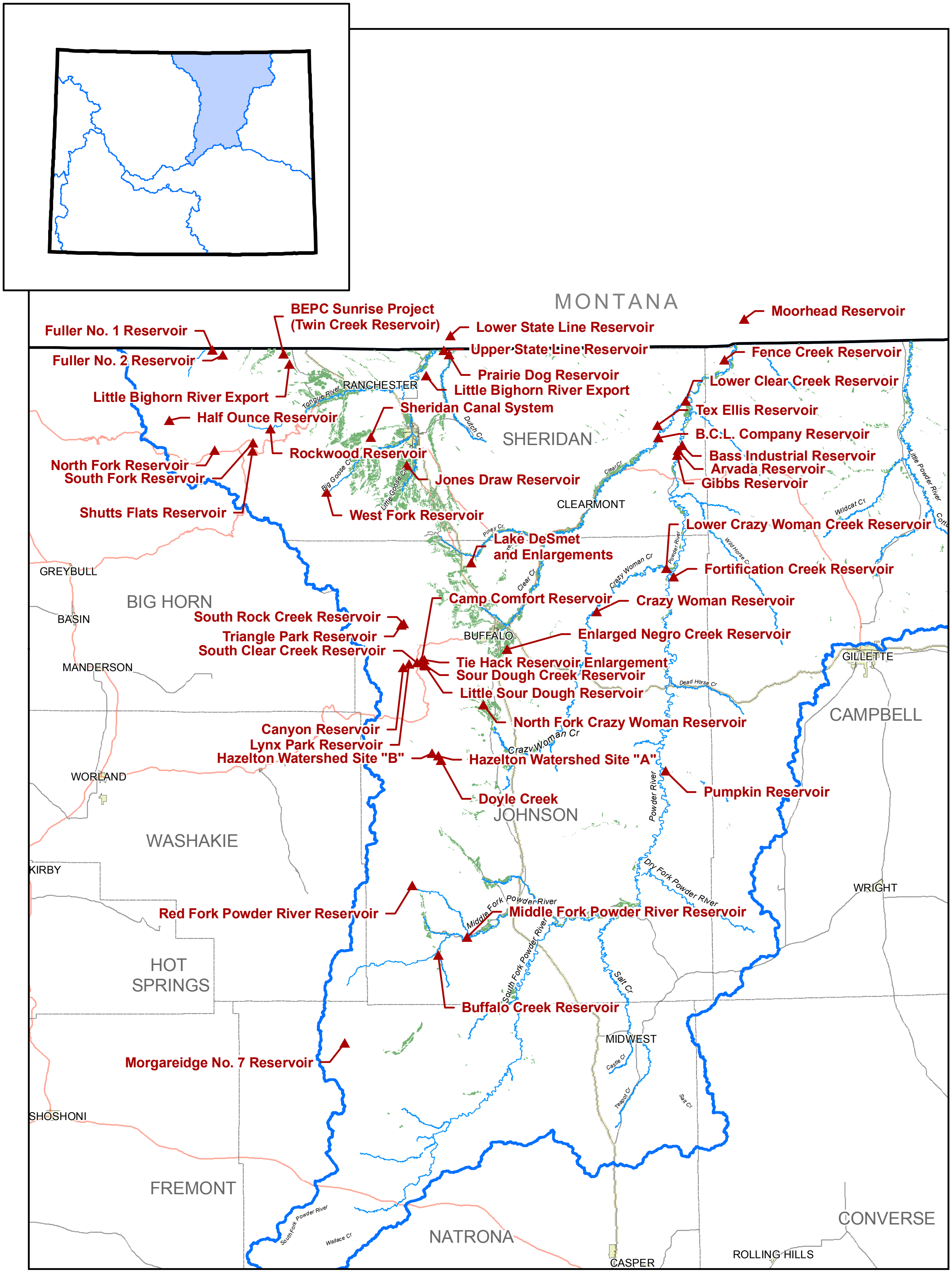



**LEGEND**

Irrigated Lands

Future Water Use Opportunity Sites

**Figure 8-4**
**Northeast River Basin**
**Potential Reservoir Sites**

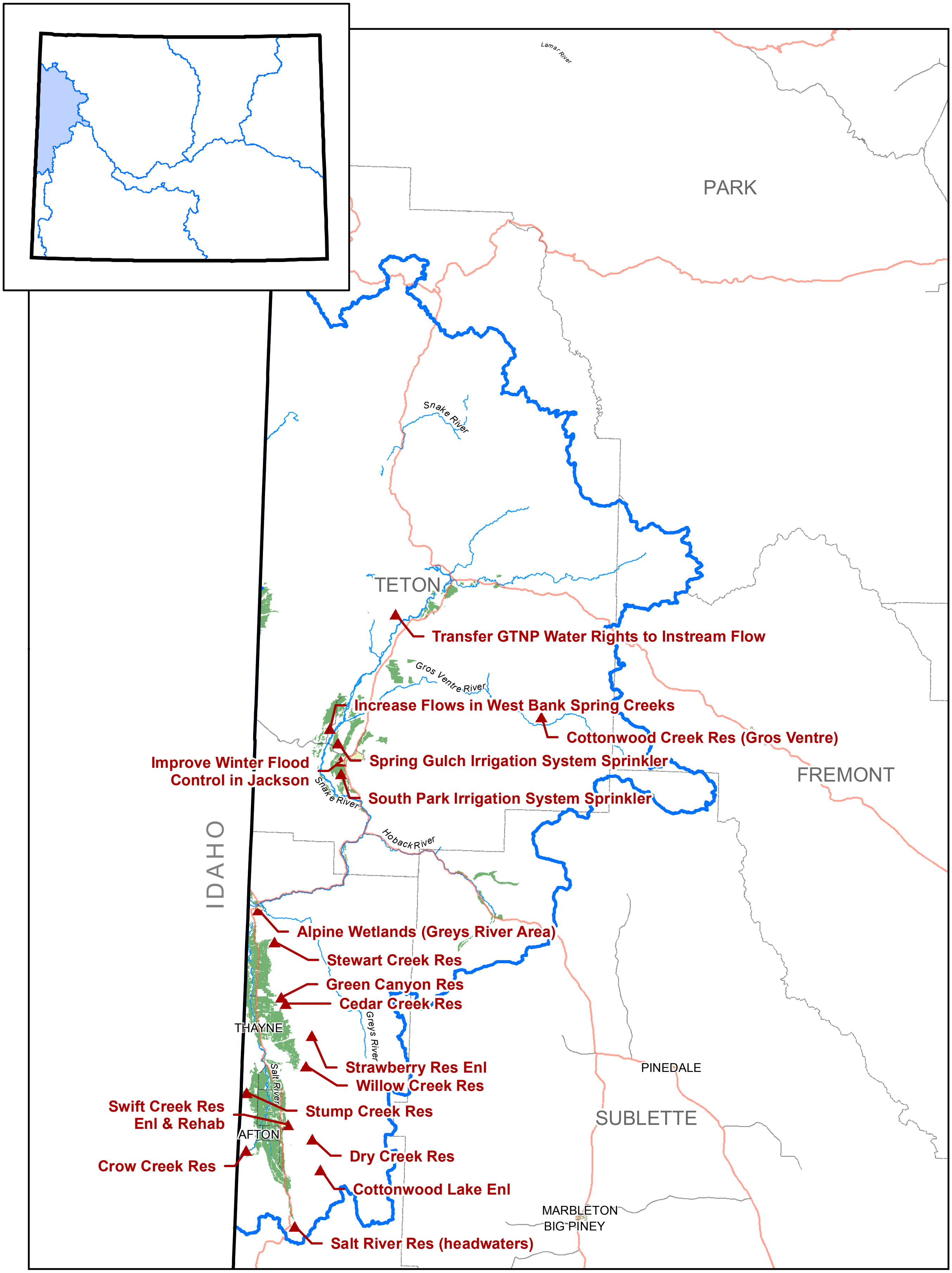



**LEGEND**

Irrigated Lands

Future Water Use Opportunity Sites

**Figure 8-5**
**Powder/Tongue River Basin**
**Potential Reservoir Sites**

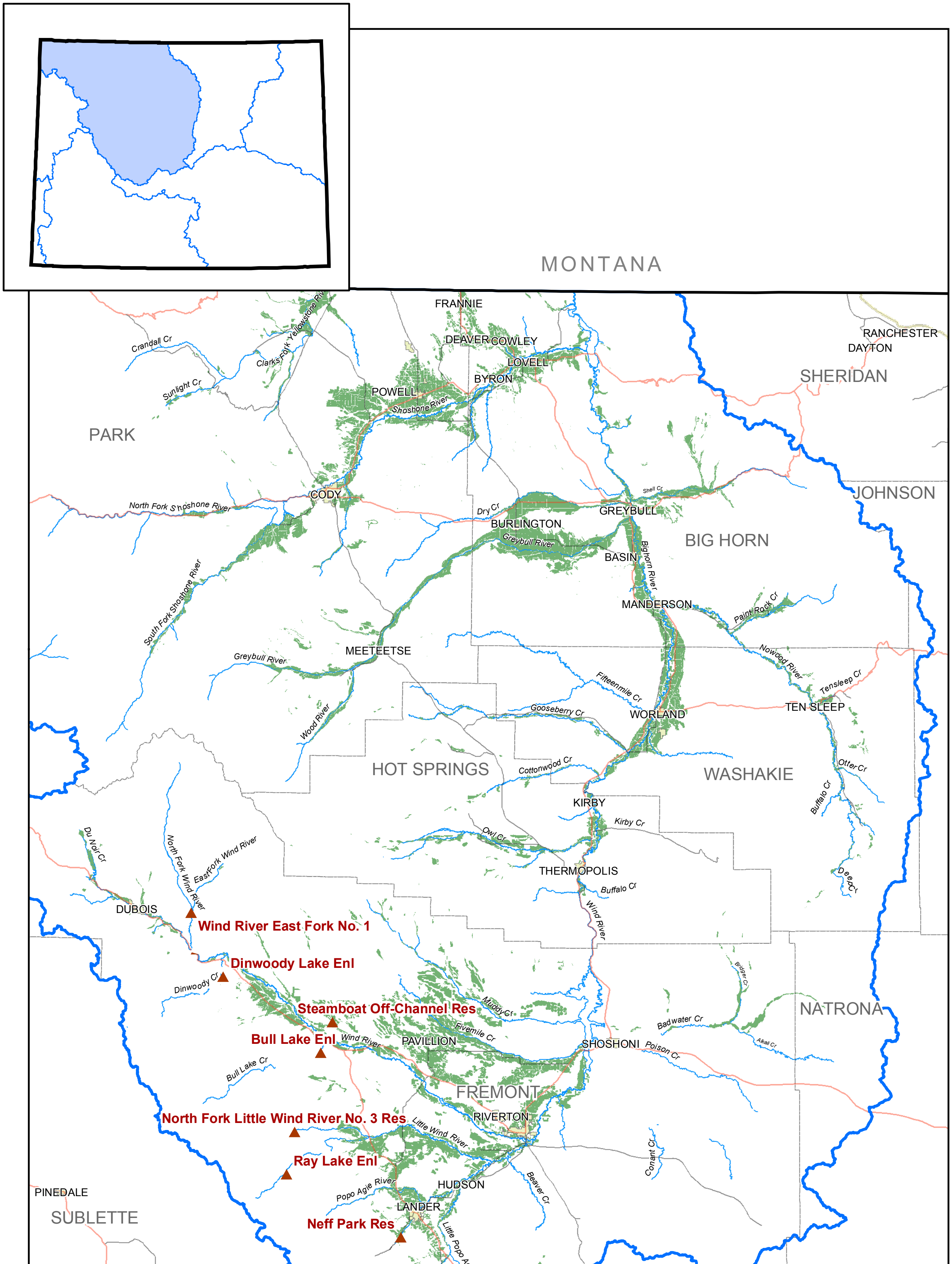



**LEGEND**

Irrigated Lands

Future Water Use Opportunity Sites

**Figure 8-6**
**Snake/Salt River Basin**
**Potential Reservoir Sites**




**LEGEND**

Irrigated Lands

Future Water Use Opportunity Sites

**Figure 8-7**
**Wind/Bighorn River Basin**
**Potential Reservoir Sites**

# 9.0 PROJECT FUNDING

## 9.1 INTRODUCTION

Previous chapters of this report quantify water resources available for development and use. The report also identifies present and future water needs in the basins and identifies future water use opportunities that could be used to satisfy the identified water demand. In Chapter 8, development costs of the identified opportunities were presented as well as annual user costs. Chapter 9 addresses various funding options that project sponsors might choose to pursue.

## 9.2 FUNDING OF WATER DEVELOPMENT PROJECTS

Water development projects are funded from federal, state, and private sources. Historically, federal funding has been responsible for the bulk of the large water development projects in the western U.S. Several examples of this are large reservoirs located in Wyoming. Many of these reservoirs were associated with large irrigation development. Federal funding for water development projects has become increasingly difficult to secure. Competition from other needs for limited federal money has been a major reason large federally financed projects have been on the decline.

However, programs exist within federal agencies for smaller and more environmental projects. These types of projects might include habitat development, wetlands, or water quality.

The State of Wyoming has the Water Development Program that is administered by the Wyoming Water Development Commission (WWDC) and is subdivided into three programs. Each program has its own financial account. Account Number 1 is the New Development Account that funds projects that develop new water or develops a new use for a developed but unused supply. Account Number 2 is the Rehabilitation Account and deals with rehabilitation and improvement of existing projects. Account Number 3 is the Storage and Reservoir Development Account. This account is used to fund new dam and reservoir development.

The State also has the State Clean Water Revolving Fund and the State Drinking Water Revolving Fund. These two funds are administered by the Wyoming Department of Environmental Quality (WDEQ), Water Quality Division (WQD). The Clean Water Revolving Fund deals with effluent and the Drinking Water Revolving Fund funds municipal systems. These two funds are not large contributors to developing new water but have resulted in significant infrastructure improvements.

The following sections explain some of the more common funding options that are available to water developers.

### 9.2.1 Federal Programs

*U.S. Department of Agriculture Rural Development Programs*

The U.S. Department of Agriculture (USDA) has its state offices in Casper. The USDA Rural Development Program administers several grant and loan programs for rural water projects, including:

- Water and waste disposal direct and guaranteed loans for water and waste disposal systems in rural areas and small towns.
- Water and waste disposal grants covering up to 75 percent of the costs of eligible rural water and waste disposal projects.

The State through the Water Development Program has partnered with USDA, Rural Development, to jointly fund development of small community water supply systems throughout the state.

Additional information regarding the USDA and its programs in Wyoming is available at http://www.rurdev.usda.gov/wy.

*Natural Resources Conservation Service*

The Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) of the USDA, administers a wide variety of programs that provide funding for water-related projects, including but not limited to the:

- Wildlife Habitat Incentives Program (WHIP) to improve wildlife and fish habitat on private lands.
- Wetlands Reserve Program to protect, restore, and enhance wetlands on private lands.
- Watershed Program to protect and restore watershed from damage caused by erosion and flooding and to conserve and develop water resources on a watershed basis.

Information regarding the NRCS and the various funding and assistance programs that the agency administers is available at http://www.nrcs.usda.gov/programs.

### 9.2.2 State Programs

*Wyoming Water Development Commission*

The WWDC, including a 10-member board and a professional staff, administers state funding of water development programs. The WWDC administers:

- New development program, which focuses on development of unused and/or unappropriated water.
- Rehabilitation program, which focuses on improving existing water systems.
- New dam and reservoir program, which focuses on developing storage reservoirs to capture excess streamflows so they can be put to beneficial use during late summer when water is short.

Water resource planning programs, of which this Framework Water Plan is a component, use funding from the new development account, the rehabilitation account, or the dam and reservoir account.

Projects begin with an application from a project sponsor. Applications are due by August 15 of each year and must include a $1,000 filing fee. The WWDC provides funding for a variety of water projects based on following prioritized categories:

- Multipurpose programs.
- Water storage projects.
- New water supply projects.
- New supply (conveyance) system projects.
- Hydropower projects.
- Purchase of existing storage projects.
- Watershed improvement projects.
- Recreation projects.
- Drinking Water State Revolving Fund projects.

The WWDC provides a detailed description of application procedures, eligibility criteria, and related information for use by entities wishing to apply for WWDC water project funding. Detailed information regarding WWDC funding of Wyoming Water Development Program projects may be found at http://wwdc.state.wy.us/opcrit.

*Wyoming Department of Environmental Quality*

Several types of funding programs are available from the WDEQ, including:

- 205j Funds, named for Section 205j of the Federal Clean Water Act, to establish water quality monitoring programs when existing water quality data are inadequate to assess local water quality conditions. Information is available at http://deq.state.wy.us/wqd/watershed.
- 319 Funds, named for Section 319 of the Federal Clean Water Act, to implement new non-point source pollution water quality improvement projects or to evaluate the effectiveness of ongoing projects. Information is available at http://deq.state.wy.us/wqd/watershed.
- State revolving funds for drinking water and clean water projects. The Drinking Water State Revolving Fund is for drinking water systems, including source, treatment plant, storage tank, and transmission and distribution line projects. The Clean Water State Revolving Fund is for sanitary sewer treatment and collection, storm water control, landfill water pollution control, and other water pollution control projects. Information regarding the funds is available at http://deq.state.wy.us/wqd/www/srf/index.asp
- Abandoned Mine Land Program's (AML) mission is to eliminate safety hazards and repair environmental damage from past mining activities, and to assist communities impacted by mining. Impact assistance can include development of public facilities. Information regarding AML's funding program is available at http://deq.state.wy.us/aml.

*State Land and Investment Board*

The State Land and Investment Board (SLIB) administers both loan and grant programs that can be used for project development and rehabilitation, including:

- Mineral Royalty Grant Program, to alleviate an emergency situation which poses a direct and immediate threat to health, safety, or welfare or to comply with federal or state mandate or to provide an essential public service.
- Joint Powers Act Loan Program, to provide loans for planning, construction, acquisition, improvement, emergency repair, acquisition of land, refinancing of existing debt, and operation of revenue generating public facilities.
- Impact Mitigation Grants and County Block Grants for Capital Projects, to provide grants for capital projects under provisions of Chapter 24 Emergency Rules and Regulations State Loan and Investment Board based on county-wide consensus lists and funding availability for the benefit of the citizens of the state. Information regarding this program is available at http://slf-web.state.wy.us/grants/revgrantupdate.aspx

In addition, the SLIB provides the financial oversight and management of the State Revolving Fund programs. These State Revolving Fund programs are jointly managed by WWDC, WDEQ, and SLIB. More information on SLIB funding programs is available at http://slf-web.state.wy.us/grants.aspx.

*Wyoming Game and Fish Department*

The Wyoming Game and Fish Department administers a trust fund to preserve and restore wildlife habitat and open spaces. The income from the trust fund is used to supply grants to nonprofit and government groups for specific projects. Information regarding the fund is available at http://gf.state.wy.us.

# GLOSSARY

| | |
|---|---|
| acre-foot | A unit of measurement for water equal to a volume of water covering a surface area of one acre to a depth of one foot (equal to about 326,000 gallons). |
| aquifer | A body of earth material saturated with groundwater that can yield usable quantities of groundwater for human uses; a zone of freely extractable groundwater in sediment or rock. |
| aquitard | A body of earth material (sediment or rock) of intrinsically low hydraulic conductivity (low permeability) which prevents significant flow of groundwater, either upward or downward; an aquitard is less permeable than an aquifer. |
| artesian condition | When the groundwater level rises above the top of the aquifer in a well (or borehole, fracture, etc.) due to the presence of a low-permeability layer of earth and/or rock above the aquifer. |
| coal bed methane use | Water produced in the production of coal bed methane gas via wells; wells used for the production of coal bed methane require a permit from the Wyoming Oil and Gas Conservation Commission. |
| community public water supply system | A U.S. Environmental Protection Agency (USEPA) designation for a public water supply system that provides water year-round for at least 15 service connections or at least 25 residents, such as the public water supply system for an incorporated municipality. |
| confined conditions or confined aquifer | Groundwater occurring in a condition such that a low-permeability zone is present above the water-bearing zone; when the overlying low-permeability zone is penetrated, the groundwater level rises to the potentiometric surface (equal pressure level) of the water-bearing zone. |
| conjunctive use | The coordinated use of surface water and groundwater resources. |

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| cubic feet per second (cfs) | The rate of water flow representing a volume of one cubic foot of water passing a given point in one second; is equivalent to flow rates of 7.48 gallons per second, 448.8 gallons per minute, or 0.02832 cubic meter per second. |
| domestic water use (residential water use) | Use of water from a single source in three single family dwellings or less, including noncommercial watering of lawns and gardens totaling one acre or less in area. |
| drainage area | The surface area around a stream as typically plotted and measured on a horizontal plane (on a map) that has a single surface water runoff and/or streamflow discharge point. |
| fully appropriated stream | A body of surface water to which the entire allocation of a state’s water rights has been distributed among existing water users. |
| geohydrology | An engineering field concerning the study of subsurface fluid hydrology. |
| groundwater | Water that flows or seeps downward and saturates soil or rock, supplying springs and wells; the upper level or surface of the saturated zone is called the water table; water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust; that part of the subsurface water which is in the zone of saturation; phreatic water; water found beneath the ground surface in porous rock strata and soils, as in a spring; generally, all subsurface water, as distinct from surface water; specifically that part of the subsurface water in the saturated zone where the water is under pressure greater than atmospheric pressure. |
| groundwater recharge | The flow to groundwater storage of precipitation, infiltration from streams, and other aboveground sources of water. |
| groundwater surface | The uppermost surface of groundwater as representative of the uppermost aquifer when under either unconfined or confined conditions and when the water level is allowed to reach a static level. |
| groundwater table | The upper boundary or surface of groundwater where water pressure is equal to atmospheric pressure, i.e., the stationary water level in a borehole. |

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| head | Differential pressure causing flow in a fluid system, usually expressed in terms of the height of a liquid column. |
| hydrogeology | The study of water and interrelated geologic materials and processes. |
| hydrology | The study of water. |
| industrial use | One type of Wyoming State Engineer's Office (SEO) "beneficial use" of water; permitted long-term use of water for the manufacture of a product or production of oil/gas or other minerals, including oil field water flood operations, power plant water supplies, etc. |
| instream bypass | Federal regulations requiring minimum streamflow rates immediately below specific water facilities located on U.S. Forest Service land. |
| instream flow | A Wyoming water right that is owned by the State and that guarantees a minimum rate(s) of flow along specified stream segments. |
| irrigation season | The months of April through September, inclusive. |
| irrigation use | One type of Wyoming State Engineer's Office (SEO) "beneficial use" of water; permitted watering of commercially grown crops, including large scale watering of golf courses, cemeteries, recreation areas, etc. |
| karst | An area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams, and caverns. |
| leaky conditions or leaky aquifer | A subsurface condition such that groundwater passes through or "leaks" through low-permeability zones adjacent to an aquifer, thus recharging groundwater in the receiving aquifer. |
| miscellaneous use | One type of Wyoming State Engineer's Office (SEO) "beneficial use" of water; any permitted use of water not defined under another SEO beneficial use definition such as stock water, pipelines, subdivisions, mine dewatering, mineral/oil exploration drilling, potable supplies, etc.; includes water use by subdivisions, mobile home parks, service stations, campgrounds, churches, schools, temporary drilling activities, etc. |

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| municipal use | One type of Wyoming State Engineer’s Office (SEO) “beneficial use” of water; permitted use of water in and by the citizens of incorporated towns and cities. |
| non-point source pollution | A contributing factor to water pollution that cannot be traced to a specific spot; man-made or man-induced alteration of the chemical, physical, biological, or radiological integrity of water, originating from any source other than a point source; pollution which comes from diffuse sources such as urban and agricultural runoff, including storm water runoff containing excess farm and lawn nutrients that move through the soil into the groundwater or enter local surface water. |
| phreatophyte | A deep-rooted plant that obtains water from a permanent groundwater supply. |
| point source pollution | Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, container, rolling stock, concentrated animal feeding operation, vessel, or other floating craft; a stationary location or fixed facility from which pollutants are discharged or emitted into groundwater or surface water. |
| public water supply system | A U.S. Environmental Protection Agency (USEPA) designation for a water supply system that provides potable water for at least 15 service connections or 25 people per day for a minimum of 60 days per year. |
| recharge | Water flow into an area, aquifer, or well, typically from a surface water source to groundwater in an aquifer. |
| recharge area | The land area(s) over which recharge of an aquifer, typically by infiltration of surface water, occurs. |
| stock watering use | One type of Wyoming State Engineer’s Office (SEO) “beneficial use” of water; permitted water appropriation including normal livestock use at up to four tanks and within one mile of the well or spring source of water supply. |
| surface water | Water on the surface of the earth; an open body of water, such as a river, stream, or lake. |

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| till | Glacial drift consisting of an unassorted mixture of clay, sand, gravel, and boulders. |
| transmissivity | The rate of groundwater flow in an aquifer in gallons per minute of flow through a one foot wide vertical section of the entire aquifer thickness under a hydraulic gradient of one foot. |
| unconfined condition | Groundwater present in an aquifer without an overlying low-permeability bed or upward water pressure. |
| waste (irrigation) | Water which is diverted from a river in a canal or ditch for irrigation use but which, because of conveyance system limitations, is not diverted from the canal or ditch to irrigate land and is discharged to a drain or stream via wasteways along the irrigation canal. |
| water level | The water surface elevation or stage of the free surface of a body of water above or below any datum or the surface of standing water in a well, usually indicative of the position of the groundwater surface (the "water table") or other potentiometric groundwater surface. |
| water table | An archaic term from the 1800s that is now superseded in modern technical use by the term "groundwater surface;" use of the term "water table" should be discontinued in technical documents. |
| water year | October 1 - September 30 (e.g., Water Year 2005 begins October 1, 2004, and ends September 30, 2005). |

# ACRONYM LIST

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|---|---|
| AF or AC-FT | Acre-feet |
| ASCE | American Society of Civil Engineers |
| ASR | Artificial aquifer Storage and Recovery |
| BAG | Basin Advisory Group |
| BCF | Billion cubic feet |
| BLM | U.S. Bureau of Land Management |
| BTU | British Thermal Unit |
| CBM | Coal bed methane |
| CBMCC | Coal Bed Methane Coordination Coalition |
| cfs | Cubic feet per second |
| CIR | Consumptive Irrigation Requirement |
| CRP | Conservation Reserve Program |
| CU | Consumptive Use |
| $CU_w$ | Consumptive use of irrigation water, usually in units of inches per acre per month |
| DOI | United States Department of the Interior |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| ET | Evapotranspiration |
| ESA | Endangered Species Act |
| FERC | Federal Energy Regulatory Commission |
| FONSI | Finding of No Significant Impact |
| ft | Feet |
| gal | Gallons |
| gpcpd | Gallons per capita per day |
| gpd | Gallons per day |
| gpm | gallons per minute |
| GUI | Graphical User Interface |
| GW | Ground water |
| IWR | Irrigation Water Requirements |
| MCF | Million cubic feet |
| MCL | Maximum contaminant level |
| MW | Megawatts |
| NASS | National Agricultural Statistics Service |
| NEPA | National Environmental Policy Act |
| NPDC | North Platte Decree Committee |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| NWI | National Wetlands Inventory |

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| OGCC | Oil and Gas Conservation Commission (State of Wyoming) |
| PAM | Polyacrylamide |
| PIA | Potential Irrigable Acres |
| PRRIP | Platte River Recovery and Implementation Program |
| PRSB | Powder River Structural Basin |
| SCS | Spill Conservation Service |
| SEO | Wyoming State Engineer's Office |
| SLIP | State Land and Investment Board |
| SMP | State Management Plan (State of Wyoming) |
| SW | Surface water |
| SWWRC | States West Water Resources Corporation |
| TDS | Total dissolved solids (in units of milligrams per liter, mg/L) |
| TMDL | Total minimum daily load (of pollutants in a water body) |
| USBR | U.S. Bureau of Reclamation |
| USCB | U.S. Census Bureau |
| USCOE | U.S. Army Corps of Engineers |
| USDA | U.S. Department of Agriculture |
| USEPA | U.S. Environmental Protection Agency |
| USFS | U.S. Forest Service |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| WBHB | Wind/Big Horn River Basin |
| WDAI | Wyoming Department of Administration and Information |
| WDEQ | Wyoming Department of Environmental Quality |
| WGF | Wyoming Game and Fish Department |
| WHIP | Wildlife Habitat and Incentives Program |
| WQD | Wyoming Dept. of Environmental Quality, Water Quality Division |
| WRDS | Water Resource Data System |
| WRIR | Wind River Indian Reservation |
| WRP | Wetlands Reserve Program |

# INDEX