

Chapter 3

Description of the study area

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The WBRB drainage basin covers approximately 25 percent of the state in north-central and northwestern Wyoming, plus smaller areas of south-central Montana. **Figure 3-1** is an index map of the approximately 678 townships within the WBRB in Wyoming (625) and Montana (53). As determined from the GIS database developed for this study, the WBRB covers approximately 22,883 square miles (14.65 million acres) in Wyoming and 894 square miles (0.57 million acres) in Montana. The WBRB encompasses federal, state, and privately owned land in all or part of eight Wyoming counties:

- All of Big Horn, Park, and Hot Springs counties
- Approximately 95 percent of Washakie County
- Approximately 85 percent of Fremont County
- Approximately 10 percent of Teton County
- Small, relatively undeveloped parts of northwestern Natrona and western Johnson counties

Approximately 80 percent of Yellowstone National Park (in Park and Teton counties) is included in the drainage basin, as is the Wind River Indian Reservation (Fremont and Hot Springs counties). The northern WBRB (Bighorn Basin) includes small areas of Park, Sweet Grass, Carbon, and Big Horn Counties in south-central Montana.

The current population of the Wyoming WBRB is estimated to be 89,500 (MWH, 2010). The WBRB has a substantial rural population.

3.1 Physiography, landforms, topography, and surface drainage

In their surface-water report, MWH et al. (2010a, draft p. 13) describe the physiography of the WBRB as follows:

“The basin is generally characterized by broad, rolling high plains with sparse vegetation surrounded by high mountains. The Wind River Range, Owl Creek Mountains, Absaroka Range and the Bighorn Basin are within the Middle Rocky Mountain major physiographic province, while the Wind River Basin is generally within the Wyoming major physiographic province, as defined by the WSGS. The Wind River Basin and the Bighorn Basin also form their own minor physiographic provinces within the major provinces.”

– MWH, 2010a

The WBRB is bounded by topographic or surface-water divides – and by the Wyoming state line in the northwestern corner of the state and along part of the northern border. The ten segments of the WBRB boundary enumerated below are shown in **Figure 3-2** and can be followed on those USGS 1: 500,000-scale maps of Wyoming and Montana that show

streams and elevation. Clockwise from the Pryor Mountains in Montana, the boundary runs:

1. Northward then southeastward along a Pryor mountain ridgeline bordering drainage into Wyoming, to the Wyoming/Montana state line;
2. Thence eastward along the Wyoming/Montana state line and along a divide in the Bighorn Mountains;
3. Thence generally south-southeastward along the arcuate ridge of the Bighorn Mountains to T39N, R87W;
4. Thence generally south-southwestward along a divide on the Casper Arch from T39N, R87W to the northwestern tip of the Rattlesnake Hills, T34N, R89W;
5. Thence a short distance southeastward along the ridgeline of the Rattlesnake Hills into T33N, R88W;
6. Thence irregularly west-southwestward along the Beaver Divide (Beaver Rim) – an irregular drainage divide on the Casper arch north and west of the Granite Mountains – to T30N, R101W, where it meets the Continental Divide;
7. Thence following the Continental Divide northwestward along the ridge of the Wind River Range, past the western end of the Washakie Range, along the southwestern edge of the Absaroka Range, and along a divide on the Yellowstone Plateau to the Wyoming/Idaho/Montana state line intersection;
8. Thence along the state line northward then eastward around the northwestern corner of Wyoming;
9. Thence arcing into Montana along a divide bordering drainage into Wyoming in part of the Absaroka Range and continuing generally east-southeastward along a ridge line in the Beartooth Mountains to the Wyoming state line;
10. Thence eastward along the state line between the eastern edge of the Beartooth Mountains drainage and the western edge of the Pryor Mountain drainage into Wyoming, where the Bighorn structural basin opens north-northwestward into Montana.

In this memorandum, the WBRB comprises four, three, or two areas, according to context. In the context of geography and surface geology the WBRB comprises the four areas shown on **Figure 3-2**: the Wind River Basin, the Bighorn Basin, the Absaroka Range, and the Yellowstone Plateau. In the context of subsurface geology, Bighorn-basin pre-volcanic stratigraphy extends westward beneath the Absaroka Range volcanics, as shown on **Plate VI**, sections A-B' and B-B'. The sub-volcanic structure may be seen as a highly faulted and folded extension of the Bighorn basin on the basis of similar stratigraphy or as a separate basin, the Absaroka Basin of Sundell (1993), separated from the Bighorn Basin by the Cody Arch, on the basis of structure. Under either interpretation, the western and southwestern borders of the Absaroka Basin or extended Bighorn Basin is probably the Washakie Range.

In the context of hydrogeology, the Wind River Basin and Bighorn River Basin, having a far higher density of data than the Absaroka and Yellowstone areas, are the two areas of interest;

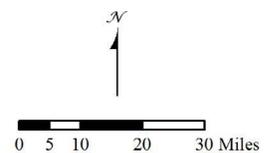


Explanation

- City or town
- Hydrologic divide between the Wind and Bighorn river basins
- Structural divide between the Wind and Bighorn basins
- ▭ WBRB boundary
- ▭ State boundary
- ▭ County boundary
- ▭ Township
- ▭ Wind River Indian Reservation boundary
- ▭ Yellowstone National Park boundary
- Ⓜ U.S. highway
- Ⓢ State highway

Data Sources:

Bureau of Land Management	Spatial Data and Visualization Center
Esri	U.S. Census Bureau
Montana Department of Administration	U.S. Forest Service
Premier Data Services	Wyoming State Geological Survey
Spatial Analysis Center	



WSGS 2011
 Projection: NAD 1983
 UTM Zone 12N

Figure 3-1. Geographic index map, Wind/Bighorn River Basin.



Explanation

(See figure 3-1 for explanation of additional symbols)

- Hydrologic divide between the Wind and Bighorn river basins
- ~ River
- ~ Lake
- | 6 | Boundary segment described in Section 3.1



WSGS 2011

Projection: NAD 1983
UTM Zone 12N

Data Source:

USGS National Hydrography Dataset



Figure 3-2. Major structural/physiographic features, drainages, and bodies of water, Wind/Bighorn River Basin (WBRB). Numbered segments (in red) of the WBRB boundary correspond to boundary description in Section 3.1.

and the Bighorn River Basin may include the eastern drainage of the Absarokas and sub-volcanic units beneath. In detailed hydrogeologic descriptions the Wind River Basin, Bighorn Basin, and Absaroka/Yellowstone areas are treated separately (Chapter 7).

The topography of the WBRB is defined by two intermontane basins surrounded and separated by mountain ranges, and the Yellowstone Plateau. Surface elevations within the WBRB drainage basin range from roughly 3,500 feet above sea level where the Bighorn River crosses the Wyoming/Montana state line in the Bighorn Basin to 13,804 feet at the summit of Gannett Peak in the Wind River Range. Within the basin interiors, elevations range from 4,000 to 6,000 feet. The Yellowstone Plateau in the northwestern corner of the WBRB is elevated relative to the basins, with elevations ranging from 7,731 feet at Yellowstone Lake to 12,244 feet at Trout Peak.

The WBRB drainage basin is a headwater of the Missouri River drainage system. Principal rivers include the Wind/Bighorn, Nowood, Greybull, Shoshone, Clark's Fork (Yellowstone), Yellowstone, Madison, and Gallatin and their tributaries (**Figure 3-2**). The distal divides of these drainage systems define the limits of the WBRB study area. The Wind River structural basin – the basinal area bordered by uplifts – is drained by the Wind River and its tributaries. The Wind River leaves the Wind River Basin flowing northward through the Wind River Canyon, and becomes the Bighorn River at Wedding of the Waters just into the Bighorn Basin. Most of the Bighorn Basin and the eastern slope of the Absaroka Range is drained by the Bighorn River and its tributaries; a northern part of the eastern slope of the Absarokas and a contiguous southern part of the Beartooth Mountains are drained by the Clarks Fork Yellowstone River. The Bighorn River and Clarks Fork leave the Bighorn Basin flowing northward across the Wyoming/Montana state line. Much of the Yellowstone Plateau within the WBRB and the western slope of the Absarokas is drained by the Yellowstone River; small areas in the northwestern corner of the state are drained by the Madison River and Gardiner River. The Yellowstone and Gardiner Rivers leave the state flowing northward – the Madison flowing westward – across the Wyoming/Montana state line.

3.2 Climate, precipitation, and vegetation

The climate within the WBRB is primarily a function of altitude – to a lesser degree latitude and topography – and ranges from semi-arid continental within the basin interiors to humid-alpine in the bordering mountain ranges. The mountain ranges surrounding the basins tend to catch much of the atmospheric moisture flow through precipitation caused by orographic uplift, substantially decreasing precipitation in the basin interiors. Temperature varies by season from well below zero degrees Fahrenheit in the winter to more than

100 degrees in the summer. Most precipitation within the WBRB occurs during winter as snowfall and during spring and summer as thunderstorms (Libra et al., 1981). Average annual precipitation ranges from 6 to 10 inches in the basin interiors, 11 to 20 inches along the elevated foothills of the basins, 21 to 45 inches in the mountain ranges, and up to 70 inches along the mountain peaks above approximately 10,000 feet elevation (**Figure 3-3**). Average annual precipitation within Yellowstone National Park ranges from 13 to 70 inches (**Figure 3-3**; Cox, 1976). For an updated map of mean annual precipitation within the WBRB (1971-2008) see MWH et al., 2010, **Figure 6**.

Vegetation in the WBRB is influenced by elevation, soil, exposure, and precipitation. In the lowland basin areas, mixed-grassland and sagebrush steppe vegetation dominates, with grasses, sagebrush, saltbush, greasewood, and desert shrub; and with cottonwood and Russian olive trees along drainages. Some of the lowland areas, especially along perennial streams, have been converted to cropland. Higher-altitude desert vegetation along the uplifts and foothills adjacent to the surrounding mountains includes a greater abundance of grasses, sagebrush, saltbush, greasewood, and desert shrub, along with woodland species that include cottonwood, willow, boxelder, juniper, and limber pine. Alpine forest and alpine tundra are characteristic of the higher mountain regions; vegetation includes a variety of grasses, sagebrush, lodgepole pine, ponderosa pine, spruce, fir, and aspen. Above timberline (approximately 10,000 feet), tundra supports alpine grasses (Peterson, Mora, et al., 1987).

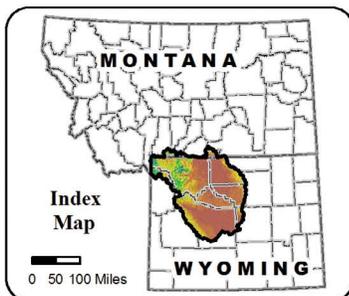
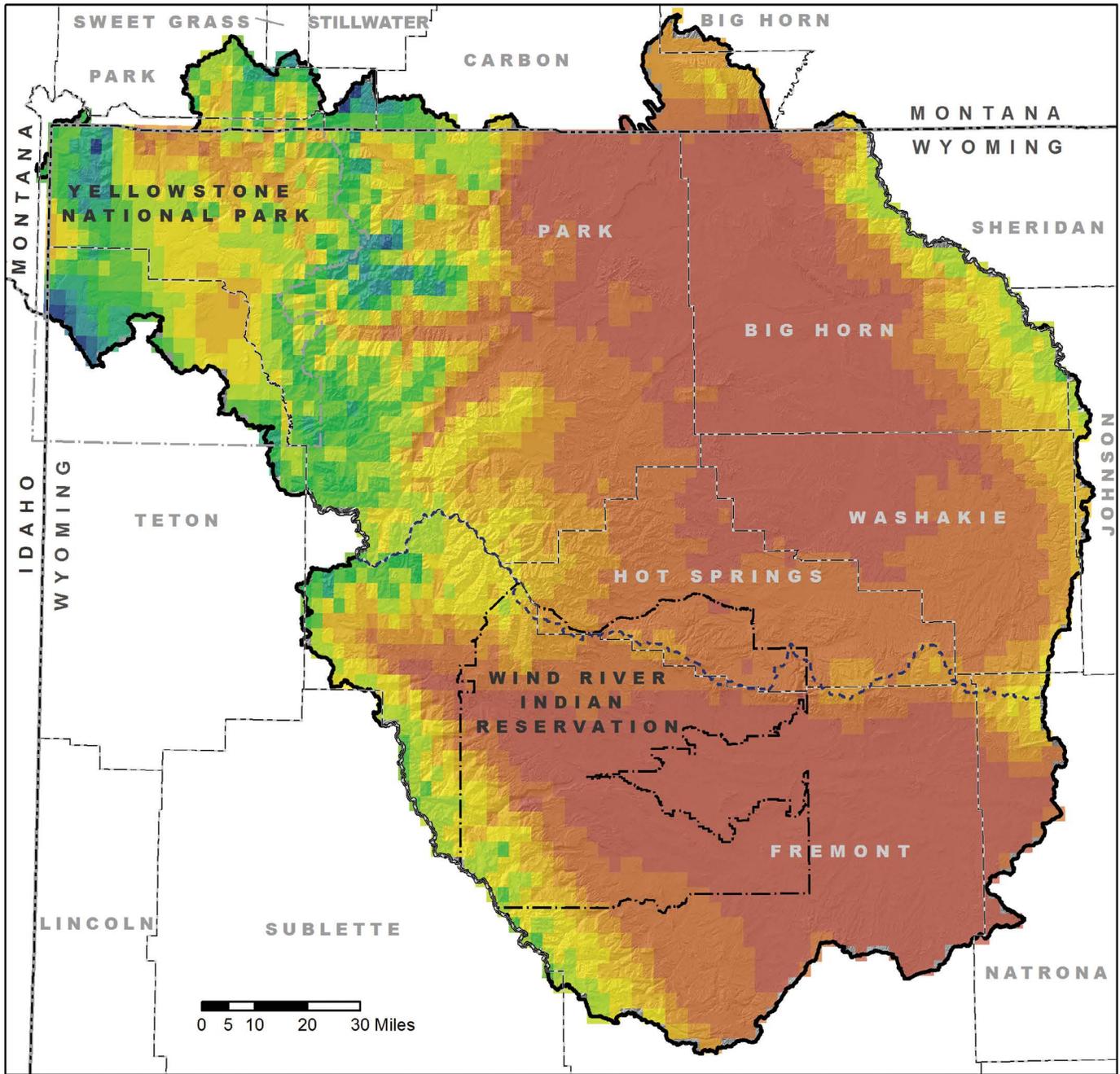
3.3 Setting – Wind River Basin

This section describes the setting of the Wind River Basin, as derived primarily from Richter, 1981 and Libra et al., 1981.

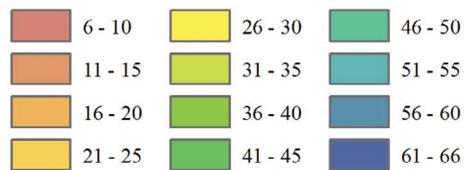
3.3.1 Physiography and topography

The Wind River Basin as defined for this memorandum (**Figure 3-2**) covers an area of approximately 7,900 square miles; it is approximately 150 miles east-west and approximately 100 miles north-south. The structural basin is bordered on the southwest by the Wind River Range, on the northwest by the Absaroka Range and Washakie Range, on the north by the Owl Creek and Bridger Mountains, on the east by the Casper Arch and Rattlesnake Hills, and on the southeast by the Beaver Divide (Beaver Rim) section of the Casper Arch. Drainage from the basin is to the north where the Wind River transects the Owl Creek Mountains (**Figure 3-2**).

The topography within the interior of the basin is characterized by gently rolling plains broken by broad river valleys, narrow terraces, and badlands. Elevations within the basin interior range from 5,400 to 6,000 feet above sea level. The lowest elevation within the Wind River Basin is 4,336 feet, at the base of Boysen Dam where the Wind River enters Wind River Canyon. The bounding mountain ranges rise steeply on the



**Average Annual Precipitation
1961 - 1990
(inches)**



WSGS 2011

Projection: NAD 1983
UTM Zone 12N

Data Source:

PRISM Group at Oregon State University

(See Figure 3-1 for explanation of additional symbols)

Figure 3-3. Average annual precipitation (1961 – 1990), Wind/Bighorn River Basin.

western and northwestern sides of the basin and more gradually on the eastern and southern sides. Elevations in the mountains commonly exceed 10,000 feet, reaching a maximum of 13,804 feet at Gannet Peak in the Wind River Range. Total topographic relief in the Wind River Basin is approximately 9,500 feet.

3.3.2 Surface drainage

Major drainages in the Wind River Basin headwater in the Wind River Range. Most flow in perennial streams is from snowmelt in the mountains. Rejected recharge from Mesozoic through Precambrian aquifers in the Wind River Range and irrigation return flows from Quaternary and Tertiary aquifers add to perennial flows. Ephemeral streams in the central basin flow only in response to thunderstorms and do not contribute significantly to overall stream flow. The Wind River, which drains the Wind River Basin, flows southeastward from the westernmost border of the basin to near Riverton, where it swings northwestward and then northward to drain the basin through Wind River Canyon. The Wind River continues northward in the Bighorn Basin to Wedding of the Waters, where it becomes the Bighorn River. Major streams and their tributaries within the Wind River Basin are listed in **Table 3-1**; several are shown in **Figure 3-2**, and all are shown on **Plate I and IV**.

3.3.3 Population distribution, land use, and land ownership

Every large community within the Wind River Basin is located within a few miles of a major stream or river. Riverton, Dubois, and Shoshoni were developed along the Wind River, and Lander was developed near the Popo Agie River. Only a few settlements have been located where there is no nearby supply of surface water; these settlements generally are associated with mineral development.

Land use in the Wind River basin is controlled primarily by the distribution of surface waters, precipitation, and the location of mineral resources. In the high mountain areas, above timberline, the alpine lands are generally used only for recreational purposes. At lower elevations, thickly forested areas are utilized for recreation and limited logging. Grazing is the dominant use on grasslands along the mountain fronts and riparian areas. Approximately 55 percent of the land within the basin is utilized for agriculture. Approximately 6 percent of the basin is irrigated cropland, and 85 percent of the cropland is on the Wind River Indian Reservation. Croplands are located primarily along the major streams where irrigation with surface water is possible. Most of the basin lowlands are covered sparsely with sagebrush and are used for grazing. The locations of active and historic mineral development properties are shown on **Figures 5-3, 5-7, 5-8, and 5-9** (and see Section 5.7.2 on potential groundwater contaminant sources).

Table 3-1. Wind River Basin surface drainage divisions by tributary rank and downstream order.

Wind River
Du Noir Creek ¹
Horse Creek ¹
Wiggins Fork ¹
Dinwoody Creek
Crow Creek ¹
Bull Lake Creek
Little Wind River
Sage Creek
North Fork
South Fork
Popo Agie River
North Popo Agie River
Little Popo Agie River
Beaver Creek
Muskrat Creek ²
Fivemile Creek ³
Poison Creek ²
Badwater Creek ²
Muddy Creek ⁴

¹Flows south from the Absarokas

²Flows west

³Flows southeast from the Owl Creeks

⁴Flows east, fed from the Owl Creeks

Table 3-2. Bighorn Basin surface drainage divisions by tributary rank and downstream order.

Yellowstone River	
Clarks Fork Yellowstone River	
	Sunlight Creek
	Pat O'Hara Creek
	Big Sand Coulee
Bighorn River	
	Owl Creek
	Kirby Creek
	Cottonwood Creek
	Gooseberry Creek
	Nowater Creek
	Fifteen Mile Creek
	Nowood River
	Tensleep Creek
	Paint Rock Creek
	Greybull River
	Wood River
	Dry Creek
	Shell Creek
	Shoshone River
	North Fork
	South Fork

Industrial, residential, and recreational areas occupy nearly all nonagricultural land.

Approximately 47 percent of the land area of the Wind River Basin is federally owned; it is controlled by the U.S. Bureau of Land Management within the basin lowlands and by the U.S. Forest Service in the forested/mountainous areas. The Wind River Indian Reservation occupies 34 percent – 68 percent of the reservation area is owned and managed by the Eastern Shoshone and Arapaho Tribes, and 32 percent is under jurisdiction of the U.S. Bureau of Reclamation. Approximately 15 percent of the land in the basin is privately owned – it is concentrated along rivers and streams; 4 percent is owned by the State of Wyoming; and less than 1 percent is owned by other entities.

3.4 Setting – Bighorn Basin

This section describes the setting of the Bighorn Basin, as derived primarily from Libra et al., 1981.

3.4.1 Physiography and topography

The Bighorn Basin as defined for this memorandum (Figure 3-2) covers an area of approximately 12,500 square

miles, measuring approximately 140 miles east-west and approximately 100 miles north-south to the Montana state line – and continues northward about 22 miles into Montana. The basin is bordered on the northeast by the Pryor Mountains, on the east by the Bighorn Mountains, on the south by the Owl Creek and Bridger mountains, and on the northwest by the Beartooth Mountains. To the west, the structural basin is covered by the volcanic Absaroka Range and extends westward onto the Yellowstone Plateau. The basin is open northward into Montana.

The topography of the basin interior is characterized by rolling plains broken by broad river valleys, narrow terraces, and badlands. Elevations in the plains range from 4,000 to 5,600 feet above sea level. The lowest elevation within the Bighorn Basin is approximately 3,500 feet, where the Bighorn River crosses the Wyoming/Montana state line. The bounding mountain ranges rise steeply on the eastern, western, and northwestern sides of the basin and more gradually on the southern side. Elevations in the mountains commonly exceed 10,000 feet, reaching a maximum of 13,175 feet at Cloud Peak in the Bighorn Mountains. Total topographic relief in the Bighorn Basin is approximately 9,700 feet.

3.4.2 Surface drainage

Most flow in perennial streams is from snowmelt in the mountains. Rejected recharge from Mesozoic through Precambrian aquifers in the surrounding mountains and irrigation return flows from Quaternary and Tertiary aquifers add to perennial flows. Ephemeral streams in the central basin flow only in response to thunderstorms; they do not contribute significantly to overall stream flow. The Wind/Bighorn River is the primary drainage for the WBRB drainage basin. The river cuts the Wind River Canyon through the Owl Creek Mountains, which separates the two structural basins. The name changes from Wind River to Bighorn River a few miles south of Thermopolis at the mouth of Wind River Canyon, a location called “Wedding of the Waters.” The Bighorn River, which drains most of the structural BHB, flows northward from Wedding of the Waters and into Montana. The Clarks Fork Yellowstone River drains a small north-central area of the basin, and the Yellowstone River drains much of the Yellowstone Plateau; both rivers flow northward into Montana. Major streams and tributaries in the Bighorn Basin are listed in **Table 3.2**, and some are shown in **Figure 3-2**.

3.4.3 Population distribution, land use, and land ownership

Every large community within the Bighorn basin is located within a few miles of a major stream or river. Worland, Thermopolis, Basin, and Greybull were developed along the Bighorn River, and Cody, Powell, and Lovell were developed near the Shoshone River. Only a few settlements have been located where there is no nearby supply of surface water; these

settlements generally are associated with mineral development.

Land use in the Bighorn Basin is controlled primarily by the distribution of surface waters, precipitation, and the location of mineral resources. In the high mountain areas, above timberline, the alpine lands are generally used only for recreation. At lower elevations, thickly forested areas are utilized for recreation and limited logging. Grazing is the dominant use on grasslands along the mountain fronts and riparian areas. Croplands are located primarily along the major streams where irrigation with surface water is possible. Most of the basin lowlands are covered sparsely with sagebrush and are used moderately for grazing. The locations of active and historic mineral development properties are shown on **Figures 5-3, 5-7, 5-8, and 5-9** (and see Section 5.7.2 on potential groundwater contaminant sources). Industrial, residential, and recreational areas occupy nearly all the nonagricultural land.

Approximately three-quarters (75.2 percent) of the of the land in the Bighorn basin is federally owned; it is controlled by the U.S. Bureau of Land Management (33 percent), the U.S. Forest Service (22.8 percent), the National Park Service (16.6 percent), and the Bureau of Indian Affairs, Bureau of Reclamation, and Department of Defense (together ~ 2.8 percent). Approximately 4.3 percent of the land in the basin is owned by the State of Wyoming, and approximately 20 percent is privately owned. The privately owned property is concentrated along rivers and streams.

