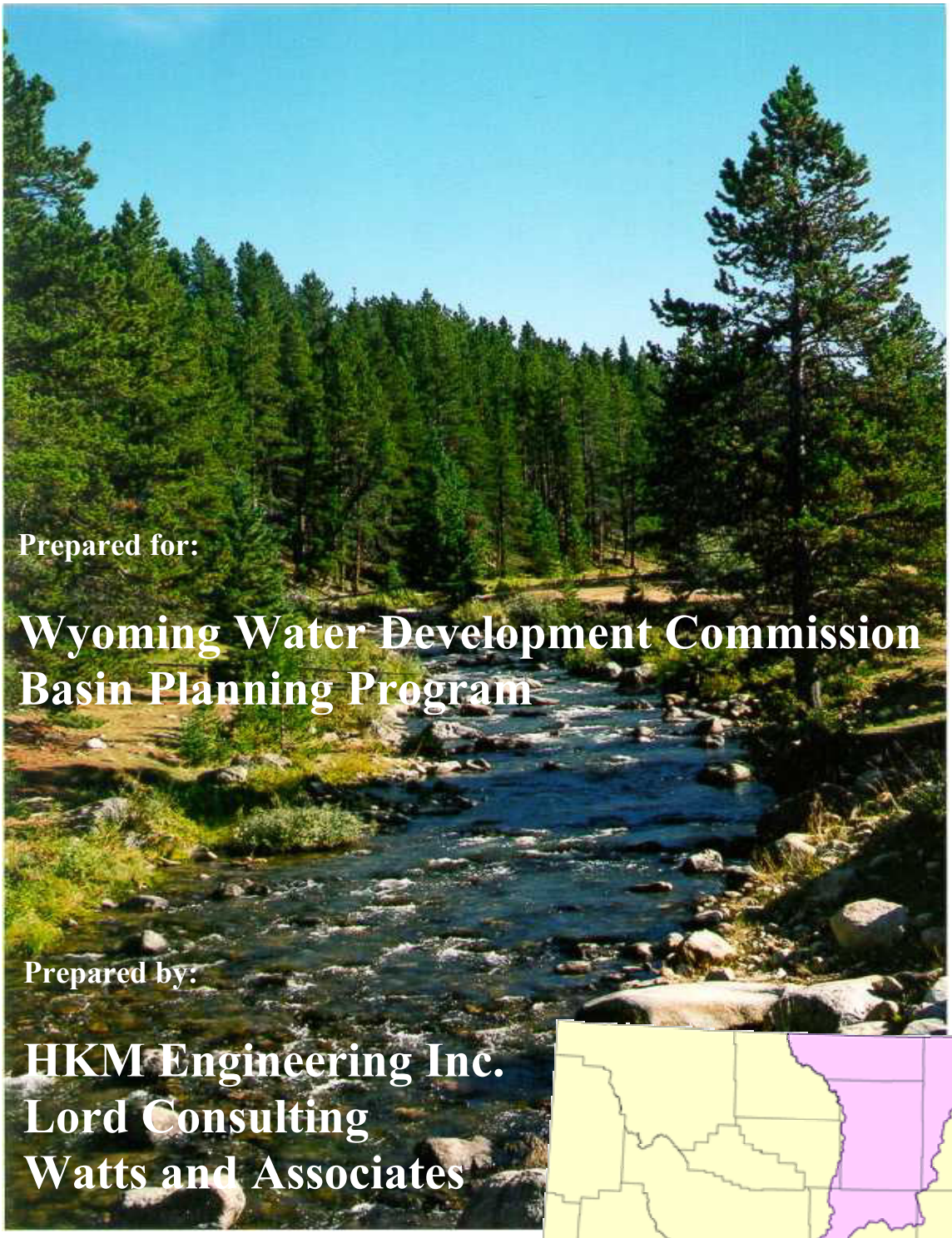
Powder/Tongue River Basin Plan
Final Report

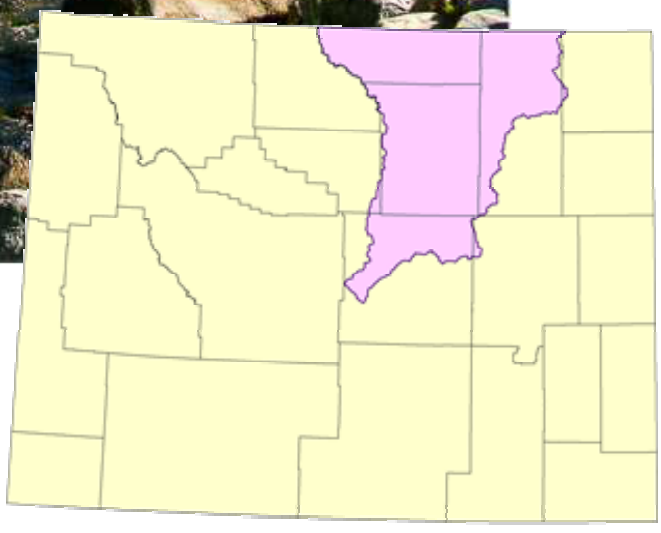


Prepared for:

Wyoming Water Development Commission
Basin Planning Program

Prepared by:

HKM Engineering Inc.
Lord Consulting
Watts and Associates



February 2002

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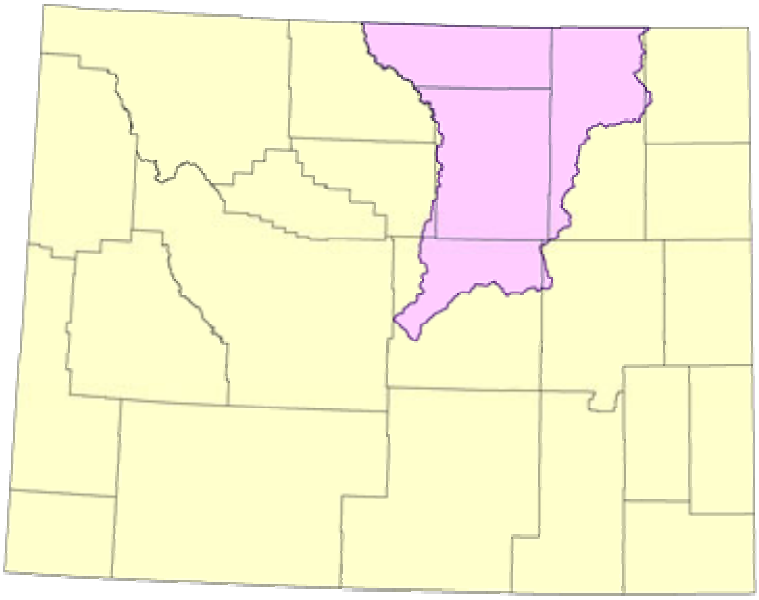

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I Introduction

A. Introduction

The Powder/Tongue River Basin Plan was authorized by the Wyoming Legislature in 2000. The objectives of this plan are to:

- determine the current level of water consumption for agriculture, municipal, domestic, industrial, environmental and recreational uses;
- quantify available surface water and ground water supplies;
- project water demands over the 30-year planning horizon; and,
- identify future water use opportunities and constraints for satisfying existing shortages and future demands.

The primary products of this planning study are technical memoranda prepared for the large number of topics addressed in the plan. These memoranda provide detailed descriptions of the data collected, analyses performed, tools developed, and the results of each investigation required to fully explore the water resources within the planning area.

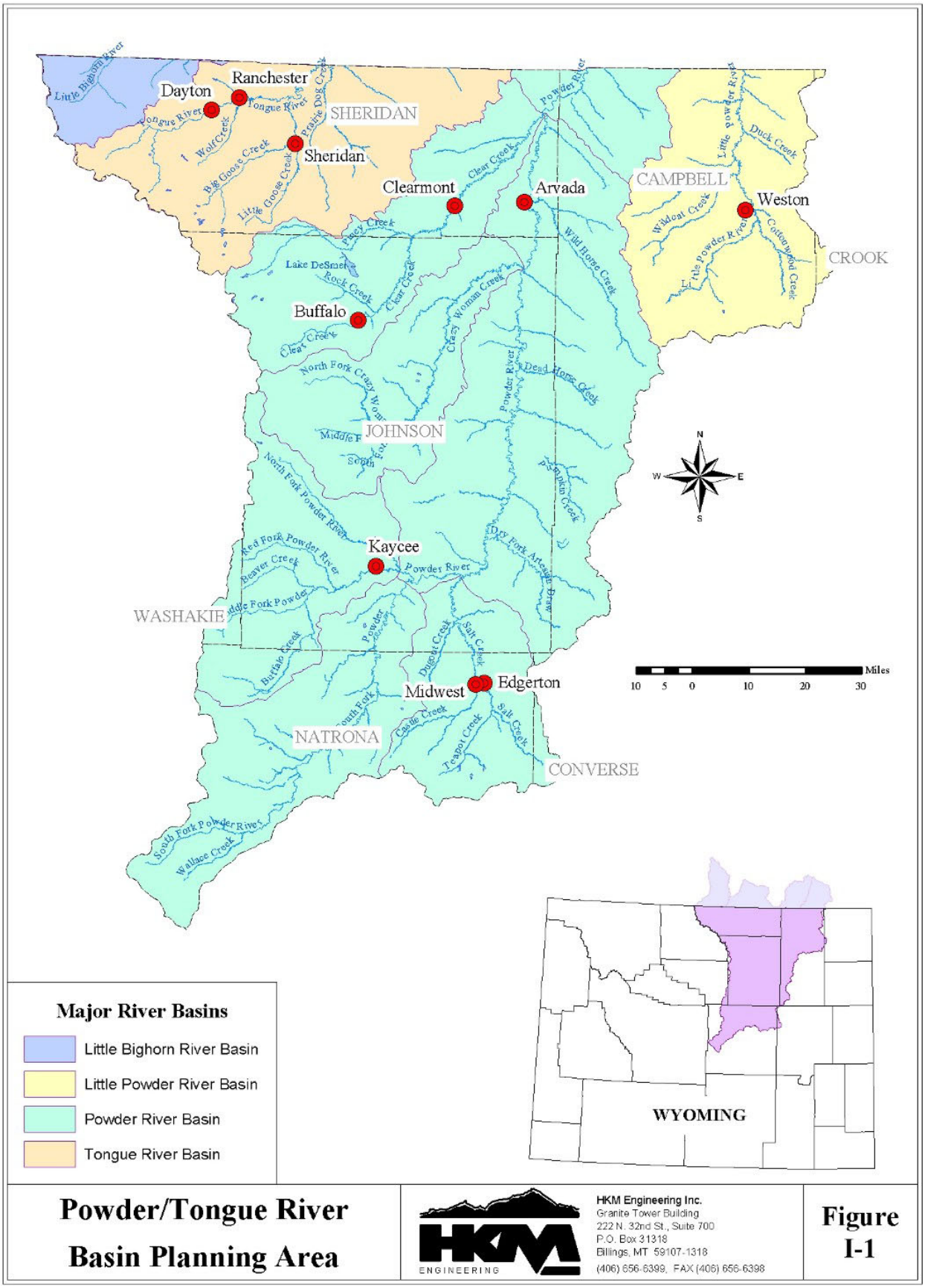
The intent of this summary report is to describe the planning study in sufficient detail for the reader to gain a general understanding of the investigations that were performed and the results of those investigations. For detailed information on a specific topic the reader is directed to the technical memorandum prepared for that topic. References used in preparing the technical memoranda are not repeated in this summary report. These references are presented in the individual technical memoranda.

B. Description

Location

The planning area of the Powder/Tongue River Basin Plan includes the drainages of the Little Bighorn River, Tongue River, Powder River, and Little Powder River. These river basins encompass all or part of Sheridan, Johnson, Campbell, Natrona, and Converse counties in north central Wyoming.

The planning area is bounded on the north by the Wyoming-Montana stateline, and on the west by the Bighorn Mountains. The east and south boundaries are the limits of the Powder and Little Powder River drainages. The planning area is presented in Figure I-1.



Powder/Tongue River Basin Planning Area

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Figure I-1

Topography

The Little Bighorn, Tongue, and Powder Rivers flow generally east out of the Bighorn Mountains and north into Montana where they join the Yellowstone River. The Little Powder River flows north and joins the Powder River in Montana.

The Bighorn Mountains, which generally crest between 8,000 feet and 10,000 feet, give way abruptly to a relatively narrow band of foothills standing about 2,000 feet above the plains. The remainder of the planning area consists primarily of hilly to rugged uplands, wide valleys, and badlands. The lowest elevations of the planning area are the locations where each of the rivers cross the stateline, the lowest elevation being about 3,320 feet where the Little Powder River flows into Montana.

Climate

Annual precipitation across the planning area ranges from a low of approximately 10 inches along the South Fork of the Powder River to a high of in excess of 30 inches in the Bighorn Mountains. Average total annual precipitation between 13 and 15 inches appear to be the norm throughout the majority of the planning area. Figure I-2 describes precipitation characteristics of the planning area.

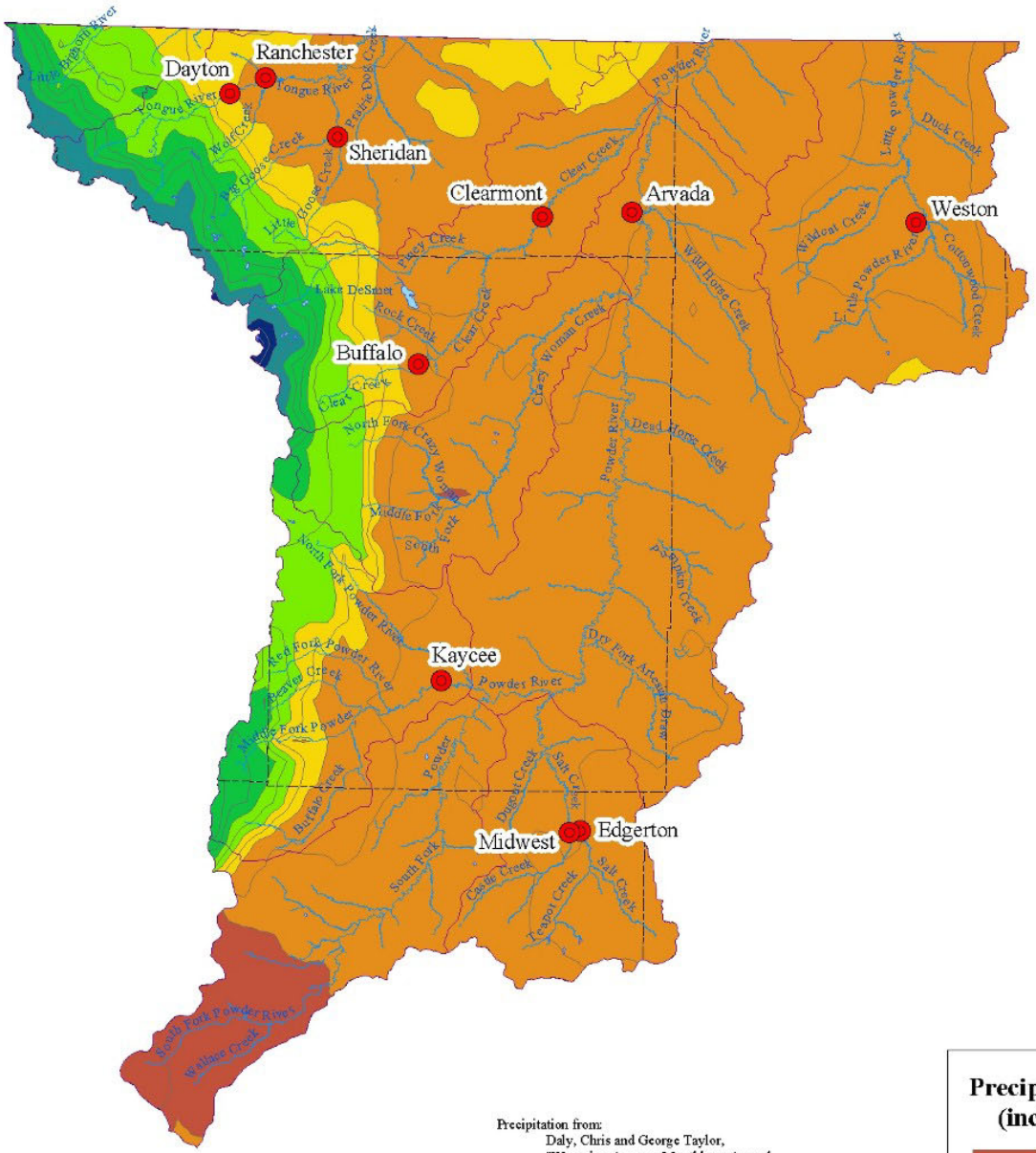
Water Features

Significant water features in the Little Bighorn River Basin include the Little Bighorn River, Elkhorn Creek, Red Canyon Creek, and East Pass Creek. There are no significant reservoirs in the Little Bighorn River drainage.

The major rivers and streams in the Tongue River Basin include the Tongue River, Goose Creek, Big Goose Creek, Little Goose Creek and Prairie Dog Creek. Principal tributaries of these streams include:

- Tongue River – Little Tongue River and Wolf Creek
- Goose Creek – Soldier Creek
- Big Goose Creek – Beaver Creek and Rapid Creek

Significant storage facilities developed in the Tongue River Basin include Twin Lakes, Big Goose Park Reservoir, Bighorn Reservoir, and Dome Lake.



Average Annual Precipitation

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Figure I-2

The major streams of the Powder River Basin include the Powder River, Little Powder River, Clear Creek, and Crazy Woman Creek. Principal tributaries of these streams include:

- Powder River – Salt Creek, South Fork Powder River, North Fork Powder River, Red Fork Powder River, Beaver Creek, Middle Fork Powder River, and Buffalo Creek
- Clear Creek – Piney Creek, Little Piney Creek, North Piney Creek, South Piney Creek, Shell Creek, Rock Creek, Johnson Creek and French Creek
- Crazy Woman Creek – Middle Fork Crazy Woman Creek, Billy Creek, Muddy Creek, North Fork Crazy Woman Creek, Little North Fork Crazy Woman Creek, and Kelly Creek

Significant storage facilities developed in the Powder River Basin include Lake DeSmet, Kearney Lake, Willow Park Reservoir, Cloud Peak Reservoir, and Tie Hack Reservoir, all in the Clear Creek watershed, and Wallows Creek in the drainage of Crazy Woman Creek, Dull Knife Reservoir on the North Fork of the Powder, and Lower Salt Reservoir on Salt Creek.

C. Water-Related History of the Basin

The following excerpt from *Water-Right Problems of the Bighorn Mountains* written in 1899 by Elwood Mead provides a synopsis of water development in the 19th Century. Dr. Mead served as Wyoming's first Territorial Engineer, and, following statehood in 1890, served as the State Engineer until 1899.

The Bighorn Range is the most impressive feature in the landscape of northern Wyoming, and its scenic beauties are made the more attractive by the striking contrast they afford to the surrounding region. The traveler from the East or the South finds the clear, cold, perennial streams which flow from its snow-clad summits a grateful relief from the alkaline pools or dry sand channels which have to be largely relied on when journeying toward them. The lofty and rugged pinnacles of Cloud Peak are made all the more commanding because the bad-land hills, which form the summit of the Cheyenne watershed, are so commonplace and unattractive. West of the range is the Bighorn Basin, the lowest and most arid section of the State, where the dusty roads and gray stretches of sagebrush make a traveler look with longing at the snow-crowned, forest-clad slopes of -the mountain barrier to the east.

In the arid States mountains, not plains, control agricultural development, and this isolated barrier, which rises near the middle of the northern boundary and extends southeast nearly to the center of the State, has done more to people the northern half of Wyoming than all other influences combined. Without it the section, now gridironed with ditches and supporting about one-fourth the population of the State, would be an open range supporting a few migratory flocks of sheep and herds of cattle. The latent wealth of the few hundred square miles of rocky, barren, and almost unoccupied land surface, over 8,000 feet above sea level, is far greater than that of any equal area in the valley below. This region gathers and stores the moisture which alone gives value to the land below. The perennial streams thereby created have, in their diversion and use, given employment to more people, attracted the investment of more capital, and created

more problems to tax the wisdom of the lawmakers than has all the unimproved unirrigated farming land in the State.

The ease and cheapness with which the streams can be diverted, the fertility of the soil, and the exceptional value of the surrounding grazing land have made this section an attractive location for the home seeker of limited means. It is a region of small ditches and individual appropriators of water. On the eastern slope appropriation began before there were any laws governing the recording or establishment of rights thereto, while the isolation of the early settlers made them disregard or give little heed to water-right problems until the needs of users began to exceed the available supply; since then the multitude of rights, resulting from the haphazard location of ditches, has made a satisfactory settlement of many of these problems unusually difficult. Before discussing these problems a brief review will be given of the progress made in the twenty years which have elapsed since Manlius Redmond, a settler on Clear Creek, built the first ditch and became the pioneer farmer of the northern half of the State.

At that time the nearest railway station in the State was Rock Creek, on the Union Pacific, nearly 300 miles away. There was not a flour mill in the State, and the long, hazardous, and expensive trip necessary to secure the plow which turned the first furrow and the food for the men who worked on it added greatly to its cost. Reclaiming the desert under such conditions had many drawbacks, and the earlier ditches were of the crudest and simplest character. There was no attempt at any comprehensive projects. Each irrigator was a law to himself. Cooperative ditches or canals were rare exceptions. This explains the large number of ditches of record, and is the cause of many of the obstacles to the satisfactory division of water which confront those charged with this duty.

The records of the State engineer's office show that there are 1,051 adjudicated rights to the water flowing out of these mountains. There are also 269 claims which have been recorded and approved, but not adjudicated. In addition there are probably 100 ditches using water for which no claim has been filed. The adjudicated rights describe 139,478 acres of land to which these rights are attached in the orders of the board of control establishing them, and there are appropriations from Crazy Woman Creek aggregating 925.25 second- feet where the land irrigated is not described. Four flour mills have rights to water for power purposes aggregating 324.50 second-feet, and the several cities and towns of this region have adjudicated rights for power and domestic purposes amounting altogether to 80.6 second-feet.

Along the northern end of the range some promising placer fields have been discovered, and rights to 137.6 second-feet have been acquired with which to work them. The total volume of the adjudicated rights (3,455.4 second-feet) is in excess of the low-water discharge of the streams against which they are held, but is below the maximum discharge, so that the securing of a stable and adequate water supply for many of the irrigators holding adjudicated rights is a question of storage. While all of the rights for irrigation, established by the board of control, are based on State surveys of the ditches and on sworn statements of the acreage irrigated by the appropriators, there is no question that these statements are somewhat in excess of the truth. Irrigation and reclamation are elastic terms. Spreading water over land to increase the growth of grass for pasturage purposes is irrigation and is so held by the board of control, but it is not

the complete reclamation that is accomplished by cultivation. The tendency to augment the acreage actually watered is so common as to lead to the belief that it is unconscious. In the absence of exaggeration so gross as to constitute an injustice to other users, such a claim usually passes without protest unless it includes land which the State engineer's surveys show to be not susceptible of irrigation. The total acreage irrigated is, therefore, below the figures before given. A deduction of 10 per cent for exaggerated acreages and for areas which have only a surplus or flood-water supply would not be excessive, and would leave 126,000 acres as the actual area irrigated under rights established by the board of control. This is more than half the acreage given as irrigated in the entire State by the Tenth Census.

It is impossible to speak with equal certainty regarding the acreage irrigated under appropriations approved by the State engineer's office, but which have not yet been established by order of the board of control. In making a summary of these rights from the records of the engineer's office, all canceled permits, or those which have not complied with the requirements of the State law, have been excluded. This disposes of all the speculative filings which were made prior to 1894, during the time that no fee was required for the examination and record of applications to appropriate water. Since that time the stringent regulations governing the preparation of these filings have made applications so expensive that the tendency to make these for speculative purposes has almost disappeared. While the applications for permits recently approved do not represent actual utilization, they do represent projects based on reliable surveys, which are being carried out by people who are in earnest and who have sufficient investment in the work to make its completion probable. This is more nearly true of the appropriation of water from the streams of this region than of any other section of the State, as there are no large projects. These recorded and approved permits describe 214,000 acres of land for which irrigation appropriations are claimed, and 34 rights to water for power and domestic purposes.

After the turn of the century water development was pursued more to enhance and expand existing uses rather that to develop new sources of supply for new uses. Nearly all of the storage that has been developed in the planning area has been constructed in the 20th Century. Regarding storage development, Elwood Mead offers the following discussion in his 1899 paper:

By drawing on the larger streams when the smaller ones were exhausted it has been possible to utilize a large percentage of the flow from the east side of the range without resorting to storage, but the time is approaching when storage will be necessary if the reclaimed area is to be extended. Storage has been somewhat delayed, because there is no law at present defining and protecting rights to stored water. This is one of the legislative questions to be dealt with in the near future. Much can be done whenever it becomes necessary. The sites for mountain reservoirs are both numerous and valuable. From the summit of Cloud Peak over 100 mountain lakes can be counted, and a large percentage of these will in time be utilized.

Actual construction has begun on only one of these reservoir sites – Dome Lake. … The elevation of the lake is 8,720 feet, as determined by the topographers of the United States Geological Survey during the season of 1897. The area of the water surface is 320 acres, the average depth 20 feet and the total flow of water 6,400 acre-feet. The estimated cost of the

reservoir is $50,000. The improvements have been made with the double object of storing water for irrigation and of making this point an attractive summer resort.

The most notable storage development in the planning area has been Lake DeSmet. Beginning as a small natural lake situated between Piney Creek and Clear Creek, a number of construction projects have increased both the storage capacity of the lake and the ability to deliver water to the reservoir. The expansion projects were initiated by the Reynolds Mining Corporation and were completed by Texaco, Inc. after all interests in the facilities were acquired by Texaco, Inc. In 2001, all interests excepting a small storage allocation, which was retained by Texaco, where transferred to Sheridan, Johnson, and Campbell counties and are currently being managed by the Lake DeSmet Joint Powers Board.

D. Wyoming Water Law

The Wyoming constitution establishes water in the state to be the property of the state. Consequently, all development and management of water resources in Wyoming is governed by the water laws embodied in the Constitution and Statutes. These water laws are recognized as inviolate in the river basin planning program.

The use of water is administered by the State Engineer and the State Board of Control which consists of the State Engineer and the Superintendent of each of the four water divisions of the state. Water is administered under the prior appropriations doctrine that dictates the water right with a senior or earlier priority date is entitled to receive its full amount before water rights with later, or junior, priority dates receive any of their allocation. The priority date of a water right is established as the date the water right application is filed with the State Engineer. Before water is available for use by a new project all water rights with priority dates senior to the priority of the proposed project need to be satisfied.

E. Interstate Compacts

Another significant event in the water history of the basins is the negotiation, adoption, and ratification of the Yellowstone River Compact of 1950 which controls the development and use of water from the Tongue River, Powder River, and Little Powder River. This compact divides the water of the tributaries of the Yellowstone River between the States of Wyoming and Montana under the following rules:

- existing rights as of January 1, 1950 maintain their status quo;
- existing and future domestic and stock water uses including stock water reservoirs up to a capacity of twenty acre-feet are exempted from the provisions of the compact; and,
- devices and facilities for the control and regulation of surface water are exempted from the provisions of the compact.

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% to Wyoming, 60% to Montana
- Powder River and Little Powder River: 42% to Wyoming, 58% to Montana

The Compact defines the location on each tributary where the divertible flow is measured. For the Tongue River this location is at the mouth near Miles City, Montana. For the Powder River this location is at the mouth near Locate, Montana.

Article X of the Compact stipulates that no water shall be diverted out of the Yellowstone River Basin without the unanimous consent of the three signatory states, Wyoming, Montana, and North Dakota.

The Yellowstone River Compact Commission was established by Article III. The Commission meets annually and is comprised of a representative of each of the states of Montana and Wyoming, and a federal representative appointed by the Director of the United States Geological Survey. The primary function of the Commission is to develop and maintain a network of stream gages to collect data required to administer the provisions of the Compact. To date there has been no interstate regulation. However, an unresolved issue before the Commission is how diversions in Wyoming and Montana would be regulated if there were ever a need for administration. This issue arises from the fact the official gaging locations established by the Compact to effect a regulation are located at the downstream end of the basins. These downstream locations can't be used to forecast water supply conditions that would trigger the need for regulation.

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II Basin Water Use Profile

A. Overview

This chapter describes and quantifies the current water uses in the Powder/Tongue River Basin planning area. The quantification of current water consumption is used to evaluate the overall use of water in the Basin relative to Compact allotments, for comparing existing water use to existing water supplies, and as a basis for projecting future water demands by the various uses.

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to reports, maps, and personal communications are provided in the Technical Memoranda prepared for each category of water use. The reader is referred to the following technical memoranda for a more detailed description of each topic as well as the list of references:

- Irrigation Diversion and Operation Description
- Storage Operation and Description
- Irrigated Lands Mapping and Water Rights Data
- Irrigated Crops
- Agricultural Water Use
- Municipal Water Use
- Domestic Water Use
- Industrial Water Use
- Recreational Water Uses
- Environmental Water Uses

B. Agricultural Water Use

Introduction

Irrigated agriculture in the planning area is primarily associated with forage production for the livestock industry. Ranchers depend on irrigated cropland to provide winter feed and summer grazing for a successful ranching enterprise. Early in Wyoming's history, ranchers had discovered that successful farming required irrigation. By the 1890's, many ranchers were taking advantage of cheap irrigation of bottomlands along the small tributary streams, but most of the water from the large rivers was being carried unused into other states. As the direct flow supply of the streams became fully appropriated, reservoirs were constructed, where suitable sites could be found, to store spring runoff for late-season irrigation uses. One of the earliest of these was Cloud Peak Reservoir. This reservoir began as a natural lake on the main stem of South Piney Creek. An earthen embankment and an outlet works were constructed to increase the storage regulation potential of this site. Today there are 14 significant storage facilities in the

Powder/Tongue River Basin planning area, allowing for expanded irrigation use of the natural flows in the planning area

According to the 1972 Framework Water Plan, well over 80 percent of the water consumed by man's activities in the Northeastern corner of Wyoming is used for irrigation. An accurate estimate of current agricultural water use is, therefore central to a comprehensive water use inventory. Estimates of water use by agriculture can generally be divided into the following three components:

1. Quantity of irrigated lands
2. Types of crops grown
3. Amount of water consumed for irrigation

Irrigated Lands

A 1:24,000 scale Geographic Information System (GIS) data theme was developed to represent the spatial extent and character of irrigated lands throughout the planning area. The most current (1994 to 1996) stereo aerial photography was used as the primary basis for mapping the irrigated lands. In addition to the 1994/1996 stereo aerial photography, 1983 Color Infrared (CIR) aerial photography, and 1979 black-and-white aerial photography available for portions of the planning area were utilized to verify the limits of irrigation. The Tabulation of Adjudication Surface Water Rights of the State of Wyoming, ditch plat maps, and irrigation wells data obtained from the State Engineer's Office were utilized to further double-check areas of prospective irrigation. Following the office mapping process, field verification of the mapping results was performed and the mapping was provided to the SEO Division 2 field personnel for further verification. All man induced irrigation or subirrigation was delineated and irrigated lands were divided into the following categories:

A - Full service irrigation (typically receives a full water supply);
B - Partial service irrigation (typically receives a reduced water supply due to limited water availability or the inability to provide complete field coverage);
C - Man induced subirrigation (beneficial use resulting from incidental irrigation such as ditch seepage to areas below a canal);
E - Idle irrigation (lands not currently receiving water, typically due to nonfunctional delivery facilities);
S - Spreader dike irrigation (dikes constructed across ephemeral streams to spread infrequent flows over the land to increase beneficial use);
H - Minor beneficial use, (lands that receive some beneficial use on occasion such as lands served by "kick-out" ditches on ephemeral streams).
AD, BD, and ED – A, B, or E lands that have underwent or are currently undergoing residential development.

The irrigated lands were grouped together into Service Areas, defined as lands served by a common supply ditch. A Point of Diversion GIS data theme was developed to identify the point of diversion for lands served within each service area. Vectorized digital base mapping

developed from USGS quadrangle maps was obtained for this Basin Plan to provide perspective in the areas of irrigation.

A database of the water rights associated with the mapped irrigation was also developed. This database, when linked to the irrigated lands polygons through the Geographic Information System (GIS), allows for identification of the water rights attached to the polygons of irrigated land.

For a more detailed description of the attributes provided for the Irrigated Lands and Point of Diversion spatial data themes and the Water Rights tabular database, as well as the digital base maps and other associated data themes, see the "Irrigated Lands and Water Rights Data" technical memorandum.

The extent of irrigated land within the planning area is shown on Figures II-1 through II-4. A typical area of irrigated lands mapping is illustrated on Figure II-5. The extent of the digital base map coverage is shown on Figure II-6 and the Agricultural Wells with yields of at least 50 gpm are shown on Figure II-7.

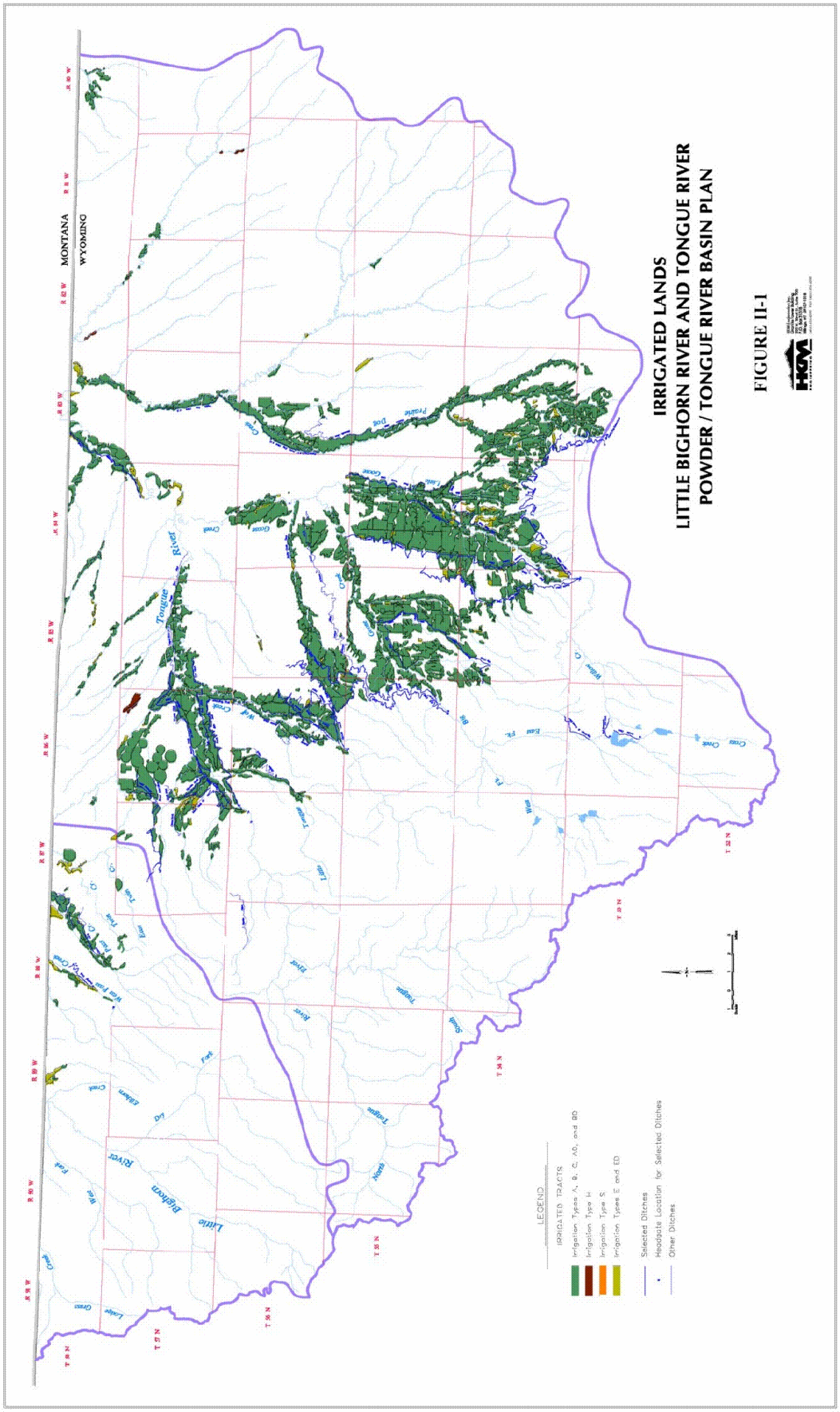
A summary of the quantity of irrigated lands is provided on Tables II-1 and II-2 and on Figure II-8.

Irrigated Crops

Irrigated agriculture in the planning area is primarily associated with forage production for the livestock industry. Ranchers depend on irrigated cropland to provide winter feed and summer grazing for their stock. Alfalfa, grass hay, and pasture grass are the dominant crops grown in the planning area. Lesser amounts of small grains and corn are also produced.

Stereo aerial photography was used as a primary basis for determining the types of crop grown in the various portions of the planning area. A visual assessment of the condition of the fields and the foliage density was used as a primary means of distinguishing between alfalfa and grass hay or pasture. Row crops such as grain crops or corn were more easily distinguished visually although they were of much more limited extent. Following the office mapping process, field verification of the crop identifications was performed. Crop distributions from County Agricultural Statistics were used as a further crosscheck of the results.

The resulting distribution of irrigated crops is summarized in Table II-3 and on Figure III-9 by Hydrologic Unit Code (HUC4) subbasin.


IRRIGATED LANDS
LITTLE BIGHORN RIVER AND TONGUE RIVER
POWDER / TONGUE RIVER BASIN PLAN
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MONTANA
WYOMING
LEGEND
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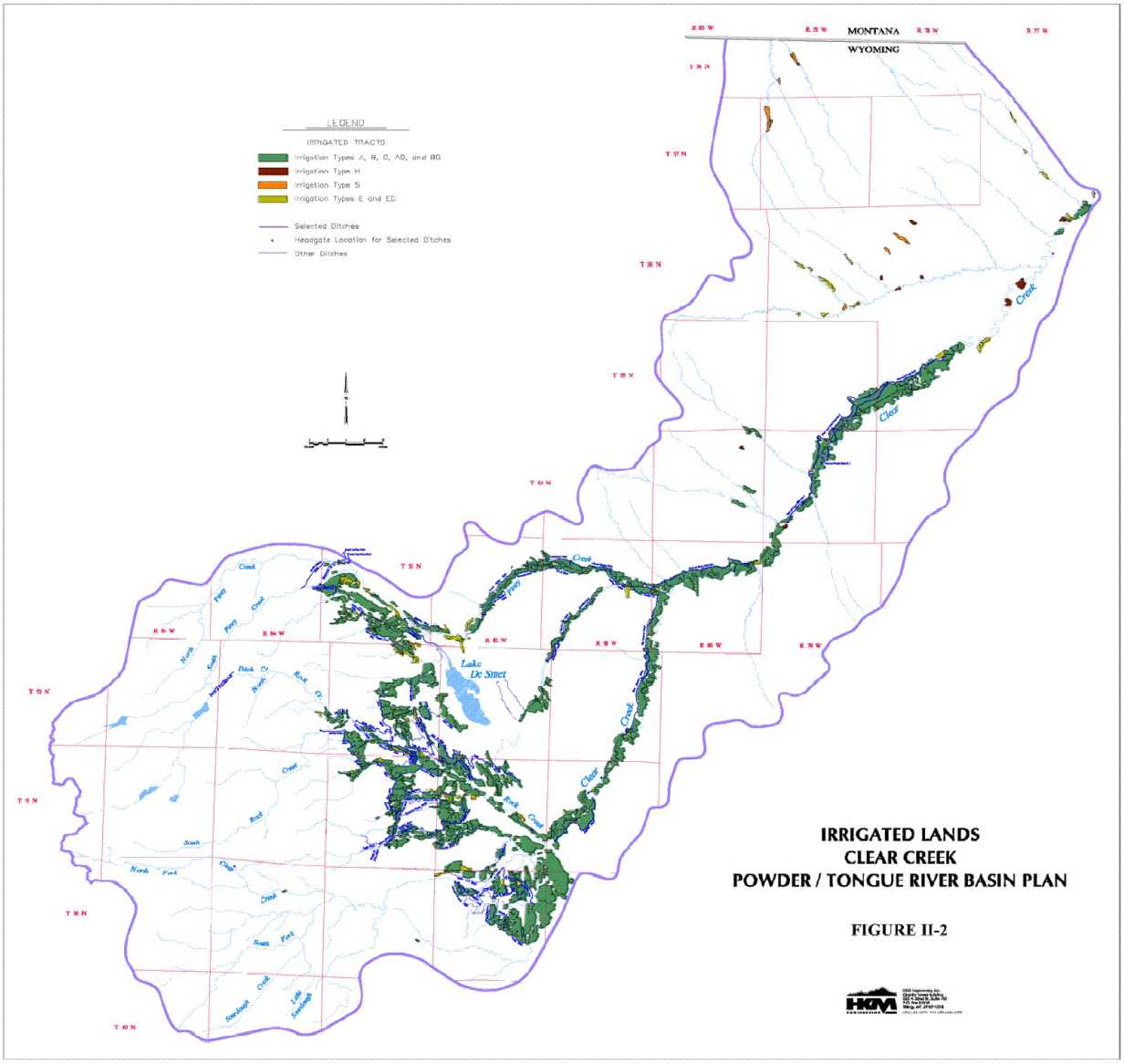
Irrigation Type H
Irrigation Type S
Irrigation Types E and ED
Selected Ditches
Headgate Location for Selected Ditches
Other Ditches
Tongue River
Little Bighorn River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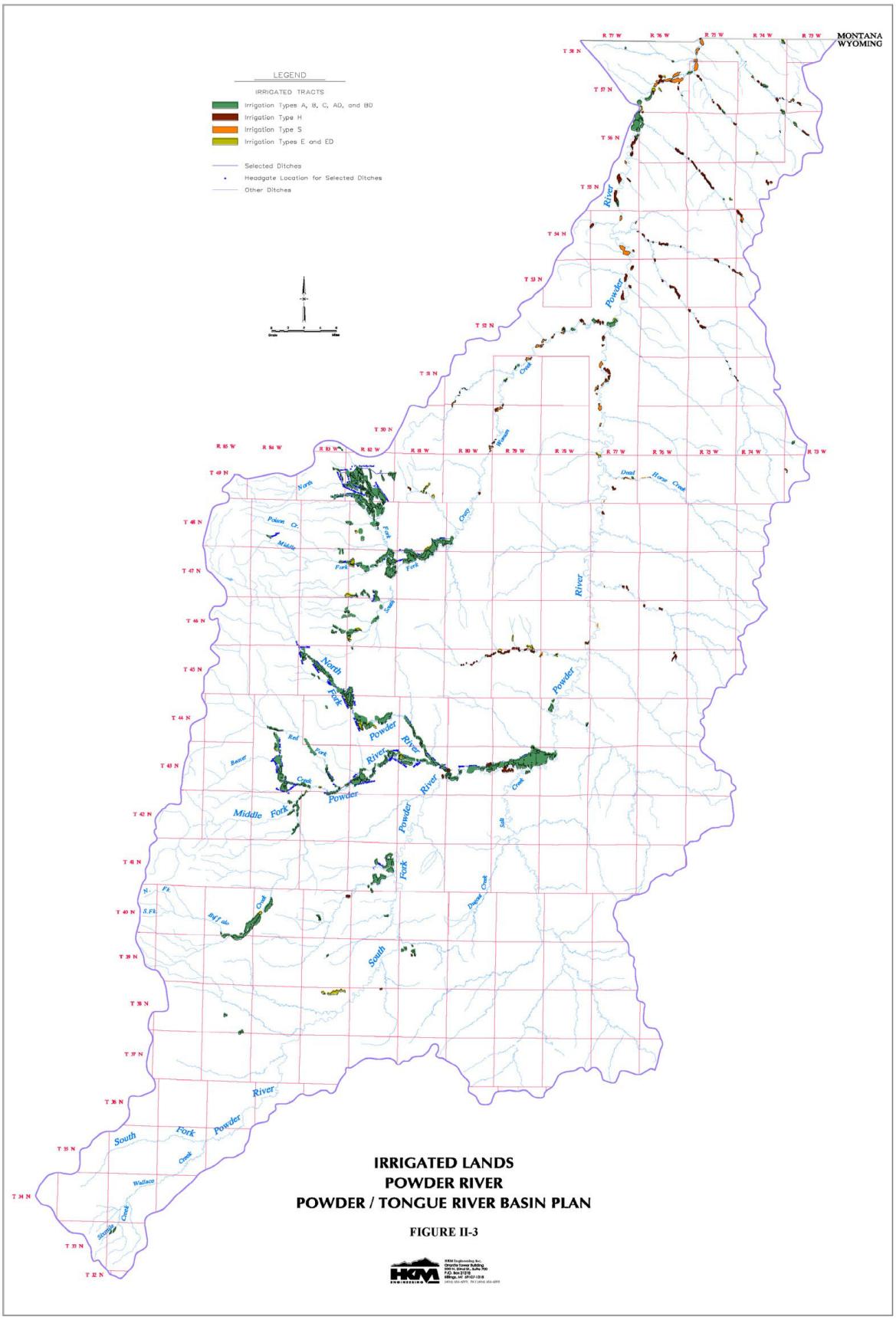
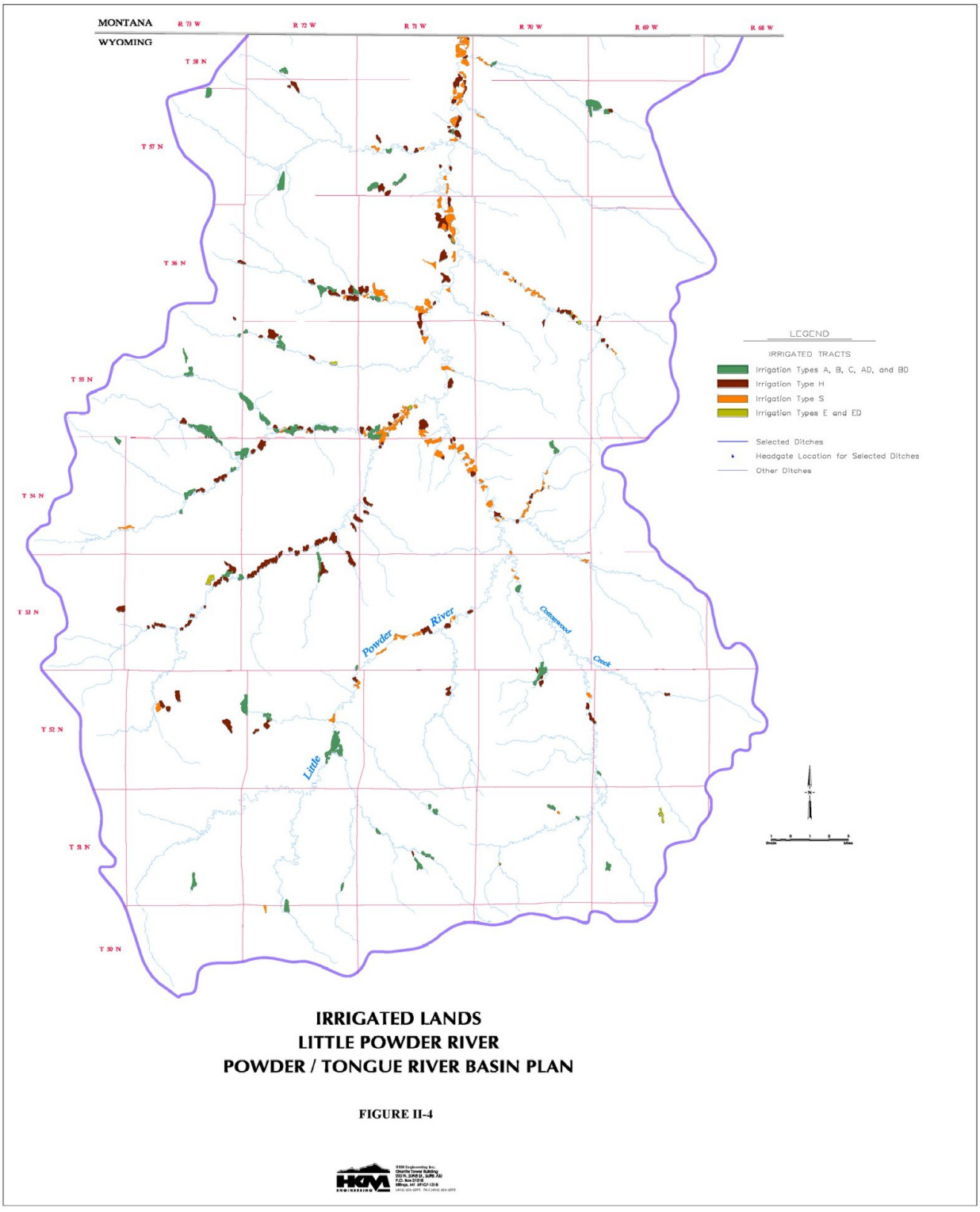
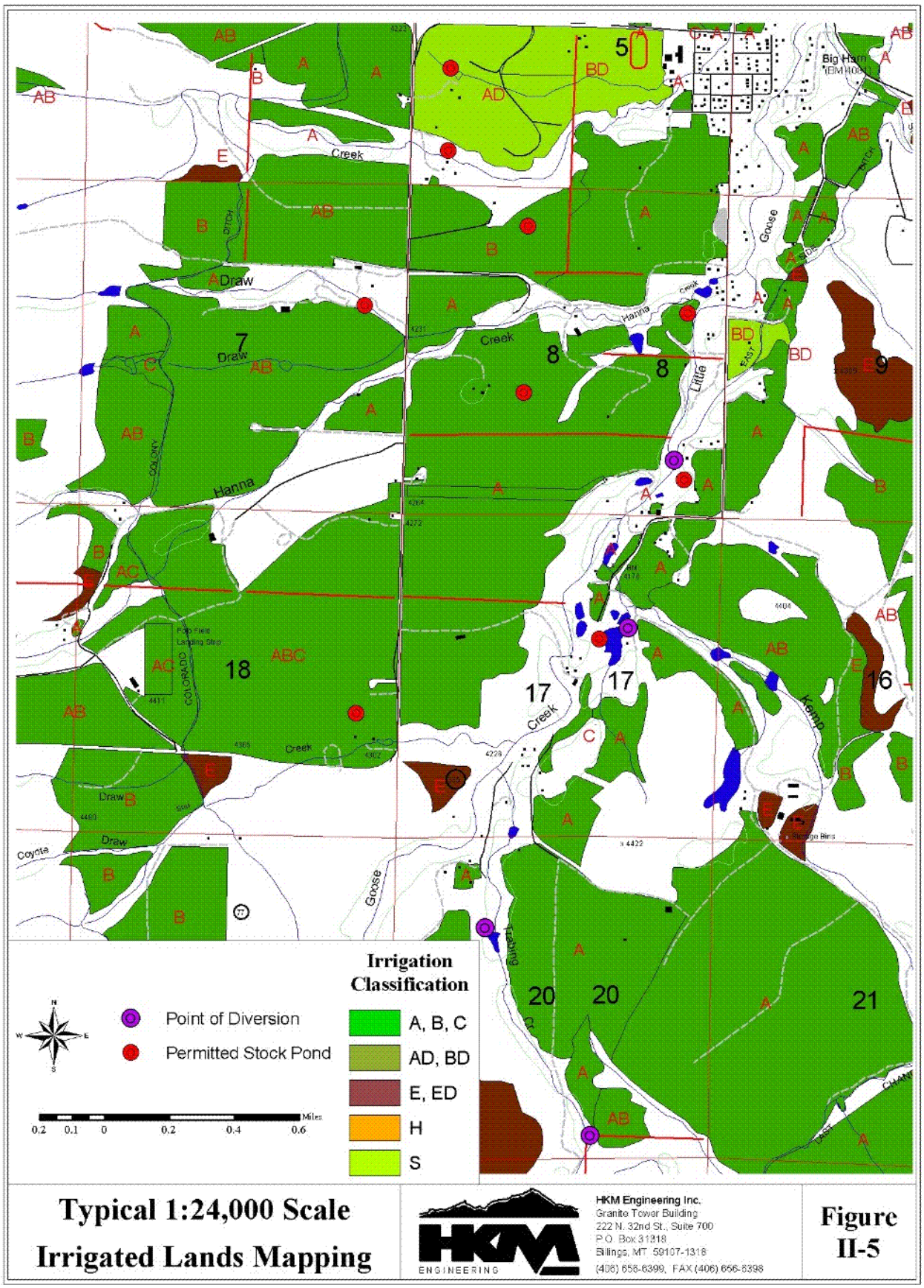
IRRIGATED LANDS
CLEAR CREEK
POWDER / TONGUE RIVER BASIN PLAN
FIGURE II-2


LEGEND
IRRIGATED TRACTS
Irrigation Types A, B, C, AD, and BD
Irrigation Type H
Irrigation Type S
Irrigation Types E and ED
Selected Ditches
Headgate Location for Selected Ditches
Other Ditches
MONTANA
WYOMING
IRRIGATED LANDS
POWDER RIVER
POWDER / TONGUE RIVER BASIN PLAN
FIGURE II-3



IRRIGATED LANDS
LITTLE POWDER RIVER
POWDER / TONGUE RIVER BASIN PLAN

FIGURE II-4



Typical 1:24,000 Scale Irrigated Lands Mapping

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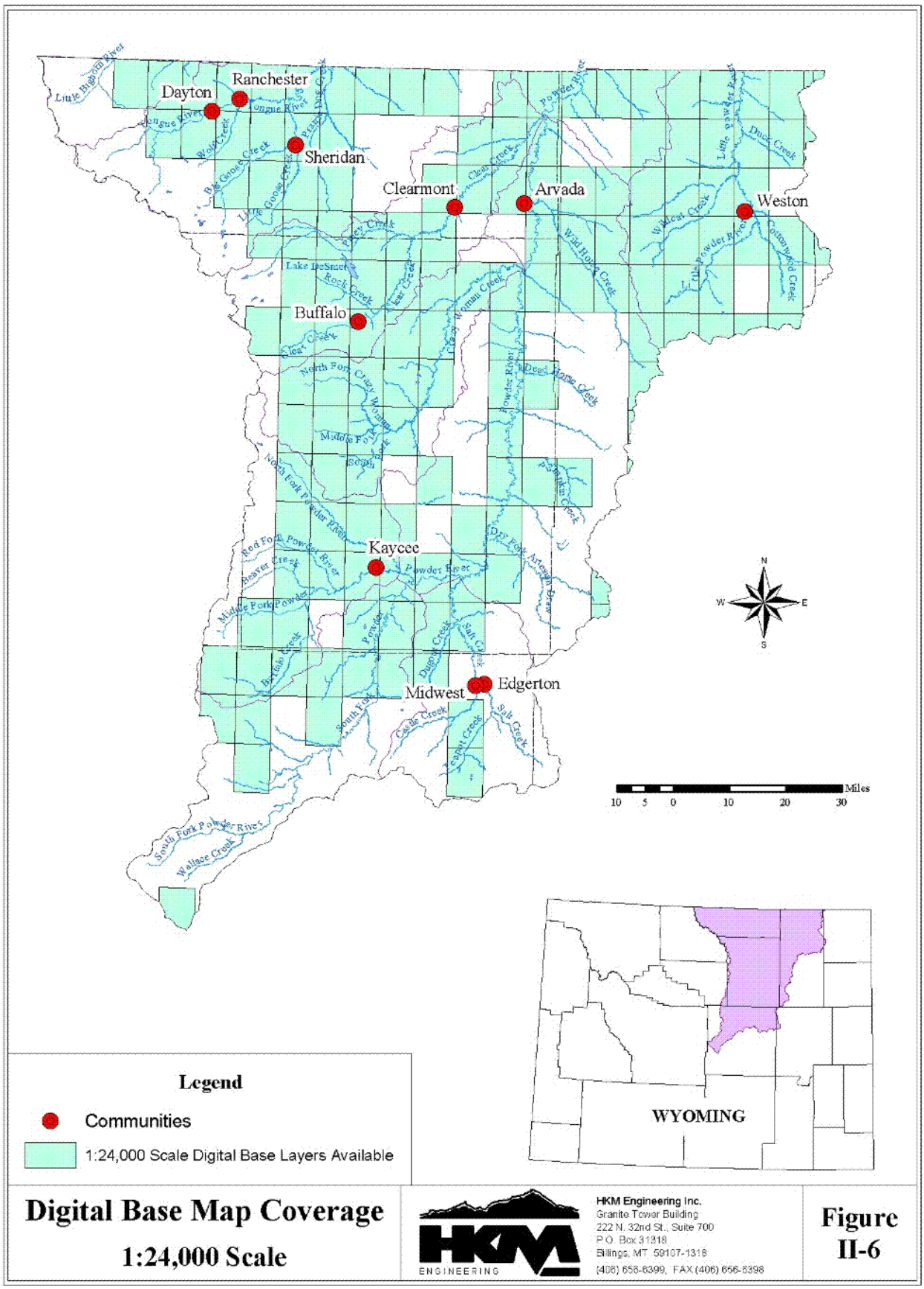
Billings, MT 59107-1318
(406) 656-6399, FAX (406) 656-6398

Figure II-5



Digital Base Map Coverage

1:24,000 Scale

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Figure II-6

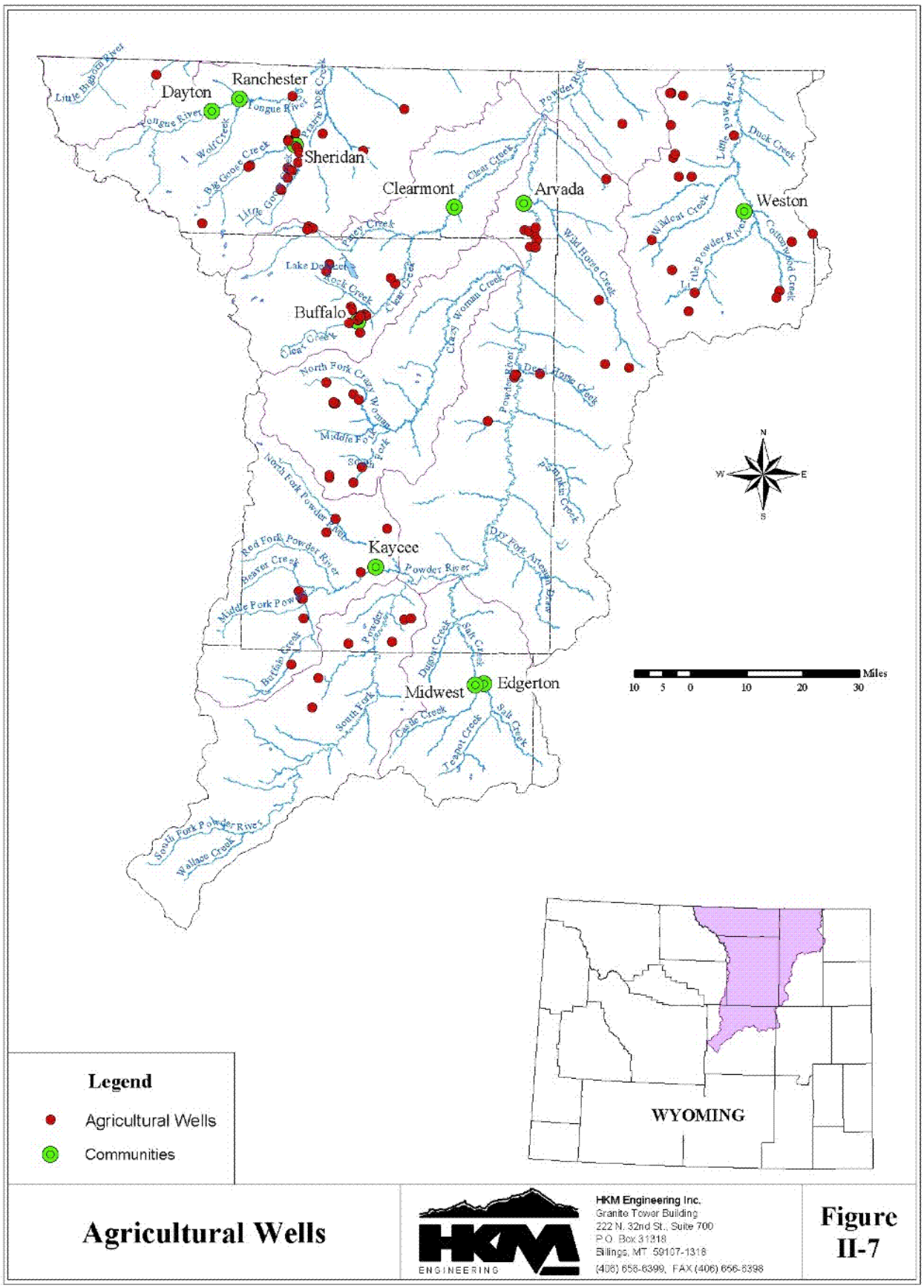
Dayton
Ranchester
Sheridan
Clearmont
Arvada
Weston
Buffalo
Kaycee
Midwest
Edgerton
Little Bighorn River
Tongue River
Wolf Creek
Big Goose Creek
Little Goose
Prairie Dog Creek
Clear Creek
Piney Creek
Lake Desmet
Rock Creek
Crazy Woman Creek
North Fork Crazy Woman
Middle Fork
South Fork
Powder River
Wild Horse Creek
Little Powder River
Duck Creek
Wildcat Creek
Cottonwood Creek
Pumpkin Creek
Dry Fork Artesian Draw
Red Fork Powder River
Beaver Creek
Middle Fork Powder
Buffalo Creek
Dugout Creek
Salt Creek
Castle Creek
Teapot Creek
South Fork Powder River
Wallace Creek
N
S
E
W
Miles
10 5 0 10 20 30
WYOMING
Legend
Agricultural Wells
Communities
Agricultural Wells
HKM ENGINEERING
HKM Engineering Inc.
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Figure II-7

Table II-1
Summary of Irrigated Lands By Irrigation Classification (Acres)

Subbasin Name	HUC	Irrigation Classification																
		A	B	C	AB	AC	BC	ABC	Total ABC	AD	BD	Total AD, BD	S	H	E	ED	Total E, ED	Total
Little Bighorn	10080016	635	685	16	340	61	0	0	1,737	7	0	7	0	0	632	0	632	2,376
Upper Tongue	10090101	22,085	12,294	655	16,099	4,808	906	9,487	66,334	1,926	1,881	3,807	245	52	2,757	25	2,782	73,220
Middle Fork Powder	10090201	2,866	3,156	0	2,179	871	20	2,031	11,123	0	0	0	0	0	512	0	512	11,635
South Fork Powder	10090203	645	734	91	561	0	0	0	2,031	0	0	0	0	72	383	0	383	2,486
Upper Powder	10090202	1,257	987	17	724	125	0	4,850	7,960	0	0	0	1,495	2,795	619	0	619	12,869
Crazy Woman Creek	10090205	2,351	2,993	32	2,007	568	0	4,669	12,620	0	0	0	688	254	843	0	843	14,405
Clear Creek	10090206	11,326	5,622	724	6,895	3,565	598	8,056	36,786	145	316	461	140	261	1,869	193	2,062	39,710
Middle Powder	10090207	0	581	0	0	0	0	0	581	0	0	0	1,553	484	275	0	275	2,893
Little Powder	10090208	163	2,950	49	0	0	38	0	3,200	0	0	0	3,363	3,312	172	0	172	10,047
	TOTAL	41,328	30,002	1584	28,805	9,998	1562	29,093	142,372	2,078	2,197	4,275	7,484	7,230	8,062	218	8,280	169,641

Table II-2
Summary of Irrigated Lands By Primary Source of Supply (Acres)

Subbasin Name	HUC	Primary Source Of Water Supply		
		Ground Water	Surface Water	Total
Little Bighorn	10080016	0	2,376	2,376
Upper Tongue	10090101	0	73,220	73,220
Middle Fork Powder	10090201	58	11,577	11,635
South Fork Powder	10090203	0	2,486	2,486
Upper Powder	10090202	45	12,824	12,869
Crazy Woman Creek	10090205	97	14,308	14,405
Clear Creek	10090206	20	39,690	39,710
Middle Powder	10090207	0	2,893	2,893
Little Powder	10090208	0	10,047	10,047
	TOTAL	220	169,421	169,641

Table II-3
Summary of Irrigated Crops (Acres)

Subbasin Name	HUC	Acreage						Total Active	% Of Active Irrigated Acres			
		Alfalfa	Grass	Grain	Corn	Idle	Total		Alfalfa	Grass	Grain	Corn
Little Bighorn	10080016	591	1,030	86	38	632	2,377	1,745	34	59	5	2
Upper Tongue	10090101	45,981	15,050	6,596	2,812	2,782	73,221	70,439	65	21	10	4
Middle Fork Powder	10090201	6,345	3,479	916	383	512	11,635	11,123	57	31	8	4
South Fork Powder	10090203	1,289	550	186	78	383	2,486	2,103	61	26	9	4
Upper Powder	10090202	5,821	5,239	837	353	619	12,869	12,250	47	43	7	3
Crazy Woman Creek	10090205	8,337	3,512	1,192	521	843	14,405	13,562	61	26	9	4
Clear Creek	10090206	24,223	8,464	3,490	1,471	2,063	39,711	37,648	64	23	9	4
Middle Powder	10090207	155	2,430	21	11	275	2,892	2,617	6	93	1	0
Little Powder	10090208	342	9,471	60	0	172	10,045	9,873	3	96	1	0
	TOTAL	93,084	49,225	13,384	5,667	8,281	169,641	161,360	58	30	8	4

Figure II-8
Acreage of Irrigated Land by Irrigation Classification

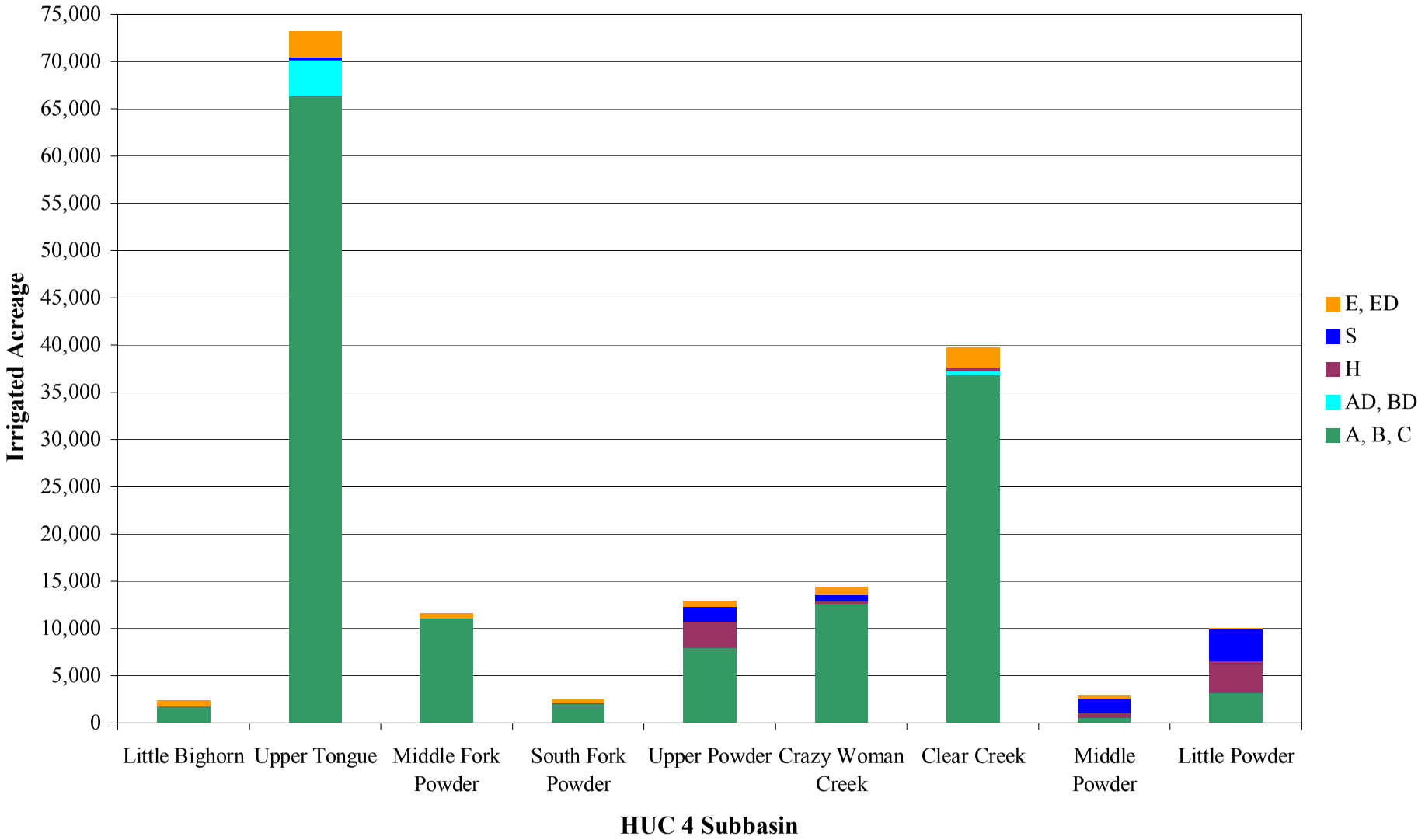
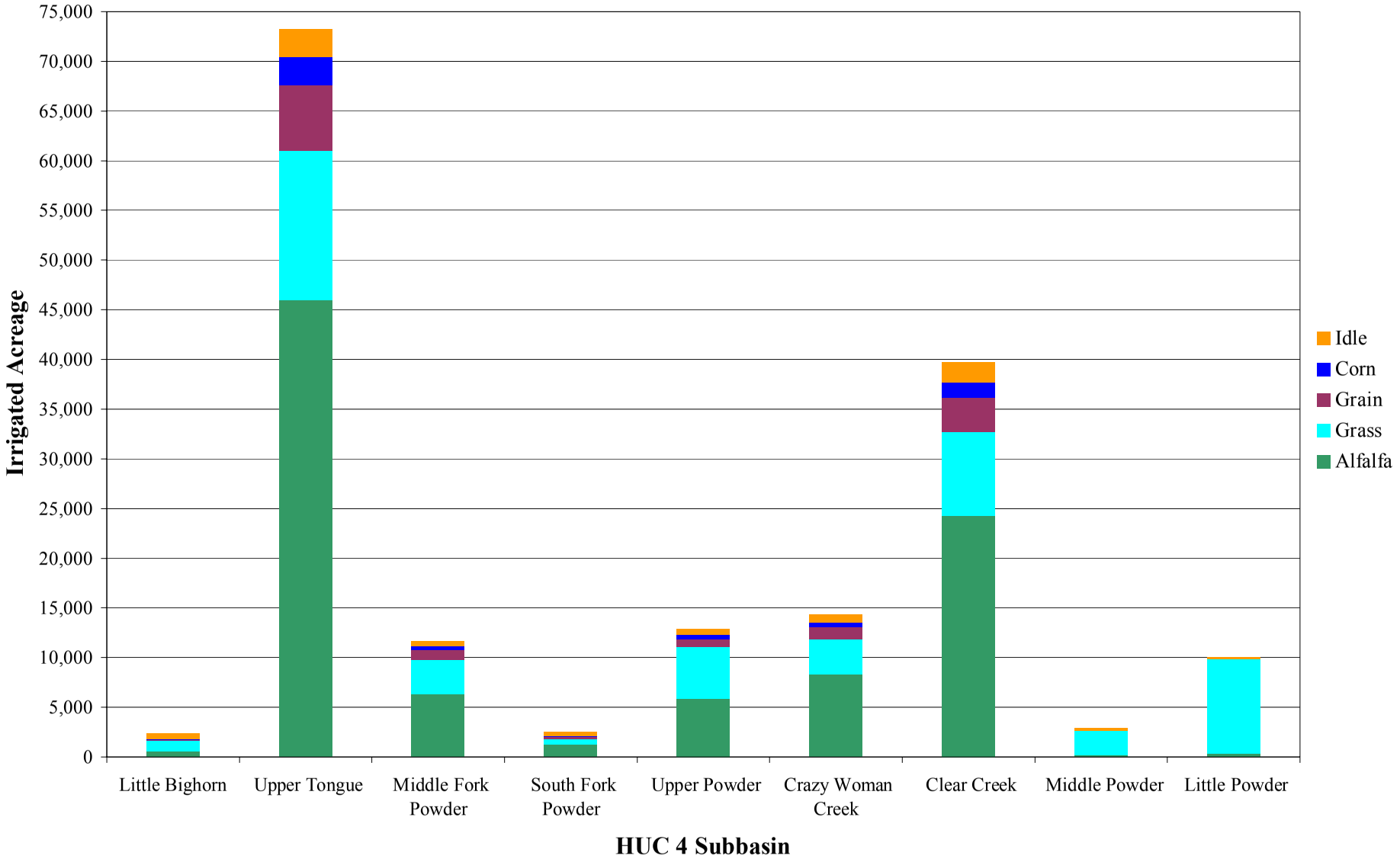


Figure II-9
Acreage of Irrigated Land by Crop



Irrigation Water Consumption

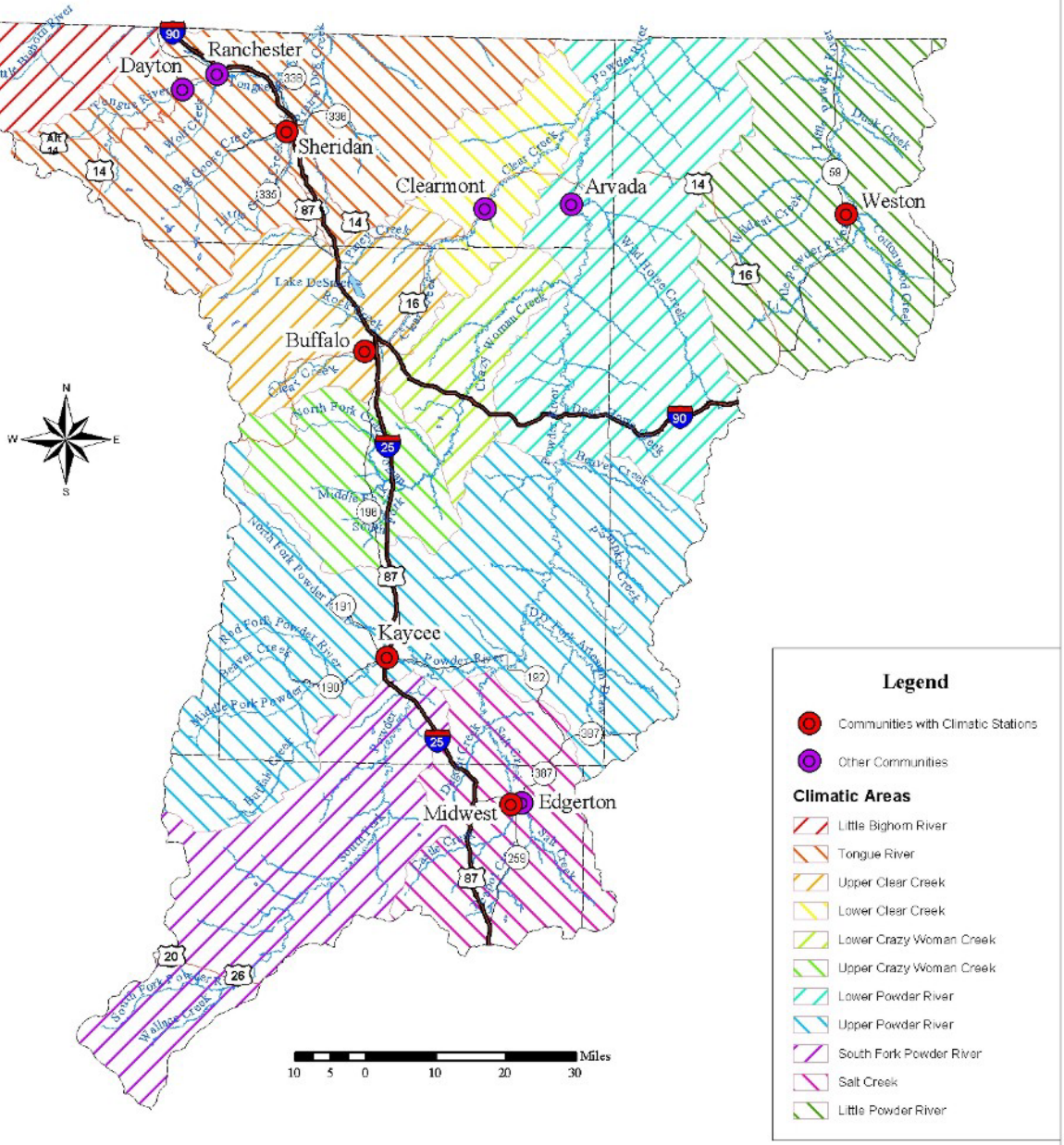
The depletion of water by irrigation is primarily dependent on the number of acres irrigated, the crop water demands, and the amount of water available to meet these demands.

Total crop water demands are dependent on the consumptive use of the crop. The crop consumptive use requirement is the maximum water use of a well-watered crop under optimum growing conditions. A portion of the total annual rainfall is available to meet this consumptive use requirement. Effective precipitation is defined as that part of the total rainfall during the growing season, which is available to meet the consumptive water requirements of the crops. The remaining consumptive use requirement, unmet by natural rainfall, is referred to as the Consumptive Irrigation Requirement (CIR).

Knowing the number of acres of irrigation within a Service Area (a grouping of lands served by a common supply ditch), the types of crops grown, and the climatic conditions, estimates of the theoretical maximum diversions can be made for all of the irrigated lands throughout the basin. In practice however, actual diversions commonly fall short of the amount necessary to meet the full CIR of the crops (the "theoretical maximum diversion requirement"). This is especially true with flood-irrigated, forage crops. Actual conditions seldom represent the optimum conditions necessary to achieve maximum water consumption.

Through the current planning effort, comparisons have been made between actual historic diversions for 70 key irrigation ditches and the theoretical maximum diversion to the lands served by these ditches (Service Areas). The relationships developed allow for estimation of actual diversions and depletions where records are unavailable. According to these relationships, the average proportion of actual historic diversions to theoretical maximum diversions is at a maximum in wet years (73 %), is somewhat lower in normal years (71 %), and is considerably lower in dry years (56 %). The ditches included in these averages serve a total of 79,046 acres and constitute 49 percent of the total active irrigated acreage in the planning area (161,360 acres). The climatic areas used in calculating the CIR and corresponding Theoretical Maximum Diversion Requirements are shown on Figure II-10.

Not all of the water diverted for irrigation goes to meeting the crop water demands, in fact, the crop water consumption often times represents only a minor portion of the total diversion amount. A significant portion of the diverted flow is lost to seepage from the main conveyance ditch, lateral ditches, and field ditches, headgate leakage, ditch tailwater waste, field wastewater, and deep percolation past the crop root zone. Much of this "water loss" ultimately returns back to stream system for reuse downstream. That portion of the estimated actual diversion volume that is consumed by the crop is defined here as the estimated actual depletion. The estimated actual depletions for wet, normal, and dry years total 194,000 acre-feet, 184,000 acre-feet, and 178,000 acre-feet respectively and are summarized in Table II-4. The estimated actual depletions for the lands supplied by surface water and ground water are provided in Tables II-5 and II-6 respectively.



Notes: The Climatic Areas are generally delineated according to the HUC-4 boundaries.

1. The Little Bighorn River HUC-4 represents the Little Bighorn River Climatic Area.
2. The Tongue River HUC-4 represents the Tongue River Climatic Area.
3. The Clear Creek HUC-4 is divided into the Upper and Lower Clear Creek Climatic Areas below the junction of Piney Creek and Clear Creek.
4. The Crazy Woman Creek HUC-4 is divided into the Upper and Lower Crazy Woman Creek Climatic Areas below the junction of Crazy Woman Creek and Wallows Creek (Section 20 T48N R80W).
5. The Upper Powder River HUC-4 is divided into the Upper and Lower Powder River Climatic Areas below the junction of the Powder River and Beaver Creek (Section 20 T48N R77W). The Middle Fork Powder River HUC-4 is also included in the Upper Powder River Climatic Area and the Lower Powder River HUC-4 is included in the Lower Powder River Climatic Area.
6. The South Fork Powder River HUC-4 represents the South Fork Powder River Climatic Area.
7. The Salt Creek HUC-4 represents the Salt Creek Climatic Area.
8. The Little Powder River HUC-4 represents the Little Powder River Climatic Area.

Climatic Areas by Source of Supply

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Figure II-10

Table II-4
Estimated Actual Depletions (Acre-Feet)

Source of Supply	Active Irrigation (Acres)	Hydrologic Condition	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Little Bighorn Basin	1,781	Wet	0	0	0	0	56	370	731	618	206	0	0	0	1,981
		Normal	0	0	0	6	126	421	654	640	216	0	0	0	2,064
		Dry	0	0	0	29	342	402	539	369	162	0	0	0	1,844
Tongue River Basin	62,760	Wet	0	0	0	27	1,994	12,268	24,914	20,365	9,461	2	0	0	69,031
		Normal	0	0	0	189	4,614	15,398	22,463	21,741	6,960	3	0	0	71,369
		Dry	0	0	0	1,049	11,422	14,764	21,219	14,108	5,458	8	0	0	68,028
Powder River Basin - Surface Supply	86,742	Wet	0	0	0	642	5,941	20,284	36,101	31,965	15,512	65	0	0	110,509
		Normal	0	0	0	905	8,054	22,513	28,901	28,546	10,414	81	0	0	99,414
		Dry	0	0	0	2,433	11,429	22,713	30,912	21,270	8,941	120	0	0	97,819
Powder River Basin - Ground Water Supply	203	Wet	0	0	0	0	17	49	91	83	39	0	0	0	279
		Normal	0	0	0	0	13	42	58	64	18	0	0	0	194
		Dry	0	0	0	3	18	40	68	47	18	0	0	0	194
Little Powder River Basin	9,873	Wet	0	0	0	655	939	2,339	3,435	3,183	1,611	24	0	0	12,186
		Normal	0	0	0	591	1,119	2,142	3,039	2,763	1,325	21	0	0	10,999
		Dry	0	0	0	580	1,678	1,982	2,814	2,048	825	17	0	0	9,943
Total	161,359	Wet	0	0	0	1,324	8,947	35,310	65,271	56,213	26,830	91	0	0	193,987
		Normal	0	0	0	1,691	13,926	40,516	55,115	53,754	18,934	105	0	0	184,041
		Dry	0	0	0	4,094	24,889	39,902	55,553	37,842	15,404	145	0	0	177,828

Table II-5
Estimated Actual Surface Water Depletions (Acre-Feet)

Source of Supply	Climate Stations[1]	Active Irrigation (Acres)	Hydrologic Condition	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Little Bighorn Basin	Sheridan	1,781	Wet	0	0	0	0	56	370	731	618	206	0	0	0	1,981
			Normal	0	0	0	6	126	421	654	640	216	0	0	0	2,064
			Dry	0	0	0	29	342	402	539	369	162	0	0	0	1,844
Tongue River Basin	Sheridan	62,760	Wet	0	0	0	27	1,994	12,268	24,914	20,365	9,461	2	0	0	69,031
			Normal	0	0	0	189	4,614	15,398	22,463	21,741	6,960	3	0	0	71,369
			Dry	0	0	0	1,049	11,422	14,764	21,219	14,108	5,458	8	0	0	68,028
Upper Clear Creek	Buffalo	39,176	Wet	0	0	0	18	1,606	8,482	15,170	13,273	6,295	4	0	0	44,847
			Normal	0	0	0	148	4,023	11,228	13,811	13,489	5,201	5	0	0	47,906
			Dry	0	0	0	825	6,202	11,096	13,418	9,207	3,755	8	0	0	44,511
Lower Clear Creek	Buffalo & Weston	7,174	Wet	0	0	0	27	329	1,491	2,915	2,443	1,202	3	0	0	8,409
			Normal	0	0	0	56	735	2,065	2,528	2,431	991	4	0	0	8,812
			Dry	0	0	0	203	1,325	1,924	2,488	1,656	713	6	0	0	8,315
Upper Crazy Woman Creek	Buffalo	12,324	Wet	0	0	0	6	506	2,678	4,774	4,160	1,975	1	0	0	14,100
			Normal	0	0	0	47	1,265	3,541	4,346	4,228	1,631	2	0	0	15,061
			Dry	0	0	0	259	1,949	3,498	4,222	2,885	1,178	3	0	0	13,994
Lower Crazy Woman Creek	Buffalo & Weston	1,418	Wet	0	0	0	54	130	278	498	447	213	5	0	0	1,624
			Normal	0	0	0	66	173	326	423	394	173	6	0	0	1,561
			Dry	0	0	0	96	184	302	403	305	138	9	0	0	1,438
Upper Powder River	Kaycee	18,107	Wet	0	0	0	210	2,288	5,307	9,336	8,568	4,331	20	0	0	30,059
			Normal	0	0	0	207	1,085	3,879	5,715	5,910	1,727	27	0	0	18,549
			Dry	0	0	0	551	1,214	4,558	8,036	5,462	2,393	38	0	0	22,252
South Fork Powder River	Kaycee & Midwest	2,103	Wet	0	0	0	5	304	725	1,157	1,028	548	1	0	0	3,768
			Normal	0	0	0	4	25	251	425	567	64	1	0	0	1,337
			Dry	0	0	0	6	7	218	684	457	176	1	0	0	1,548
Lower Powder River	Buffalo & Weston	6,440	Wet	0	0	0	322	779	1,324	2,253	2,045	947	32	0	0	7,701
			Normal	0	0	0	378	747	1,222	1,653	1,527	626	36	0	0	6,188
			Dry	0	0	0	494	548	1,115	1,662	1,298	588	55	0	0	5,760
Little Powder River Basin	Weston	9,873	Wet	0	0	0	655	939	2,339	3,435	3,183	1,611	24	0	0	12,186
			Normal	0	0	0	591	1,119	2,142	3,039	2,763	1,325	21	0	0	10,999
			Dry	0	0	0	580	1,678	1,982	2,814	2,048	825	17	0	0	9,943
Total		161,156	Wet	0	0	0	1,324	8,930	35,261	65,181	56,131	26,790	91	0	0	193,708
			Normal	0	0	0	1,691	13,914	40,475	55,057	53,690	18,915	105	0	0	183,846
			Dry	0	0	0	4,091	24,870	39,862	55,485	37,795	15,386	145	0	0	177,634

Notes: [1] Where more than one climate station is listed, the stations were weighted 50-50.

Table II-6
Estimated Actual Ground Water Depletions (Acre-Feet)

Source of Supply	Climate Stations[1]	Active Irrigation (Acres)	Hydrologic Condition	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Upper Clear Creek	Buffalo	20	Wet	0	0	0	0	1	4	8	7	3	0	0	0	23
			Normal	0	0	0	0	2	6	7	7	3	0	0	0	25
			Dry	0	0	0	0	3	6	7	5	2	0	0	0	23
Upper Crazy Woman Creek	Buffalo	97	Wet	0	0	0	0	4	20	37	34	16	0	0	0	112
			Normal	0	0	0	0	10	27	34	35	13	0	0	0	119
			Dry	0	0	0	2	15	27	33	24	10	0	0	0	110
Upper Powder River	Kaycee	58	Wet	0	0	0	0	8	17	31	28	14	0	0	0	98
			Normal	0	0	0	0	0	6	11	15	1	0	0	0	34
			Dry	0	0	0	0	0	6	19	12	4	0	0	0	41
Lower Powder River	Buffalo & Weston	28	Wet	0	0	0	0	4	8	15	14	6	0	0	0	46
			Normal	0	0	0	0	0	3	5	7	1	0	0	0	16
			Dry	0	0	0	0	0	2	9	6	2	0	0	0	19
Total		203	Wet	0	0	0	0	17	49	91	83	39	0	0	0	279
			Normal	0	0	0	0	13	42	58	64	18	0	0	0	194
			Dry	0	0	0	3	18	40	68	47	18	0	0	0	194

Notes: [1] Where more than one climate station is listed, the stations were weighted 50-50.

C. Municipal and Domestic Use

Municipal and domestic uses are described in this section of the report. For the purpose of this report municipal uses are defined as uses satisfied by a public water supply system. Domestic uses are those that are satisfied by individual wells and small water systems.

Municipal

There are twenty public water supply entities consisting of incorporated municipalities, districts, and privately owned water systems in the planning area. These entities are listed below along with an indication of whether their primary water source is surface water or ground water.

- Incorporated municipalities
  - City of Buffalo – surface water
  - Town of Clearmont – ground water
  - Town of Dayton – surface water
  - Town of Kaycee – ground water
  - Town of Ranchester – surface water
  - City of Sheridan – surface water
  - Town of Edgerton (water supplied by Casper Regional System, therefore the water source is not within this basin)
  - Town of Midwest (water supplied by Casper Regional System, therefore the water source is not within this basin)
- Districts
  - Anderson Improvement and Service District (water supplied by the City of Gillette)
  - Arvada Water District – ground water
  - Cook Road Water District – ground water
  - Green Valley Estates Improvement and Service District – ground water
  - Heritage Village Water and Sewer District – ground water
  - Means Water and Sewer District – ground water
  - Pine Butte Improvement and Service District – ground water
  - Prairie View/Champion Improvement and Service District – ground water
- Privately owned water systems
  - Soldier Creek Water Company (water supplied by the City of Sheridan)
  - Countryside Water Users Association – ground water
  - Eight-Mile Subdivision – ground water
  - Linch Utility – ground water

Information on the water sources and systems of the twenty entities was obtained through: 1) The year 2000 *Water System Survey Reports* compiled and published by the WWDC; 2) directly from the entity through mail surveys and personnel communication; and, 3) the

Wyoming DEQ office in Sheridan. The detail information compiled for each of the entities is presented in the Municipal Use Technical Memorandum.

Table II-7 presents the monthly surface water depletions by Buffalo, Dayton, Ranchester, and Sheridan. Depletions, in million gallons (MG), are computed as the difference between the diversions from the stream and the amount of water returned to the stream through wastewater treatment facilities. Those months with negative depletions represent lagged return flows which exceed diversions for the given month. The municipalities of Midwest and Edgerton, and the Soldier Creek Water Company, although they use surface water, are not included in Table II-7. Midwest and Edgerton are supplied by the Casper area water system, which is outside the study area, and the Soldier Creek Water Company is served by the City of Sheridan.

Table II-7
Municipal Surface Water Use
(Million Gallons)

	Municipality			
	Buffalo	**Dayton**	**Ranchester**	**Sheridan**
Population [1]	3,900	678	701	18,500
GPCPD [2]	325	234	300	260
DEPLETIONS				
Water Source	Clear Creek	Tongue River	Tongue River	Big Goose Cr.
January	1.20	0.26	-0.20	18.84
February	0.29	-0.31	-0.80	18.84
March	-0.62	-0.04	-0.43	29.22
April	-1.99	-0.03	-0.57	27.49
May	6.67	1.02	1.13	56.90
June	27.19	2.34	3.20	98.42
July	49.54	5.62	8.01	139.94
August	48.63	5.36	6.83	150.32
September	19.44	3.95	1.13	93.23
October	5.76	0.35	-0.94	25.76
November	4.39	0.08	-0.72	13.65
December	3.48	0.45	-1.02	17.11
Total	**163.98**	**19.05**	**15.62**	**689.72**

[1] 2000 census
[2] Usage rate, gallons per capita per day

Table II-8 summarizes municipal ground water and Figure II-11 displays the location of municipal wells according to the records of the State Engineer's Office. Of the thirteen municipal ground water systems, only Kaycee discharges wastewater to surface water.

A comparison of existing municipal uses to the system capacity of the entity is presented in Table II-9. The general conclusion from this table is the municipal water systems in the Powder/Tongue River Basin have adequate capacity to meet existing needs. This conclusion assumes the only restriction on the amount of water supplied to the municipality is the water right, i.e. the permitted amount that can be diverted from the stream or withdrawn from a well. Hydrologic conditions, however, can also limit the amount of water available to a community. During dry years, such as 2001, water supply is not always adequate to satisfy all users and, consequently, diversions and withdrawals by entities with junior priority water rights are restricted in favor of senior appropriators.

Table II-8
Municipal Ground Water Use
(Million Gallons)

Municipality	Population [1]	Gpcpd [2]	Annual Use
Anderson I&SD	Supplied by City of Gillette		
Arvada WD	Individual wells, no central system		
Town of Clearmont	125	220	10.0
Cook Road WD	225	N/A	
Countryside WUA	250	N/A	
Eight-Mile Subdivision	90	140	4.6
Green Valley Estates I&SD	72	N/A	
Heritage Village W&SD	700	81	20.7
Town of Kaycee	300	210	23.0
Linch Utility	20	N/A	
Means W&SD	300	600	65.7
Pine Butte I&SD	100	N/A	
Prairie View/Champion I&SD	Individual wells, no central system		

[1] 2000 census
[2] Usage rate, gallons per capita per day

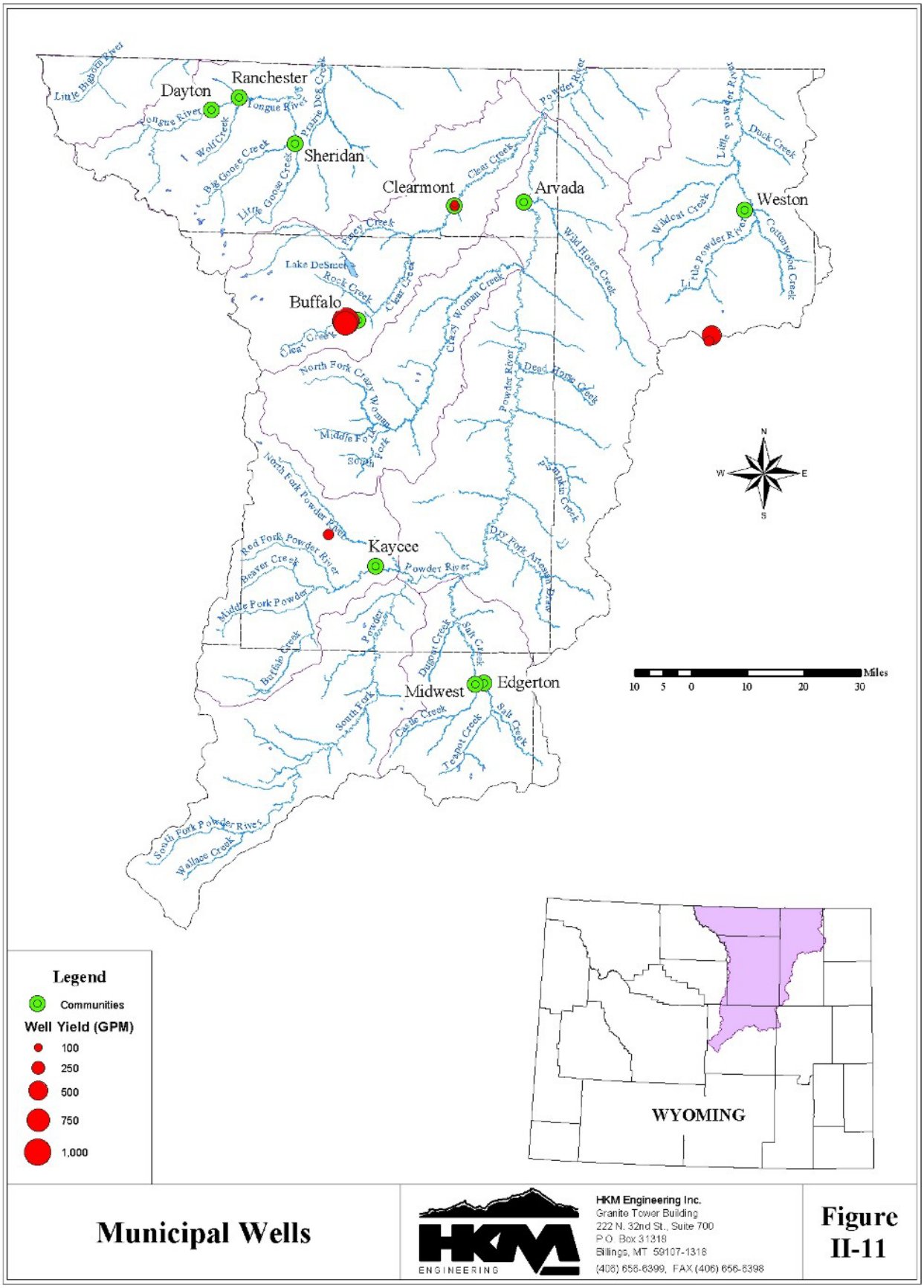
Dayton
Ranchester
Sheridan
Clearmont
Arvada
Weston
Buffalo
Kaycee
Midwest
Edgerton
Tongue River
Powder River
Clear Creek
Crazy Woman Creek
Wild Horse Creek
Dead Horse Creek
Rock Creek
Lake DeSmet
Little Powder River
Wildcat Creek
Cottonwood Creek
Duck Creek
Prairie Dog Creek
Wolf Creek
Big Goose Creek
Little Goose Creek
North Fork Powder River
Red Fork Powder River
Beaver Creek
Middle Fork Powder
Dry Fork Antelope Creek
Dugout Creek
Salt Creek
Buffalo Creek
South Fork
Castle Creek
Teapot Creek
South Fork Powder River
Wallace Creek
N
W
E
S
10 5 0 10 20 30 Miles
Legend
Communities
Well Yield (GPM)
100
250
500
750
1,000
WYOMING
Municipal Wells
HKM ENGINEERING
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Figure II-11

Table II-9
Comparison of Usage to System Capacity

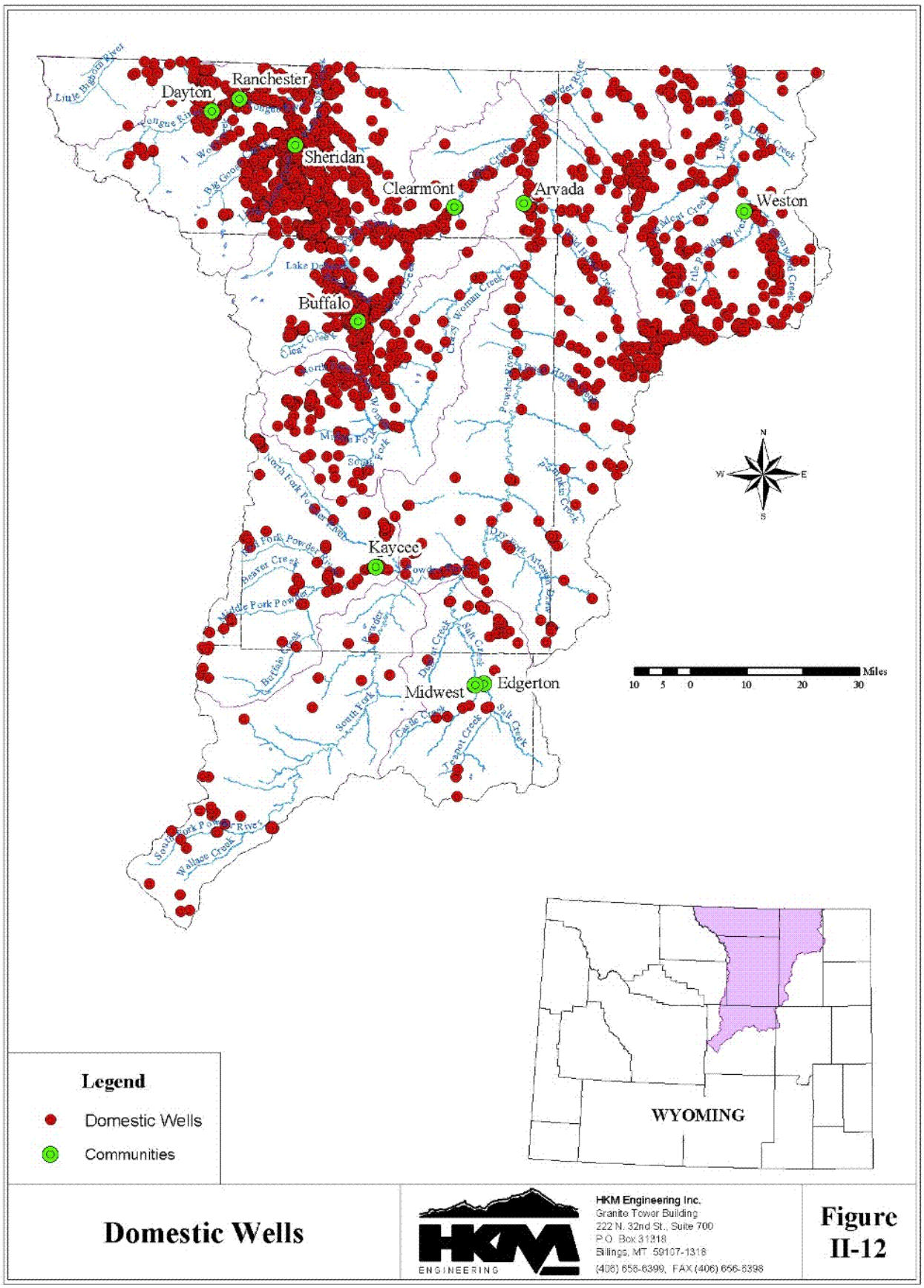
Municipality	Peak Day Demand (GPM)	System Capacity (GPM)	Water Right [1] (GPM)	Raw Water Storage (Acre-Feet)
City of Buffalo	2,220	5,380	5,848	1,647
Town of Clearmont	28	100		None
Cook Road WD	N/A	120		None
Countryside WUD	N/A	200	200	None
Town of Dayton	382	1,050		None
Town of Edgerton	21	290	None	None
Eight-Mile Subdivision	14	73	100	None
Green Valley Estates I&SD	N/A	100	100	None
Heritage Village W&SD	205	370		None
Town of Kaycee	132	165	165	None
Linch Utility		15		None
Means W&SD		200		None
Town of Midwest	130	290	None	None
Pine Butte I&SD				None
Town of Ranchester	475	700	7,180	None
City of Sheridan	7,200	12,850	7,180	3,604

[1] Water right is permitted diversion amount for surface water sources and permitted well yield for ground water sources

Domestic

Domestic use includes water supplied for 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 ground water. A notable exception is that limited irrigation of lawns and gardens from a surface water source is practiced by many rural homes where a surface source is available. Figure II-12 displays the location of domestic wells according to the records of the State Engineer's Office

The population served by individual domestic systems is estimated to be 11,938. To estimate domestic water usage it is assumed individuals served by domestic systems consume between 150 and 300 gallons per day. At this usage rate the total daily domestic use in the study area is between 1.79 and 3.58 million gallons. On an annual basis, domestic use is estimated to be between 2,010 and 4,010 acre-feet.



Domestic Wells

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Figure II-12

Domestic use also includes consumption by two special types of systems:

- non-transient non-community systems – such as rural schools or commercial operations where people don't live there but return there every day; and
- transient non-community systems – such as restaurants and campgrounds where different people use water from the system each day.

Data received from the Environmental Protection Agency Region 8 Office in Denver, Colorado, estimates the population served by these two types of systems is 4,040. Water consumption by these systems is estimated to be 0.30 million gallons per day, about 340 acre-feet per year, based on an assumed daily per capita value of 75 gallons.

Total domestic use, including permanent populations and the two special systems, is estimated to be between 2.09 and 3.88 million gallons per day, or between 2,350 and 4,350 acre-feet per year.

D. Industrial Use

Industrial water use in the Powder/Tongue River Basin, including electric power generation, coal mining, conventional oil and gas production, and coalbed methane production is described in this section. All current industrial use is from ground water. Figure II-13 displays the location of industrial water wells with capacities of at least 50 gpm according to the records of the State Engineer's Office. CBM wells are not shown on Figure II-13. One user, Lake DeSmet Energy Company, has developed a surface water supply to support future electric power generation, but this source has yet to be utilized.

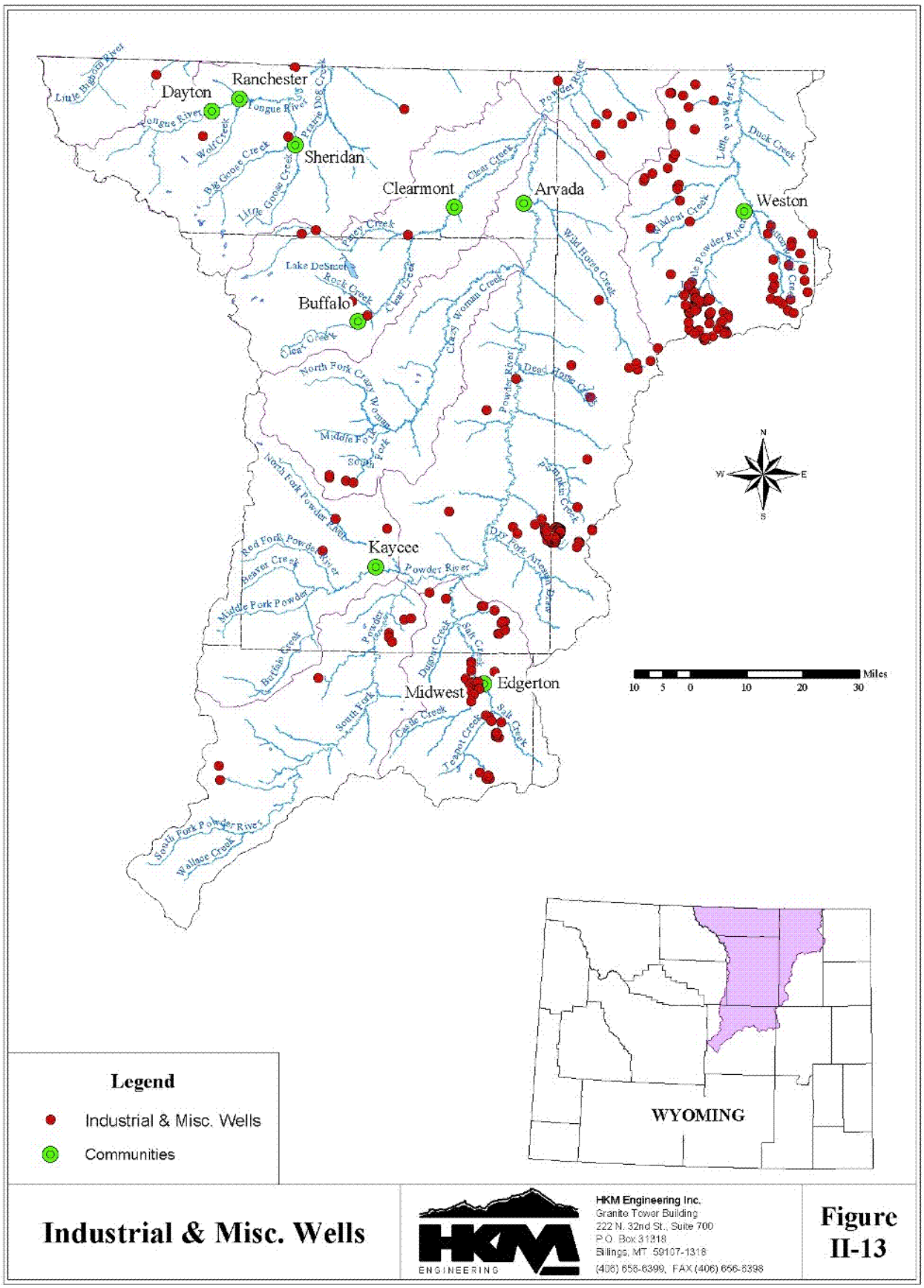
The information reported here was obtained from individual water users, the Coalbed Methane Coordination Coalition (CBMCC), the Wyoming Oil & Gas Conservation Commission (OGCC), and the U.S. Bureau of Land Management (BLM).

No water is currently being used in the study area for electric power generation. Further, the one operational mine, Spring Creek, only uses minimal amounts of water for dust suppression and domestic use. Water production and consumption associated with the conventional oil and gas and coalbed methane industries are described in the remainder of this section.

Conventional Oil and Gas Production

Conventional oil and gas wells produce as well as consume ground water. Water is consumed by injection into the oil and gas aquifers to stimulate production. According to OGCC records for the year 2000, 2,343 wells produced approximately 44,000 acre-feet of water, and 1,593 injection wells consumed about 38,000 acre-feet.

Injection water comes from two sources: oil and gas produced water and wells drilled specifically to pump injection water supply. Produced water can also be discharged to the surface. Because no agency monitors the amounts of produced water injected or discharged, the net amount of water consumed by conventional oil and gas wells can't be quantified.


Dayton
Ranchester
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Arvada
Weston
Buffalo
Kaycee
Midwest
Edgerton
Powder River
Tongue River
Little Bighorn River
Prairie Dog Creek
Wolf Creek
Big Goose Creek
Little Goose Creek
Clear Creek
Crazy Woman Creek
Lake DeSmet
Rock Creek
Wild Horse Creek
Little Powder River
Duck Creek
Wildcat Creek
Dead Horse Creek
North Fork Crazy Woman Creek
Middle Fork
South Fork
North Fork Powder River
Red Fork Powder River
Beaver Creek
Middle Fork Powder
Dry Fork Antelope Creek
Buffalo Creek
Dugout Creek
Salt Creek
Castle Creek
Teapot Creek
South Fork Powder River
Wallace Creek
N
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E
S
10 5 0 10 20 30
Miles
WYOMING
Legend
Industrial & Misc. Wells
Communities
Industrial & Misc. Wells
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Figure II-13

Coalbed Methane Production

There is little direct consumptive use of water in the CBM industry. However, the production of CBM gas results from lowering the water table over the coal seam and a significant amount of ground water is produced in this operation. OGCC records indicate approximately 24,300 acre-feet of water was pumped from the 6,184 CBM wells in the Powder/Tongue River Basin in 2001. Throughout the history of CBM production, which dates back to the 1970s, OGCC records indicate approximately 50,500 acre-feet has been pumped. The locations of the CBM wells on record with the Wyoming Oil and Gas Conservation Commission as of January 2002, by regions within the planning area are shown on Figure II-14.

There is little information available to quantify what happens to water pumped from CBM wells. The majority of this production water is discharged into existing drainages, and some is conveyed to small reservoirs where it either infiltrates or evaporates. A small portion of this water is reported to be used for irrigation.

E. Recreational Use

Recreational uses associated with the water resources of the Powder/Tongue River Basin are described in this section of the report under the general headings of boating, fishing, and waterfowl hunting. Lake DeSmet as an important recreational resource in the basin is also discussed.

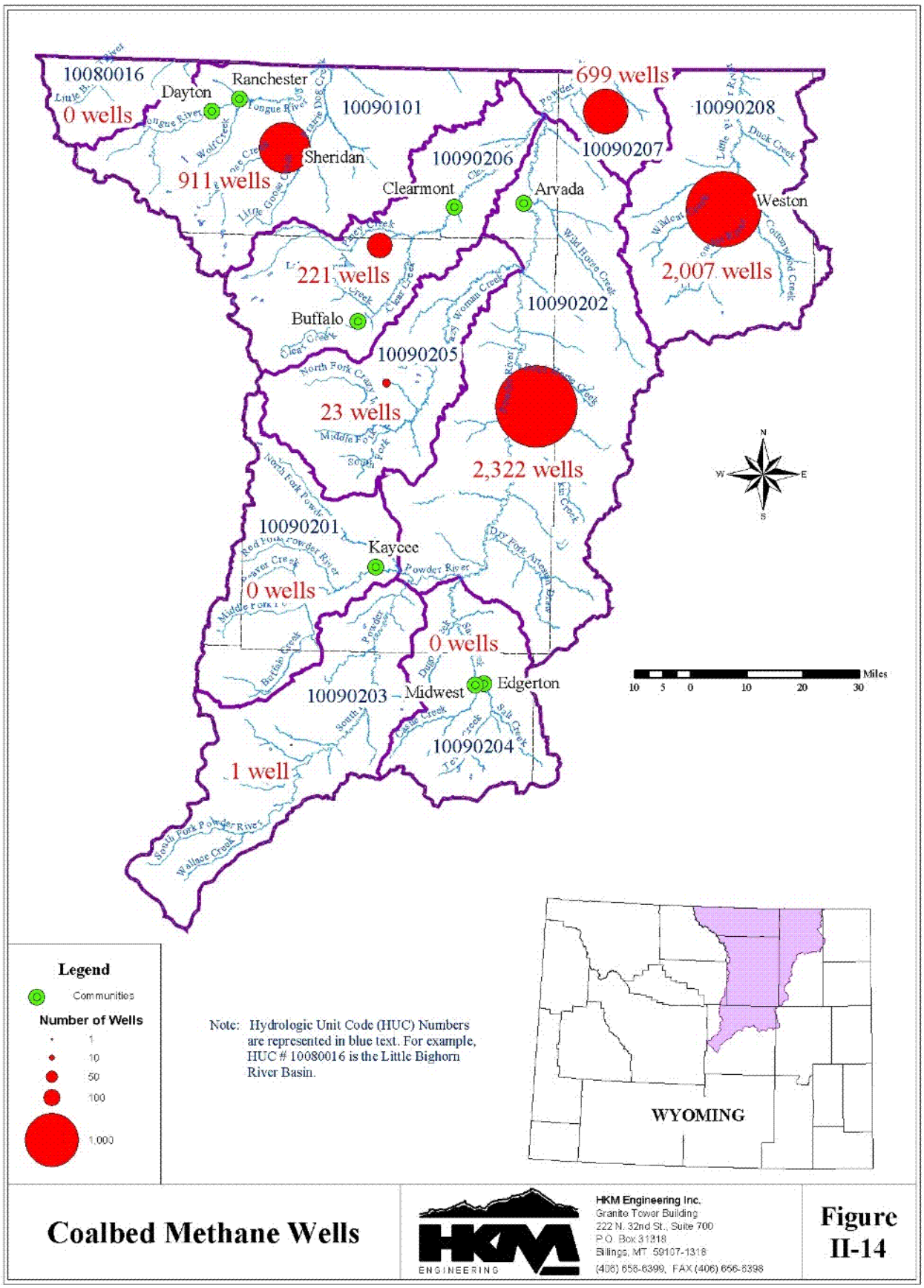
Water-based recreation is enhanced through minimum flow releases from reservoirs, minimum pool levels maintained in reservoirs, and instream flow water rights established on streams. These water administration topics are addressed in the environmental section of this chapter.

Data compiled for water-related recreational use is presented to the extent it is available. This report does not address the economic impacts of recreation in the planning area, although this data is presented in the Technical Memorandum prepared for this topic.

Boating

Many of the streams and lakes in the study area support boating activities, including whitewater, scenic, fishing, and water skiing. Boaters tend to use Dome Lake No. 1, Kearney, Lake DeSmet, Tie Hack, Twin Lakes, and Willow Park reservoirs, with Lake DeSmet getting the greatest share of motorized boating. Boating is a non-consumptive use because it depends on waters being maintained for other purposes.

Because permits are not required for boating anywhere in the planning area, usage numbers that could indicate capacity limits and pressures are not available from management agencies. The Bureau of Reclamation's default figure of one boat per ten surface acres of water is used to estimate capacities elsewhere, but until use numbers are generated in the study area to support this estimate that guideline cannot be used.



Coalbed Methane Wells

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Figure II-14

At present, no central agency monitors or controls float trips on the streams in the study area, although individuals do occasionally float the Powder River. No records are available to quantify this use of streams within the basin.

Fishing

Fishing represents the biggest recreation-related water use in the Powder/Tongue River Basin. This use is non-consumptive 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 section of the report.

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

Two Class 1 streams and many Class 2 streams in the Powder/Tongue River Basin provide significant evidence of the high quality of water and habitat found in the basin.

The Wyoming Game and Fish Department (WGFD) maintains records of fishing activity. According to recent records, the 204 streams in the Powder/Tongue study area tracked by the WGFD experience about 121,000 angler-days annually. Standing water (ponds, lakes, reservoirs) see about 109,000 angler-days in a year. These WGFD estimates are not all current and do not include the lower reaches of many drainages in the planning area. Updated estimates of fishing activity were developed for this planning study to reflect current activity in the entire planning area. These estimates indicate that the Powder/Tongue River Basin experiences approximately 140,000 activity-days of stream fishing each year and 132,000 activity-days of fishing on standing waters.

Basin management plans developed by WGFD provide additional information on fishing in the study area. This data is summarized below:

Little Bighorn River Drainage

Streams ---------- 7,039 angler-days/year
Standing Water ---------- 238 angler-days/year

Tongue River Drainage, excluding Goose Creek

Streams ---------- 57,111 angler-days/year
Standing Water ---------- 10,204 angler-days/year

Goose Creek Drainage

Streams	15,266 angler-days/year
Standing Water	10,337 angler-days/year

Clear Creek Drainage

Streams	31,382 angler-days/year
Standing Water*	57,280 angler-days/year
Lake DeSmet	43,389 angler-days/year

*excluding Lake DeSmet

Crazy Woman Creek Drainage

Streams	11,046 angler-days/year
Standing Water	4,262 angler-days/year

Middle Fork Powder River Drainage

Streams	14,914 angler-days/year
Standing Water	1,668 angler-days/year

Little Powder River Drainage

Streams	2,573 angler-days/year
Standing Water	518 angler-days/year

Powder River Drainage, excluding Clear Creek, Crazy Woman Creek, Middle Fork Powder River, and Little Powder River

Streams	891 angler-days/year
Standing Water	3,769 angler-days/year

Waterfowl Hunting

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 Powder/Tongue River Basin, which represents the western extreme of the central flyway, waterfowl hunting is pursued where sufficient local or migratory populations are available.

Harvest objectives are not currently used (post-1993), because harvest is taken into account in the setting of season length and bag limits by the USFWS using the "Adaptive Harvest Management" concept. 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 basin.

Similarly, 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 USFWS, states can set special

seasons to allow depredation harvest from growing local flocks. According to historic estimates, the Rocky Mountain Population (RMP) of Canada geese has grown approximately four-fold since 1972. Since 1989, populations have increased at a rate of eight percent per year.

Lake DeSmet

Lake DeSmet, the biggest standing water recreation attraction in the Powder/Tongue River Basin, supports skiing, fishing, swimming, boating, and camping and has a long history of doing so, despite its history of ownership by private corporations. Named after an early Jesuit priest, the lake now hosts the annual Buffalo Lions Club annual Memorial Day Weekend fishing Derby, which draws 5,000 – 7,000 people.

The lake began as a 1,500-surface-acre natural lake and was developed into a reservoir with 3,265 surface acres at operational maximum. It has an average depth of 69 feet and a maximum depth of 120 feet at capacity. This supports what the Wyoming Game and Fish Department calls "the most important reservoir trout fishery in northeastern Wyoming." At least part of what makes the lake so valuable a fishery is its stable volume. The industrial rights for the lake are not developed at present, allowing the lake's level to be maintained within four to seven feet of capacity during most years. This also provides a stable base for boating under normal circumstances.

Recreation in the lake was permitted by Texaco, which allowed boat ramps and public toilets. Current facilities include 36 camping spots, two boat ramps, a subsidiary boat launching area, and three public toilets. In 2001 the lake underwent a change in ownership from Texaco to a coalition of Johnson, Sheridan, and Campbell counties. The coalition owns the water only. A little more than 30 acres were given to Johnson County as part of the transfer, but the area south of the main boat ramps, which was previously leased, will not be developed until funding becomes available.

Public access amenities, including restrooms, boat ramps, docks, picnic areas, and camping facilities, attract many visitors to Boat Dock Bay and Barkey Draw within the Mikesell-Potts access area. Texaco, Johnson County Recreation District, the Buffalo Lion's Club, and WGFD have provided resources for development and maintenance of public access. Estimates of public access and use are not available for Lake DeSmet. Although access fees have been collected since 1997, fee collection provides only a general indication of recreational use of the lake's facilities.

The WGFD stocks and maintains the fishery in Lake DeSmet primarily for the Eagle Lake Rainbow Trout, but a number of species have been caught or spotted in the lake in the past 10 years. Fishing pressure on the lake has been calculated to be 43,400 angler-days (13.3/acre) and 166,300 hours (51/acre) in a 1991 creel survey. It is estimated 90 percent of these anglers come from the three nearby counties of Johnson, Sheridan, and Gillette.

F. Environmental Use

Environmental uses of water in the Powder/Tongue River Basin are largely non-consumptive. For instance, instream flows by definition maintain water in the channel to improve habitat.

This section of the report discusses the water administration topics of minimum flow releases, minimum pool maintenance, and instream flow water rights. Other topics included in this section include environmental concerns associated with water produced by coalbed methane development, wetland mapping, and comments and concerns of groups with environmental interests.

Water Administration

Minimum flow releases from reservoirs, minimum pool levels maintained in reservoirs, and instream flow water rights established on streams are all intended to protect and enhance water-related habitat. A major and desired consequence of implementing these water administration criteria is the increase in recreational opportunities and use.

According to the WGFD, minimum flow releases and minimum reservoir pools have been integrated into the operating parameters of seven reservoirs in the Powder/Tongue River Basin. These reservoirs and the associated operating parameters are described in Table II-10.

Table II-10
Minimum Flow Releases and Minimum Conservation Pools

Reservoir	Minimum Flow Release (CFS)	Minimum Pool (Acre-Feet)
Park	4.5	588
Dull Knife	None	100
Willow Park	None	325
Kearney	None	Original Lake
Cloud Peak	None	Original Lake
Tie Hack	6.0	780
Twin Lake	Lesser of 2.5 or inflow	None

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. Instream flow rights are filed with the Wyoming State Engineer's Office, held by the Wyoming Water Development Commission, and managed by Wyoming Game and Fish.

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." Generally speaking, instream flow is considered a non-consumptive beneficial use.

Instream flow segments in the Powder/Tongue River Basin are described in Table II-11 and shown on Figure II-15. Of the six instream flow applications, the Wyoming State Engineer's Office has granted water rights for the segments on the Little Bighorn River, Middle Fork Powder River, and Tongue River. Evaluation and action on the other segments are pending. In addition to the six segments described in Table II-11, WGFD is currently evaluating a number of streams in the Powder/Tongue River Basin as candidates for instream flow water right applications.

Coalbed Methane Water Production

Coalbed methane (CBM) is produced by lowering the pressure over the coal seam through reducing the column of water in the coal aquifer. Environmental concerns related to the water produced from CBM wells fall into two categories: quantity and quality.

Environmental concerns about this quantity of ground water now flowing over the surface include: 1) increased sedimentation in streams; 2) increased erosion in everything from the draws and gullies collecting the discharges to main-stem rivers downstream; 3) constant presence of water over soils in areas historically watered only in brief episodes; and, 4) increased flooding.

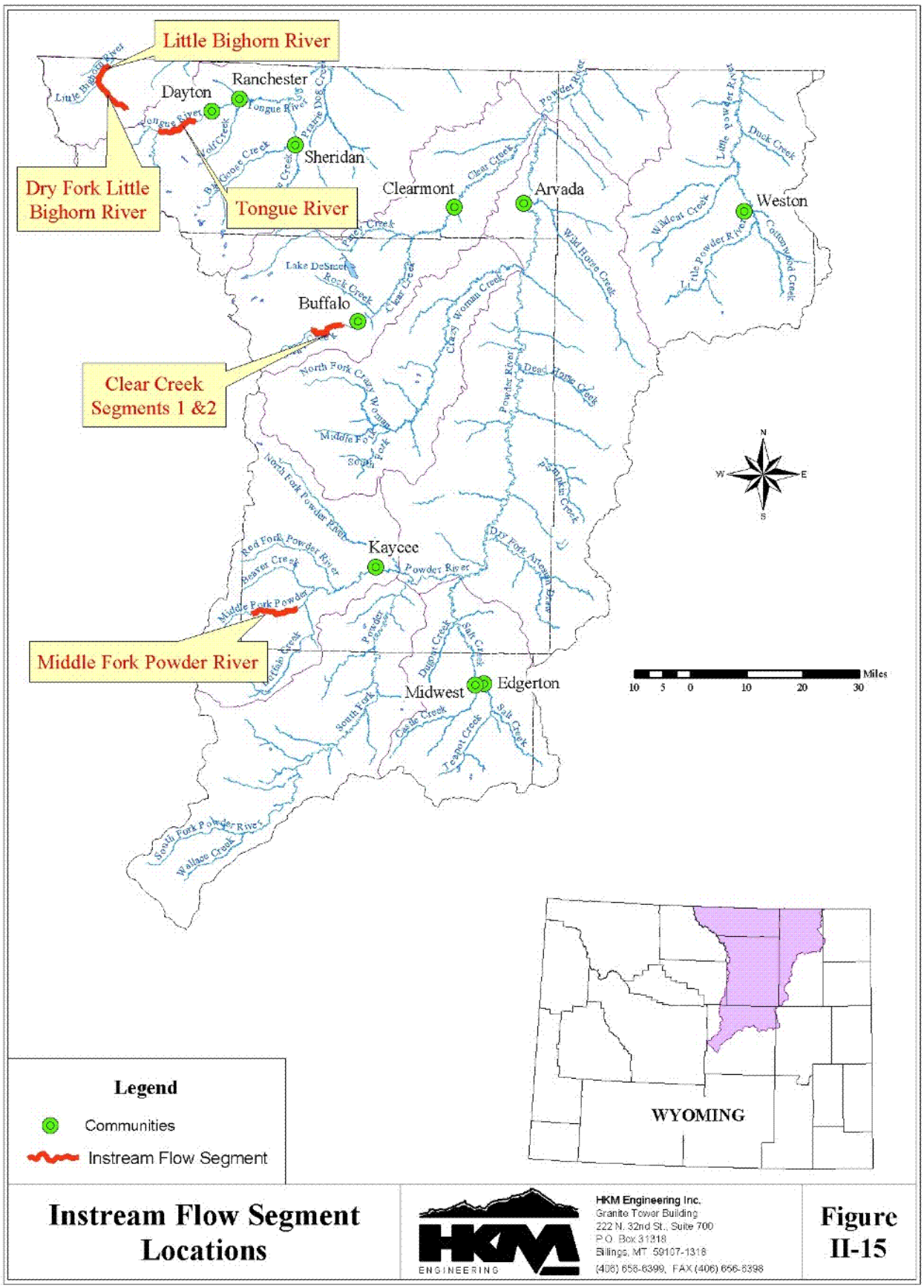
Water quality concerns associated with CBM activity include: 1) the interaction of sodium-adsorption ratio (S.A.R.) in the produced water with soils downstream of the discharge; 2) the variable nature of potential pollutants like sodium, barium, iron, and manganese in produced waters; 3) the emergence of salt crusts on newly waterlogged clays; and, 4) the reaction of organisms (from microinvertebrates to fish to humans) to the produced waters in draws, ponds, or rivers.

The Wyoming Department of Environmental Quality (DEQ) has established a general permit for CBM discharge waters. Under this permit operators are required to monitor discharges following a specified schedule, and for specified parameters, to determine if the quality of the discharge is within allowable limits. The coverage of the operators under the general permit is dependent on staying within the limits established by DEQ.

Table II-11
Instream Flow Water Rights

Stream	Location	Flow/Timing	Priority
Little Bighorn River Drainage			
Dry Fork [1]	Mouth of Garland Gulch (Section 35, T57N, R89W) to mouth of Dry Fork (NE ¼ of the NW ¼, Section 12, T57N, R90W) (7.4 miles long)	20 cfs, Oct. 1 – March 31 25 cfs, April 1 – June 30 25 cfs, July 1 – Sept. 30 [1]	11/30/2000
Little Bighorn River	Mouth of Dry Fork (NE ¼ of NW ¼, Section 12, T57N, R90W) to north boundary of SW ¼ of SW ¼, Section 20, T58N, R89W (4.40 miles long)	60 cfs, Oct. 1 – Nov. 15 50 cfs, Nov. 16 – March 31 60 cfs, April 1 – June 30 62 cfs, July 1 – Sept. 30	3/6/1989
Powder River Drainage			
Clear Creek No. 1	Confluence of North and South Clear Creek (NW ¼ of SE ¼ of Section 7, T50N, R83W) to the SE ¼ of NW ¼, Section 10, T50N, R83W (4.9 miles long)	7.8 cfs, Oct. 1 – March 31 40 cfs, April 1 – June 30 30 cfs, July 1 – Sept. 30	10/6/1994
Clear Creek No. 2	Ending point of Clear Creek No. 1 to SE ¼ of NW ¼, Section 6, T50N, R82W, approximately 750 feet downstream of USGS Gage No. 06318500 (3.2 miles long)	6 cfs, Oct. 1 – March 31 40 cfs, April 1 – June 30 25 cfs, July 1 – Sept. 30	10/6/1994
Middle Fork Powder River	West side of Section 28, T42N, R85W to east boundary of NE ¼ of NE ¼, Section 22, T42N, R84W (9.96 miles long)	12 cfs, July 1 – March 31 25 cfs, April 1 – June 30	2/2/1987
Tongue River Drainage			
Tongue River	USFS boundary upstream to the confluence of the South Fork of the Tongue. From the confluence of the North and South Forks (NE ¼ of NW ¼, Section 22, T56N, R88W) downstream to east section of Section 10, T56N, R87W (8.28 miles long)	60 cfs, July 1 – March 31 80 cfs, April 1 – April 30 180 cfs, May 1 – June 30	6/16/1987

[1] WGFD also recommends a channel maintenance flow as part of the instream flow allocation for the Dry Fork of the Little Bighorn River. This recommendation has not been approved by the State Engineer's Office.



Instream Flow Segment Locations

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Figure II-15

Organizations outside the state government have been calling for more information to form the basis for regulation of CBM produced water. For instance, a memorandum distributed by the Coalbed Methane Coordination Coalition (CBMCC) assesses the need for further research on discharge alternatives:

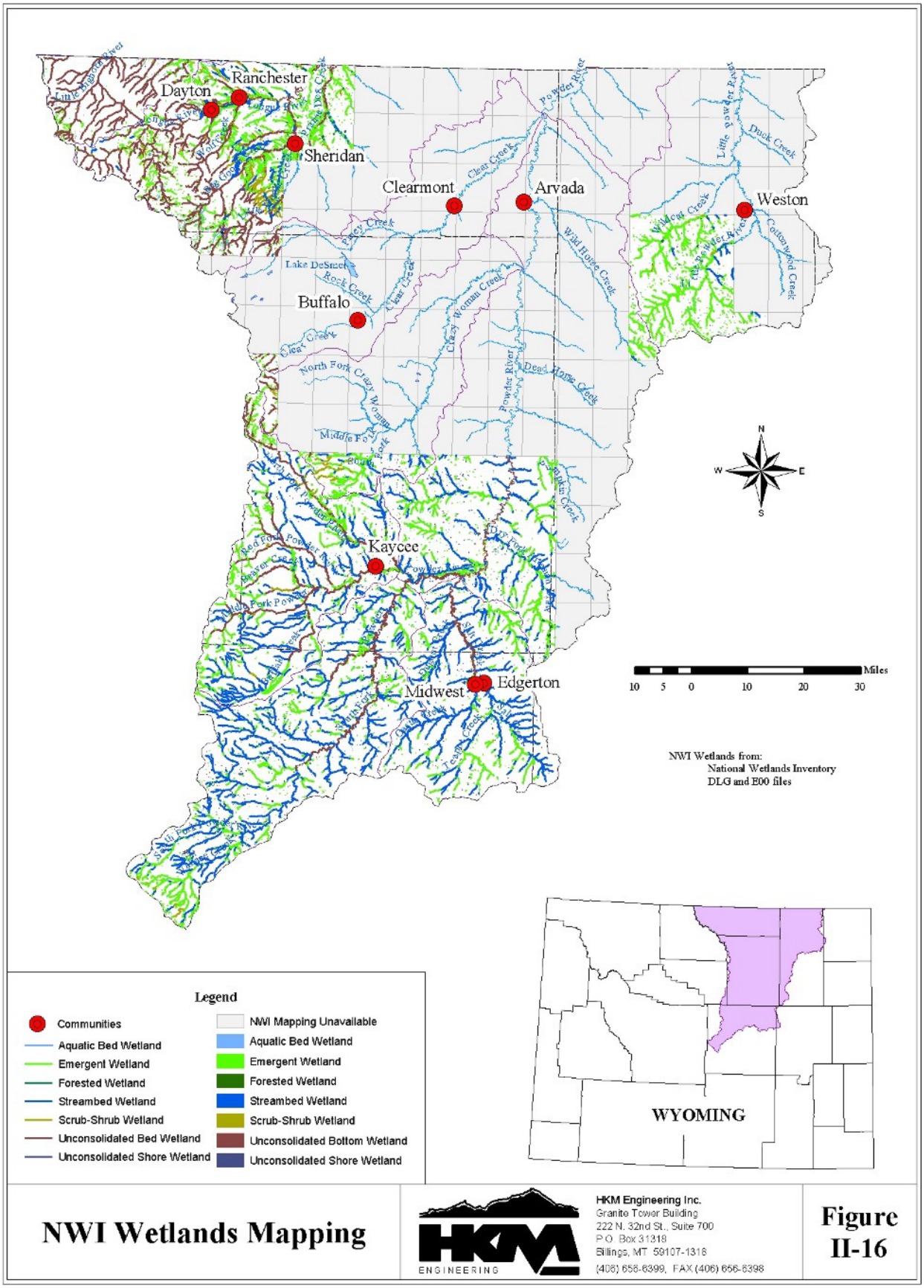
> *Watershed-based water management plans and landowner associations are key to controlling impact and taking maximum advantage of produced water. Alternatives to discharge such as irrigation, storage and retrieval, dust control, and fire suppression all must be tested and evaluated. Consideration must be given to surface water, alluvial underflow, and ground water. The effects of recharge on alluvium are difficult to study yet very important as alluvial aquifers are important for agriculture. On the obverse of the coin, drawdown issues must be addressed in the deeper aquifers. Means to minimize and mitigate transboundary effects on downstream parties must be identified and implemented where appropriate.*

Wetlands Mapping

Wetlands are transitional lands 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 the 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; and
- the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

The wetlands classification system is described in the environmental uses technical memorandum. Figure II-16 displays the wetland mapping of the Powder/Tongue River Basin compiled by the National Wetlands Inventory (NWI).



NWI Wetlands Mapping

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Figure II-16

Comments and Concerns

As part of this task, groups with environmental concerns were identified and contacted to solicit comments and concerns on environmental issues in this basin. Each of the groups were asked the following questions:

- What are the basic environmental demands/uses in the Powder/Tongue River Basin at present?
- How have those changed in the past few decades?
- How are they likely to change in the next 30 years?

Responses were received from the Wyoming Game and Fish Department, Wyoming Natural Diversity Database, Nature Conservancy, Wyoming Outdoor Council, Powder River Basin Resource Council, Ducks Unlimited, American Rivers, Sierra Club, and the U.S. Fish and Wildlife Service. Responses from these organizations are summarized in the following list. Details of the responses are presented in the technical memorandum prepared for this topic.

- Quantity and quality of water produced by coalbed methane development
- Impediments to fish migration imposed by dams and irrigation facilities
- Protection and enhancement of wetlands, riparian habitat, and fisheries
- Impact of reservoir level fluctuations on fisheries
- Inadequacies of the TMDL program
- Protection and enhancement of habitat for threatened and endangered species

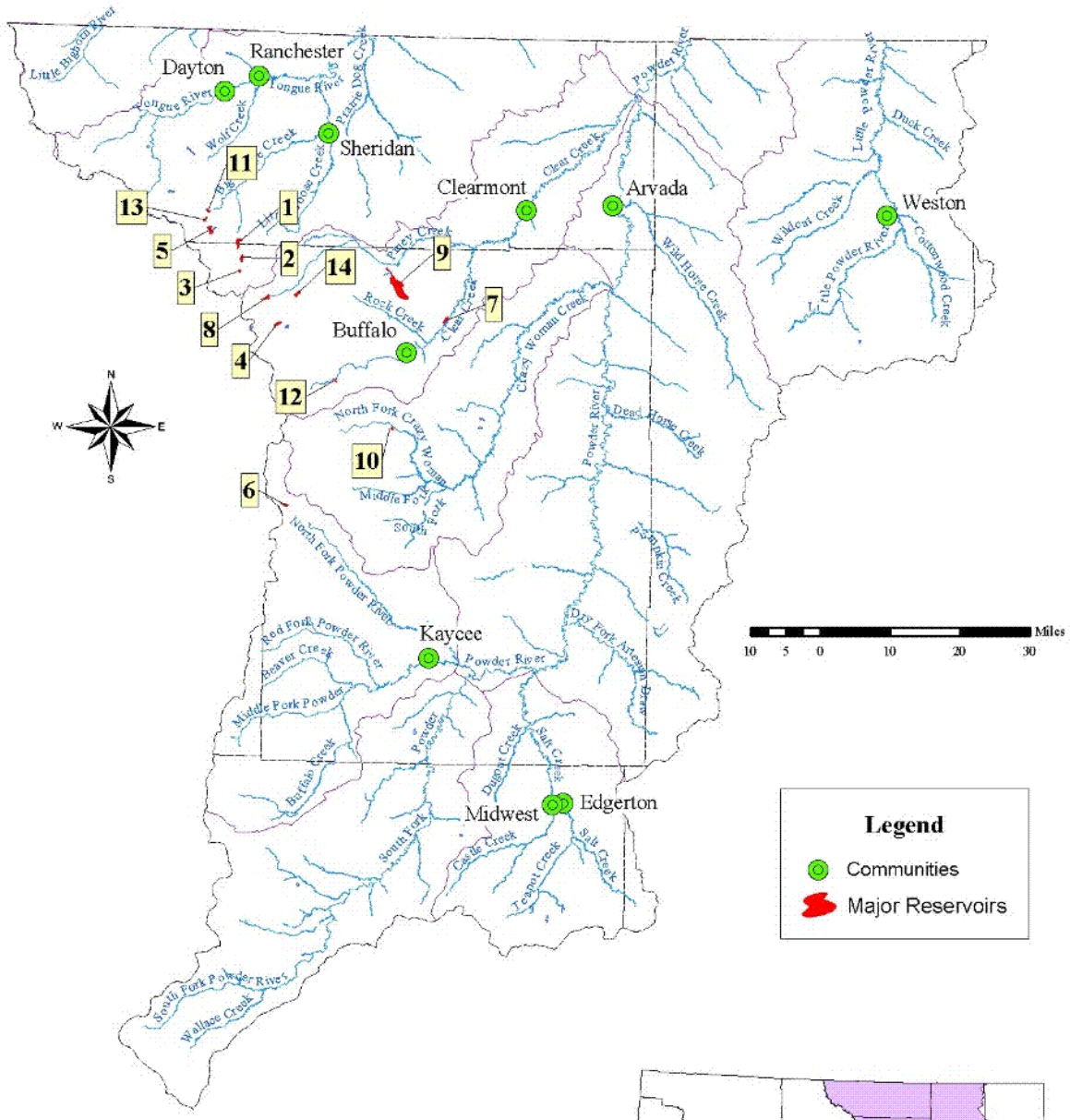
G. Reservoir Evaporation

Operation data has been compiled for the key storage facilities within the planning area. The list of reservoirs, developed in coordination with the State Engineer's Office Division 2 personnel, primarily consists of reservoirs with capacities in excess of 1,000 acre-feet, although one smaller facility was included to provide a complete representation of the significant facilities. The majority of water use from storage reservoirs within the Powder/Tongue River Basin is for irrigation. However, Tie Hack and Twin Lakes Reservoirs primarily supply municipal uses and Lake DeSmet is primarily intended to supply industrial water demands. The diversion records compiled for this study and used to estimate actual irrigation diversions and depletions, reflect the use of this supplemental storage water. Table II-12 lists the key storage facilities in the planning area.

Table II-12
Key Storage Reservoirs

Reservoir	Active Capacity (af)	Dam Height (ft)	Surface Area (acres)	Annual Net Evap. Loss (af)
Big Goose Park	10,362	85	318	557
Big Horn	4,624	45	179	296
Cross Creek	798	30	51	278
Cloud Peak	3,570	36	174	85
Dome Lake No. 1	1,506	30	96	8,372
Dull Knife	4,345	80	130	170
Healy	5,140	50	246	205
Kearney Lake	6,324	67	193	556
Lake Desmet	111,827	80	2653	291
Muddy Guard No. 2	1,934	57	48	113
Sawmill	1,275	38	75	136
Tie Hack	2,435	110	63	148
Twin Lakes	1,317	54	52	112
Willow Park	4,457	56	213	N.A.

The locations of these reservoirs are shown on Figure II-17. In addition to the detailed information compiled for these 14 key facilities, statistical data has also been compiled for 189 additional reservoirs with capacities in excess of 50 acre-feet or in excess of 20 feet in height.



1. Big Goose Park (Park) Reservoir
2. Big Horn Reservoir
3. Cross Creek Reservoir
4. Cloud Peak Reservoir
5. Dome Lake, Dome Reservoir, & Dome Weir Pond
6. Dull Knife Reservoir
7. Healy Reservoir
8. Kearney Lake
9. Lake DeSmet
10. Muddy Guard No. 2 Reservoir
11. Sawmill Reservoir
12. Tie Hack Reservoir
13. Twin Lakes
14. Willow Park Reservoir

Major Reservoirs

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Figure II-17

Evaporation from man made storage reservoirs constitutes another consumptive use of water within the planning area. The net evaporation volume from the key storage reservoirs is determined by multiplying the net depth of evaporation (gross evaporation minus precipitation) by the water surface area of the respective reservoirs. Normal precipitation depths across the planning area were shown on Figure I-2.

End-of-month storage records are available for only four of the key reservoirs (Twin Lakes, Tie Hack, Healy, and Lake DeSmet). The average, monthly water surface area was determined for these four facilities using these records and when multiplied by the net monthly evaporation loss, yielded total evaporation volumes.

Relationships of average monthly end-of-month storage to total reservoir capacity were developed for the four facilities with historical records. These monthly proportions were averaged for the four reservoirs and applied to the total reservoir capacities of the remaining 10 facilities, in order to make reasonable estimates of monthly storage volumes and the corresponding water surface areas for these facilities as well. With this information, evaporation volumes for the remaining 10 facilities was determined. Total reservoir evaporation is estimated at 11,300 acre-feet for the 14 major reservoirs in the planning area (See Table II-12).

H. Basin Water Use Summary

Table II-13 summarizes the water consumption (depletions) for the various existing uses in the planning area.

Table II-13
Summary of Current Water Uses

Water Use	Dry		Normal		Wet	
	(AF/Year)					
	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water
Agricultural	178,000	200	184,000	200	194,000	300
Municipal	2,700	500	2,700	500	2,700	500
Domestic	---	4,400	---	4,400	---	4,400
Industrial[1]	---	68,000	---	68,000	---	68,000
Recreation	Non-consumptive					
Environmental	Non-consumptive					
Evaporation	11,300		11,300		11,300	
TOTAL	192,000	73,100	198,000	73,100	208,000	73,200

Note 1: Includes conventional oil and gas production water and CBM production water.

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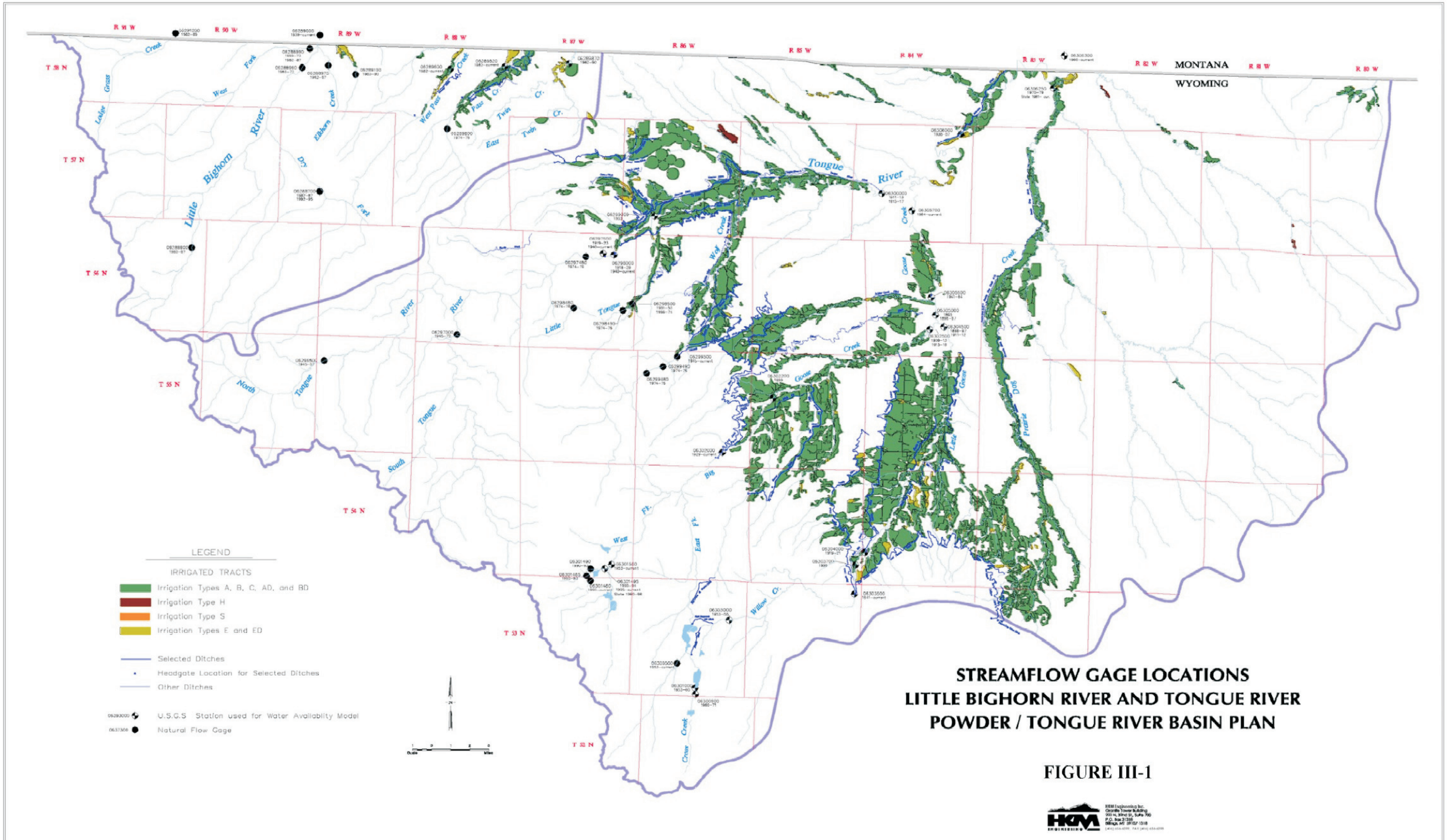

STREAMFLOW GAGE LOCATIONS
LITTLE BIGHORN RIVER AND TONGUE RIVER
POWDER / TONGUE RIVER BASIN PLAN

FIGURE III-1

LEGEND

IRRIGATED TRACTS

- Irrigation Types A, B, C, AD, and BD
- Irrigation Type H
- Irrigation Type S
- Irrigation Types E and ED

- Selected Ditches
- Headgate Location for Selected Ditches
- Other Ditches

- 06362000 U.S.G.S. Station used for Water Availability Model
- 06373000 Natural Flow Gage
- State of Wyoming Gage not at a U.S.G.S. Station used for Water Availability Model

MONTANA

WYOMING

Clear Creek

Lake De Smet

STREAMFLOW GAGE LOCATIONS
CLEAR CREEK
POWDER / TONGUE RIVER BASIN PLAN

FIGURE III-2

LEGEND

IRRIGATED TRACTS

- Irrigation Types A, B, C, AD, and BD
- Irrigation Type H
- Irrigation Type S
- Irrigation Types E and ED

- Selected Ditches
- Headgate Location for Selected Ditches
- Other Ditches

- 06393000 U.S.G.S Station used for Water Availablity Model
- 0637300 Natural Flow Gage

MONTANA
WYOMING

R 77 W R 76 W R 75 W R 74 W R 73 W

T 58 N T 57 N T 56 N T 55 N T 54 N T 53 N T 52 N T 51 N T 50 N

R 85 W R 84 W R 83 W R 82 W R 81 W R 80 W R 79 W R 78 W R 77 W R 76 W R 75 W R 74 W R 73 W

T 49 N T 48 N T 47 N T 46 N T 45 N T 44 N T 43 N T 42 N T 41 N T 40 N T 39 N T 38 N T 37 N T 36 N T 35 N T 34 N T 33 N T 32 N

Powder River
Crazy Woman Creek
Dead Horse Creek
North Fork Powder River
Middle Fork Powder River
South Fork Powder River
Red Fork Powder River
Beaver Creek
Poison Cr.
Middle Fork
North Fork
South Fork
Rock Creek
Buffalo Creek
Diamond Creek
Salt Creek
Wallace Creek
Stroble Creek
N. Fk.
S.Fk.

STREAMFLOW GAGE LOCATIONS
POWDER RIVER
POWDER / TONGUE RIVER BASIN PLAN

FIGURE III-3

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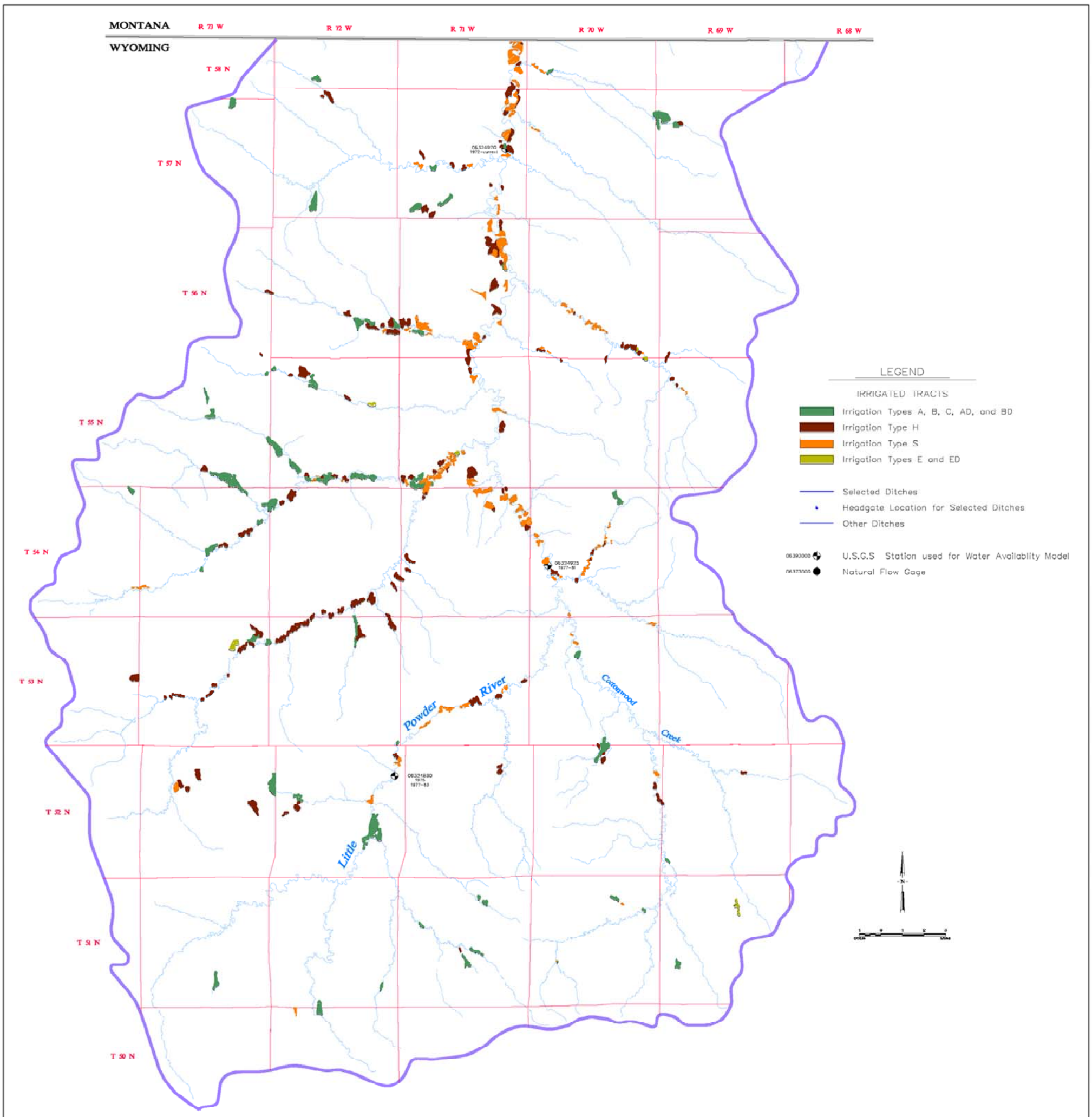

STREAMFLOW GAGE LOCATIONS
LITTLE POWDER RIVER
POWDER / TONGUE RIVER BASIN PLAN

FIGURE III-4

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regulations are characterized as natural flow stations. Where reasonably possible, those gages that are impacted by upstream irrigation depletions were adjusted to remove these effects. The list of streamflow gages inventoried for this study is provided in Table III-1.

Records from an additional 40 to 50 streamflow gaging stations are available beginning in the 1970s and 1980s in comparison to those gages with earlier records.

Study Period

It is important in any water availability evaluation to select a study period that is long enough to include a variety of hydrologic conditions including an extended period of dry years as well as wet years and normal years. At the same time, it is also important not to select a study period so long that many streamflows must be synthesized to fill-in missing data.

The USGS has maintained a streamflow station on the Tongue River near Dayton (#06298000) since 1919 and continuous records are available from 1941 to present (Table III-1). This station is impacted by diversions to the Highline Ditch just upstream of the gage. Natural flow at this station is therefore determined by adding these recorded diversions to the recorded streamflow. The 59-year period of continuous record for this station (1941 through 1999) is selected as the best single representation of long term natural hydrologic conditions in the basin. Figure III-5 is a Cumulative Surplus/Deficit plot for the Tongue River near Dayton and represents a running total of the annual deviations from the long-term mean annual streamflow. Downward sloping lines (left to right) represent periods of time during which annual streamflow is less than the long-term mean. Conversely, upward sloping lines represent years which are wetter than average. As shown on Figure III-5, the periods from 1941 through 1947 and from 1962 through 1978 can be generally characterized as wet periods, whereas the periods from 1948 through 1961 and from 1979 through 1989 can be generally characterized as dry periods. The period from 1990 through 1999 can generally be characterized as near average. Exceptions to each of these generalities exist within each period. By way of example, 1966 is a dry year within a generally wet period of years and 1984 is a wet year within a generally dry period. Based on an evaluation of the long-term hydrologic conditions on the Tongue River, together with the an understanding of the availability of historic streamflow records, the 30-year period 1970 through 1999 was selected as a candidate study period. Selection of this potential study period is also influenced by the fact that ditch diversion records are available predominantly for the period after 1970. Both streamflow records and ditch diversions records are needed to develop water availability models that accurately simulate existing water use in the basin. As shown on Figure III-5, the average annual flow of the Tongue River near Dayton, for the period 1970 – 1999, is essentially equal to the long-term (1941 – 1999) average annual flow (133,175 AF vs. 133,210 AF).

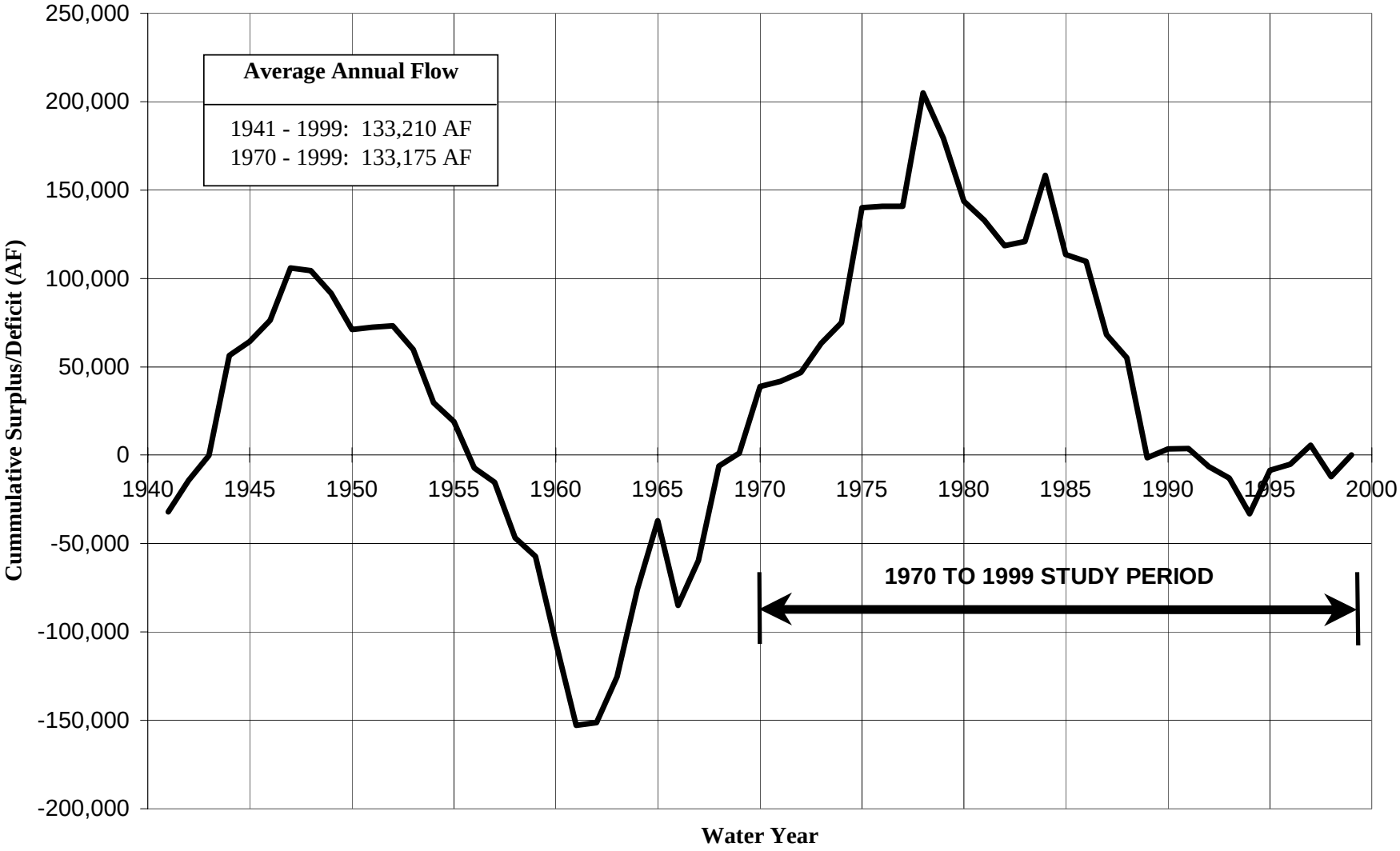
The representativeness of the 1970 to 1999 study period was further evaluated by reviewing long-term natural flow gages that more completely represent the entire Powder/Tongue River Basin, including the Little Bighorn River, the Tongue River, and the Powder River. Three gages with relatively long periods of record are selected for this purpose: 1) Little Bighorn River at State Line (#06289000); 2) Tongue River near Dayton (#06298000); and North Fork Powder River near Hazelton (#06311000). The average annual flow for the period 1970 to 1999 is relatively close to

Table III-1
Streamflow Stations in the Powder/Tongue River Basin

Basin	Station Number	Station Name	Natural Flow	Period of Record in Water Years **	Note
Little Bighorn	**06288600**	Little Bighorn River Below Dayton Gulch Near Burgess Junction, WY	YES	1983-1987	
	06288700	Dry Fork Little Bighorn Below Lick Creek Near Burgess Junction, WY	YES	1983-1987, 1993-1995	
	06288960	Little Bighorn River Near Parkman, WY	YES	1970-1972	
	06288975	Elkhorn Creek Above Fuller Ranch Ditch Near Parkman, WY	YES	1983-1987	No winter records in 1985
	06288990	West Fork Little Bighorn River Near Parkman, WY	YES	1970-72, 1983-1987	No winter records in 1987
	06289000	Little Bighorn River at State Line Near Wyola, MT	YES	1939-current	
	06289100	Red Canyon Creek Near Parkman, WY	YES	1982-1990	No winter records in 1985, 1987
	06289500	Little Bighorn River Near Wyola, MT	NO	1912-1924	No winter records; Abt. 7 mi. into MT
	06289600	West Pass Creek Near Parkman, WY	NO	1983-current	No winter records 1985-1987
	06289800	East Pass Creek Near Parkman, WY	YES	1975-1976	
	06289820	East Pass Creek Near Dayton, WY	NO	1983-current	
	06289870	Twin Creek Near Parkman, WY	NO	1983-1990	No winter records 1985-1987
	06290000	Pass Creek Near Wyola, MT	NO	1939-1975	Winter records incomplete before 1939; Abt. 4 mi. into MT
	06290500	Little Bighorn River Below Pass Creek Near Wyola, MT	NO	1939-1975	Abt. 13 mi. into MT
	06291200	Lodge Grass Creek at State Line Near Wyola, MT	YES	1982-1989	No winter records 1986
Tongue	**06296500**	North Fork Tongue River Near Dayton, WY	YES	1945-1958	No winter records before 1950
	06297000	South Fork Tongue River Near Dayton, WY	YES	1945-1972	
	06297480	Tongue River at Tongue Canyon Campground Near Dayton, WY	YES	1975-1979	
	06298000	Tongue River Near Dayton, WY	YES	1919-1929, 1941-current	Adjusted using Highline Ditch Near Dayton, WY (06297500) as published
	06298480	Little Tongue River at Steamboat Point Near Dayton, WY	YES	1975-1976	
	06298490	Little Tongue River Above South Fork Little Tongue River Near Dayton, WY	YES	1975-1976	
	06298500	Little Tongue River Near Dayton, WY	YES	1951-1974	
	06299000	Tongue River at Dayton, WY	NO	1903-1904	Seasonal (May 1903 to Oct. 1904)
	06299480	Wolf Creek Below Alden Creek Near Wolf, WY	YES	1975-1976	
	06299490	Wolf Creek Above Red Canyon Creek at Wolf, WY	YES	1975-1976	
	06299500	Wolf Creek at Wolf, WY	YES	1945-current	No winter records after 1971
	06300000	Tongue River at Carneyville, WY	NO	1911-1917	Seasonal only
	06300500	East Fork Big Goose Creek Near Big Horn, WY	YES	1954-current	No winter records after 1973
	06300900	Cross Creek Above Big Horn Reservoir Near Big Horn, WY	NO	1961-1971	
	06301000	Cross Creek Near Big Horn, WY	NO	1954-1960	
	06301480	Coney Creek Above Twin Lakes Near Big Horn, WY	YES	1991-current	No winter records 1993, 1996, 1998, 1999
	06301485	Lost Lake Creek Near Big Horn, WY	YES	1991-1993	
	06301490	Snail Creek Near Big Horn, WY	YES	1991-1993	
	06301495	Coney Creek Below Twin Lakes Near Big Horn, WY	NO	1991-1994, 1996-current	No winter records some years
	06301500	West Fork Big Goose Creek Near Big Horn, WY	NO	1954-current	No winter records after 1971
	06302000	Big Goose Creek Near Sheridan, WY	NO	1929-current	No winter records after 1971; Adjusted for diversions using PK Ditch & Sheridan City Intake Ditch
	06302200	Big Goose Creek Above Park Creek Near Sheridan, WY	NO	1999-current	Jul. - Sep. 1999
	06302500	Goose Creek at Sheridan, WY	NO	1909-1916	No winter records
	06303000	Willow Creek Near Big Horn, WY	NO	1954-1955	
	06303500	Little Goose Creek in Canyon Near Big Horn, WY	NO	1941-current	No winter records after 1971
	06303700	Little Goose Creek Above Davis Creek Near Big Horn, WY	NO	1999-current	Jul. - Sep. 1999
	06304000	Little Goose Creek Near Big Horn, WY	NO	1919-1922	No winter records 1919
	06304500	Little Goose Creek at Sheridan, WY	NO	1896-1897, 1911-1913	No winter records
	06305000	Goose Creek Below Little Goose Creek at Sheridan, WY	NO	1896-1897	No winter records
	06305500	Goose Creek Below Sheridan, WY	NO	1942-1984	
	06305700	Goose Creek Near Acme, WY	NO	1984-current	
	06306000	Tongue River Near Acme, WY	NO	1939-1957	
	06306100	Squirrel Creek Near Decker, MT	NO	1975-1986	Abt. 3.5 mi. into MT
	06306250	Prairie Dog Creek Near Acme, WY	NO	WRDS: 1965-1970; USGS: 1971-1980; SEO: 1981-1999	State data seasonal only
	06306300	Tongue River at State Line Near Decker, MT	NO	1960-current	
Powder	**06309200**	Middle Fork Powder River Near Barnum, WY	YES	1961-current	
	06309260	Buffalo Creek Above North Fork Buffalo Creek Near Arminto, WY	YES	1975-1979	
	06309270	North Fork Buffalo Creek Near Arminto, WY	YES	1975-1979	
	06309280	Buffalo Creek Below North Fork Buffalo Creek Near Arminto, WY	YES	1975-1979	
	06309450	Beaver Creek Below Bayer Creek Near Barnum, WY	YES	1975-1989	
	06309460	Beaver Creek Above White Panther Ditch Near Barnum, WY	YES	1975-1989	
	06309500	Middle Fork Powder River Above Kaycee, WY	NO	1949-1970, 1984-1992	
	06310000	Red Fork Powder River Near Barnum, WY	NO	1929-1932, 1950-1954	
	06310500	Middle Fork Powder River at Kaycee, WY	NO	1911-1913, 1929-1932	
	06311000	North Fork Powder River Near Hazelton, WY	YES	1946-current	
	06311060	North Fork Powder River Below Bull Creek Near Hazelton, WY	YES	1975-1992	
	06311400	North Fork Powder River Below Pass Creek Near Mayoworth, WY	NO	1974-current	
	06311500	North Fork Powder River Near Mayoworth, WY	NO	1941-1973	
	06312000	North Fork Powder River Near Kaycee, WY	NO	1911-1912, 1929-1932	
	06312500	Powder River Near Kaycee, WY	NO	1934-1935, 1938-1971, 1979-1980	
	06313000	South Fork Powder River Near Kaycee, WY	NO	1911-1912, 1938-1940, 1950-1969, 1979-1980, 1983-1984	
	06313180	Dugout Creek Tributary Near Midwest, WY	YES	1975-1983	
	06313400	Salt Creek Near Sussex, WY	NO	1976-1981, 1983-1993	
	06313500	Powder River at Sussex, WY	NO	1938-1940, 1950-1957, 1978-1999	
	06313700	Dead Horse Creek Near Buffalo, WY	NO	1972-1990	
	06313950	North Fork Crazy Woman Creek Below Pole Creek Near Buffalo, WY	YES	1974-1984	
	06314000	North Fork Crazy Woman Creek Near Buffalo, WY	YES	1942-1949, 1974-1984	
	06314500	North Fork Crazy Woman Creek Below Spring Draw Near Buffalo, WY	YES	1949-1972	
	06315000	North Fork Crazy Woman Near Greub, WY	NO	1950-1968	
	06315480	Poison Creek Below Tetley Spring Near Mayoworth, WY	YES	1975-1976	
	06315490	Poison Creek Near Mayoworth, WY	YES	1975-1976	
	06315500	Middle Fork Crazy Woman Creek Near Greub, WY	YES	1942-1972	No winter records 1972
	06316000	Crazy Woman Creek Near Buffalo, WY	NO	1929-1932	No winter records some years
	SEO Gage	Crazy Woman Creek at Trabing Bridge Near Buffalo, WY	NO	SEO: 1982-current	Seasonal data only
	06316400	Crazy Woman Creek at Upper Station Near Arvada, WY	NO	1963-1970, 1978-1981	
	06316500	Crazy Woman Creek Near Arvada, WY	NO	1940-1944, 1950-1964	
	06317000	Powder River at Arvada, WY	NO	1919-current	No winter records 1919-1930, 1934
	06317100	Powder River Near Arvada, WY	NO	1915-1919	No winter records
	06317300	Sourdough Creek Near Buffalo, WY	YES	1985-1990	
	06317340	Little Sourdough Creek Near Buffalo, WY	YES	1985-1988	
	06317500	North Fork Clear Creek Near Buffalo, WY	NO	1950-1968	
	06318500	Clear Creek Near Buffalo, WY	NO	1894, 1896, 1897-1900, 1917-1928, 1938-1992	Records after Oct. 1987 not equivalent due to diversion by City of Buffalo; Adjusted for diversions using 100 acres of irrigated lands upstream and 6 cfs diversion by Buffalo
	SEO Gage	Clear Creek in Buffalo City Park Buffalo, WY	NO	WRDS: 1971-1978; SEO: 1987-1999	Seasonal data only
	06319000	Clear Creek at Buffalo, WY	NO	1903-1905, 1911-1912	No winter records
	06319470	South Rock Creek at Forest Boundary Near Buffalo, WY	YES	1975-1976	
	06319480	South Rock Creek Above Red Canyon Near Buffalo, WY	YES	1975-1976	
	06319500	South Fork Rock Creek Near Buffalo, WY	NO	1941-1943, 1950-1954	No winter records 1941-1943
	06320000	Rock Creek Near Buffalo, WY	NO	1941-current	No winter records after 1971; Adjusted for irrigation using Mowry Basin Ditch
	SEO Gage	Rock Creek at Mouth Near Buffalo, WY	NO	WRDS: 1971-1975, 1977-1978; SEO: 1980-1981, 1983, 1985-1988, 1990-1999	Seasonal data only
	06320200	Clear Creek Below Rock Creek Near Buffalo, WY	NO	USGS: 1976-1981; SEO: 1982-1985, 1987-1999	State data mostly seasonal
	06320400	Clear Creek at Ucross, WY	NO	1976-1981	
	SEO Gage	Clear Creek Below Healy Reservoir Near Buffalo, WY	NO	1977-1999	State data mostly seasonal
	06320500	South Piney Creek at Willow Park Reservoir, WY	NO	1945-1957, 1960-current	No winter records before 1948 and after 1971
	06321000	South Piney Creek Near Story, WY	NO	1951-1980	No winter records 1972-1974
	06321100	South Piney Creek Below Mead-Coffeen Ditch Near Story, WY	NO	1975-1979	
	06321500	North Piney Creek Near Story, WY	YES	1951-1982	
	06321800	Spring Creek Near Story, WY	NO	1975-1979	
	06323000	Piney Creek at Kearney, WY	NO	1902-1906, 1910-1917, 1919-1923, 1941-current	No winter records some years
	SEO Gage	Little Piney Creek, WY	NO	SEO: 1981, 1983, 1985-1986, 1988, 1991-1999	Seasonal data only; from spot measurements
	SEO Gage	Piney Creek Below Lake DeSmet Tunnel Intake Near Story, WY	NO	WRDS: 1971-1973, 1977, 1979; SEO: 1980-1984, 1986-1996	Mostly seasonal data
	06323500	Piney Creek at Ucross, WY	NO	USGS: 1917-1923, 1980-1982; SEO: 1983-1987, 1989-1998	No winter records 1917-1923; State data seasonal only
	SEO Gage	Clear Creek at Double Crossing Near Clearmont, WY	NO	WRDS: 1973-1978; SEO: 1980-1996, 1998-1999	Seasonal data only
	SEO Gage	Clear Creek Below P&F#3 Ditch Near Clearmont, WY	NO	WRDS: 1978; SEO: 1980-1999	Seasonal data only
	06324000	Clear Creek Near Arvada, WY	NO	1915-1919, 1928-1929, 1940-1982	No winter records before 1929
	06324500	Powder River at Moorhead, MT	NO	1929-1972, 1975-current	Abt. 4 mi. into MT
Little Powder	**06324890**	Little Powder River Below Corral Creek Near Weston, WY	NO	1978-1981	
	06324925	Little Powder River Near Weston, WY	NO	1977-1981	
	06324970	Little Powder River Above Dry Creek Near Weston, WY	NO	1973-current	
Belle Fourche	**06426500**	Belle Fourche River Below Moorcroft, WY	NO	1943-1970, 1976-1983, 1986-1987, 1991-current	

** Unless otherwise noted, records were obtained from the USGS.

Figure III-5
Cumulative Surplus/Deficit of Annual Historic Flows -
Tongue River Near Dayton, WY (Station 06298000) - 1941 to 1999



the 1947 to 1999 average annual flow for the three stations (1% to 4% wetter). This period also includes a variety of wet, normal, and dry years at all three locations.

In summary, the period 1970 through 1999 contains 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 planning area. This period also has the greatest abundance of recorded streamflow data and ditch diversion data and therefore requires less data synthesis. A study period of 1970 through 1999 was therefore selected as appropriate for purposes of water availability modeling for the Powder/Tongue River Basin Plan.

A more detailed discussion and supporting documentation for the selection of the study period are provided in the "Surface Water Hydrology" technical memorandum.

Data Extension

The spreadsheet modeling approach used for the Basin Plan relies on both records of natural flow as well as records from stations impacted by upstream diversions or regulation. Natural flow is supplied to the model, where available, at the headwater nodes and non-natural flow records at downstream gaging stations are used to calibrate the model to historic conditions. Monthly streamflows must therefore be estimated for both categories of gaging stations for those months, during the study period, with no recorded streamflow data.

The monthly record extension approach used in this study follows the procedure used by the USGS in recent studies. This mixed-station procedure uses the best base station from among all available base stations to fill in each month of missing data for a given gage. The base station producing the smallest standard error of prediction is used for each particular month. The technique used to estimate missing values was developed by Hirsch and is referred to as MOVE.1 (Maintenance of Variance Extension, Type 1). This technique offers the advantage over ordinary least-squares regression of preserving the variance of the unextended records. This procedure was carried out using a computer program developed by the USGS.

The USGS and SEO streamflow stations are first divided into natural flow stations and non-natural flow stations. The stations are then further divided into hydrologically similar groups with each group having at least one gage with sufficient data to develop relationships based on concurrent streamflow for the entire study period. The monthly flow extension procedure is performed for each of these groupings of monthly streamflow data. There is a certain amount of overlap in hydrologic similarity among the various groupings. Some streamflow stations are therefore included in multiple groups. Records from the long-term natural flow stations are also included with some of the non-natural flow groupings where appropriate to provide adequate data for extending the records through the entire study period.

Regression of hydrologic data resulting in a coefficient of determination ($R^{2)}$ greater than 0.7 is typically considered strong enough for data estimating. This criterion was used in evaluating the results of the regression analyses performed for this study. The coefficient of determination is defined as the proportion of variation in the independent variable that can be explained by variation in the dependent variable. The higher the value of R^2, the stronger the relationship

between the two variables. A perfect relationship would have an R^2 equal to 1.0. In some instances no significant correlation (R^2 less than 0.7) could be found using concurrent monthly streamflows between any base station and the short record station. Annual flow regression rather than monthly flow regression was performed in these instances to fill-in the missing streamflow data. In a few cases, no significant correlation (R^2 less than 0.7) could be found using the annual flow regression either. These stations were dropped from the study. The monthly streamflows for the years of missing data were estimated by applying the average monthly distribution for the period of recorded streamflow to the estimated total annual flow.

The average monthly and annual streamflows for the 1970 to 1999 study period, for the natural flow streamflow stations and the non-natural flow streamflow stations are summarized in Table III-2 and Table III-3 respectively.

Supporting data and computation results for the data extension process is provided in the "Surface Water Hydrology" technical memorandum.

Natural Flow at Ungaged Model Nodes

The water availability models for this Plan have been developed identifying appropriate locations of model nodes in relation to the various surface water diversion points, return flow locations, and storage reservoirs. Model nodes are located, in large part, at historic streamflow gaging stations in order to take advantage of the historic records of streamflow at these locations. Additionally, it is necessary to locate model nodes at locations with no record of streamflow, to appropriately simulate water use in the various drainages. The locations of the ungaged model nodes are shown on Figure III-6.

The following two methods were used to estimate natural flow at these locations:

1. Use the recorded streamflow at a downstream streamflow station, adjusting for depletions and storage regulation as well as for the smaller drainage area to estimate natural flow at an upstream location.

2. Use the regression equations developed by the USGS in WRIR 88-4045, relating drainage area and either average annual precipitation or mean basin elevation to natural flow.

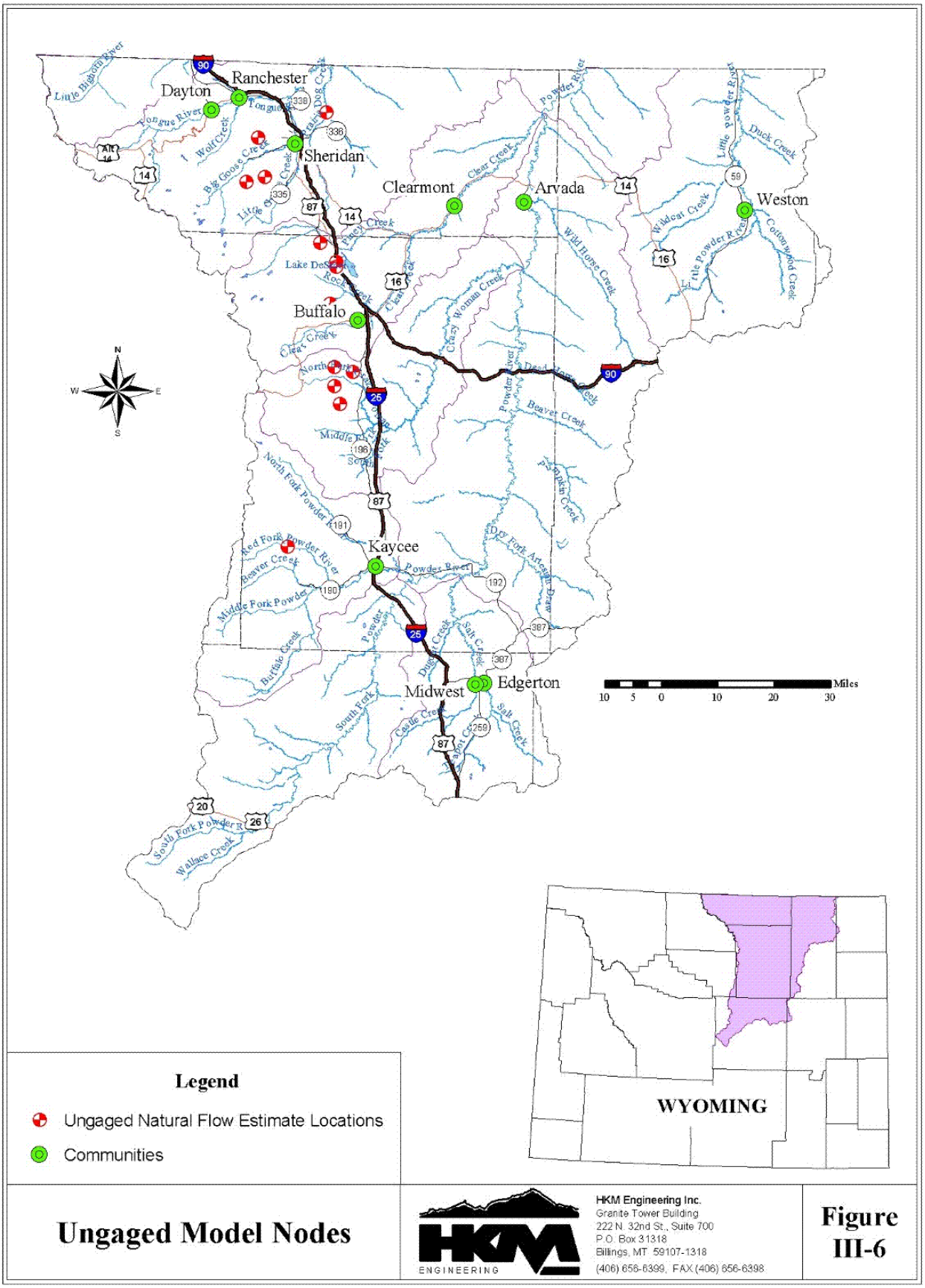
The first method was used for Prairie Dog Creek in the Tongue River basin and Little Piney Creek in the Powder River basin. This method yielded the most reasonable estimates of natural flow for these two locations as evaluated during the calibration of the water availability models. Natural flow at the upstream location is estimated as natural flow at the downstream location multiplied by the proportion of the upstream drainage area to the downstream drainage area. The depletions (diversions minus return flows) used to make the adjustments to the downstream gage records are based on three representative hydrologic conditions (wet, normal, and dry years) and are taken from the water availability modeling work.

Table III-2
Summary of Average Monthly and Annual Flows (1970 to 1999) - Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06288600	Little Bighorn River Below Dayton Gulch Near Burgess Junction, WY	414	301	268	238	195	215	358	3,600	6,008	1,685	779	463	**14,524**
	06288700	Dry Fork Little Bighorn River Below Lick Creek Near Burgess Junction, WY	1,855	1,599	1,498	1,383	1,223	1,326	1,709	6,248	9,433	4,505	2,644	2,029	**35,452**
	06288960	Little Bighorn River near Parkman, WY	4,011	3,353	3,098	2,864	2,479	2,777	3,771	17,119	27,107	11,347	6,045	4,433	**88,404**
	06288975	Elkhorn Creek Above Fuller Ranch Ditch Near Parkman, WY	114	100	92	86	75	88	141	486	618	202	135	124	**2,261**
	06288990	West Fork Little Bighorn River Near Parkman, WY	939	794	734	672	593	671	896	3,868	5,800	2,421	1,355	1,040	**19,783**
	06289000	Little Bighorn River at State Line Near Wyola, MT	5,420	4,574	4,258	3,958	3,479	3,880	5,154	21,093	32,321	14,270	7,902	5,957	**112,266**
	06289100	Red Canyon Creek Near Parkman, WY	35	32	26	28	23	42	216	561	242	65	32	28	**1,330**
	06289800	East Pass Creek Near Parkman, WY	469	389	366	338	303	328	547	1,899	2,298	1,062	638	508	**9,145**
	06291200	Lodge Grass Creek at State Line Near Wyola, MT	464	352	316	288	242	271	558	3,619	5,268	1,760	780	531	**14,449**
Tongue	06297000	South Fork Tongue River Near Dayton, WY	1,424	1,033	942	803	652	741	1,839	14,823	22,367	6,444	2,527	1,656	**55,251**
	06297480	Tongue River at Tongue Canyon Campground Near Dayton, WY	5,064	3,935	3,623	3,295	2,824	3,107	6,129	31,109	42,528	15,621	7,855	5,653	**130,743**
	06298000	Tongue River Near Dayton, WY	5,130	3,954	3,642	3,315	2,825	3,117	6,186	31,983	43,180	16,162	7,951	5,730	**133,175**
	06298480	Little Tongue River at Steamboat Point Near Dayton, WY	134	94	83	72	58	69	249	2,165	3,088	726	274	167	**7,179**
	06298490	Little Tongue River Above South Fork Little Tongue River Near Dayton, WY	98	67	58	50	40	46	139	1,641	2,643	591	200	118	**5,691**
	06298500	Little Tongue River Near Dayton, WY	225	158	139	124	105	118	402	3,299	4,503	1,144	427	268	**10,912**
	06299480	Wolf Creek Below Alden Creek Near Wolf, WY	471	341	304	267	219	255	784	6,063	8,521	2,214	855	537	**20,831**
	06299490	Wolf Creek Above Red Canyon Creek Near Wolf, WY	536	404	364	329	276	308	784	5,804	8,126	2,169	849	540	**20,489**
	06299500	Wolf Creek at Wolf, WY	539	399	356	317	271	298	854	5,767	7,980	2,237	926	603	**20,547**
	06300500	East Fork Big Goose Creek Near Big Horn, WY	426	284	220	204	154	171	557	5,296	10,978	3,740	1,096	698	**23,824**
	06301480	Coney Creek Above Twin Lakes Near Big Horn, WY	30	18	14	10	8	9	49	1,091	1,781	534	83	48	**3,675**
Powder	06309200	Middle Fork Powder River Near Barnum, WY	457	416	370	331	295	424	2,125	9,807	5,212	1,061	527	433	**21,457**
	06309260	Buffalo Creek Above North Fork Buffalo Creek Near Arminto, WY	31	28	23	20	17	28	218	1,350	649	101	38	28	**2,531**
	06309270	North Fork Buffalo Creek Near Arminto, WY	86	79	70	62	55	79	370	1,639	915	200	103	84	**3,742**
	06309280	Buffalo Creek Below North Fork Buffalo Creek Near Arminto, WY	0	0	0	0	0	0	34	1,918	950	51	2	1	**2,956**
	06309450	Beaver Creek Below Bayer Creek Near Barnum, WY	185	166	143	126	111	156	519	1,787	1,141	429	247	192	**5,202**
	06309460	Beaver Creek Above White Panther Ditch Near Barnum, WY	612	568	546	518	476	561	997	2,211	1,674	911	695	610	**10,379**
	06311000	North Fork Powder River Near Hazelton, WY	294	220	180	144	120	142	603	3,864	4,037	1,111	471	325	**11,511**
	06313950	North Fork Crazy Woman Creek Below Pole Creek Near Buffalo, WY	629	474	387	307	257	301	1,142	5,582	5,774	1,983	918	645	**18,399**
	06314000	North Fork Crazy Woman Creek Near Buffalo, WY	640	481	395	316	265	307	1,152	5,490	5,637	1,987	924	655	**18,249**
	06314500	North Fork Crazy Woman Creek Below Spring Draw Near Buffalo, WY	558	412	337	264	217	269	1,184	7,726	8,139	2,222	917	624	**22,869**
	06315480	Poison Creek Below Tetley Spring Near Mayoworth, WY	214	175	150	127	112	126	346	1,172	1,155	490	279	218	**4,564**
	06315490	Poison Creek Near Mayoworth, WY	246	202	176	150	132	151	387	1,232	1,220	542	320	251	**5,009**
	06315500	Middle Fork Crazy Woman Creek Near Greub, WY	707	551	470	391	334	411	1,290	5,891	6,016	2,072	1,031	759	**19,923**
	06317300	Sourdough Creek Near Buffalo, WY	70	52	44	34	28	34	107	775	905	265	112	78	**2,504**
	06317340	Little Sourdough Creek Near Buffalo, WY	37	22	7	3	2	5	206	214	139	36	16	25	**712**
	06319470	South Rock Creek at Forest Boundary Near Buffalo, WY	447	341	280	227	187	217	900	5,431	5,744	1,722	714	491	**16,701**
	06319480	South Rock Creek Above Red Canyon Near Buffalo, WY	426	325	264	213	177	205	870	5,367	5,703	1,675	689	471	**16,385**
	06321500	North Piney Creek Near Story, WY	800	626	511	423	354	439	1,817	10,506	10,318	2,733	1,139	842	**30,508**

Table III-3
Summary of Average Monthly and Annual Flows (1970 to 1999) - Non-Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06289600	West Pass Creek Near Parkman, WY	522	476	441	419	407	497	770	2,023	2,007	810	488	495	**9,355**
	06289820	East Pass Creek Near Dayton, WY	621	575	543	531	519	629	958	2,666	2,800	905	469	530	**11,746**
	06289870	Twin Creek Near Parkman, WY	108	92	119	328	236	741	847	1,656	349	154	115	87	**4,833**
Tongue	06302000	Big Goose Creek Near Sheridan, WY	2,307	1,727	1,576	1,427	1,199	1,336	2,247	13,175	27,034	8,560	4,642	3,625	**68,855**
	06303500	Little Goose Creek in Canyon Near Big Horn, WY	1,855	1,396	1,274	1,147	968	1,076	2,082	10,835	14,826	6,582	5,236	3,425	**50,702**
	06305500	Goose Creek Below Sheridan, WY	6,692	5,855	5,109	4,570	4,971	6,223	8,284	26,807	40,099	10,115	4,047	5,595	**128,367**
	06305700	Goose Creek Near Acme, WY	6,848	5,984	5,215	4,660	5,076	6,364	8,494	27,713	41,776	10,431	4,120	5,725	**132,406**
	06306250	Prairie Dog Creek Near Acme, WY	2,785	2,192	1,835	1,286	2,567	5,705	2,784	3,701	2,327	1,416	1,730	2,350	**30,678**
	06306300	Tongue River at State Line Near Decker, MT	16,187	13,719	11,317	11,134	13,110	19,427	21,867	73,969	98,409	29,613	11,756	13,340	**333,850**
Powder	06309500	Middle Fork Powder River Above Kaycee, WY	2,812	2,642	2,490	2,387	2,235	2,693	5,676	14,882	9,586	3,978	2,759	2,581	**54,721**
	06311060	North Fork Powder River Below Bull Creek Near Hazelton, WY	240	169	159	129	119	143	367	3,188	4,121	2,014	1,524	1,028	**13,202**
	06311400	North Fork Powder River Below Pass Creek Near Mayoworth, WY	1,326	1,138	1,139	1,110	994	1,089	1,613	4,891	5,510	2,835	2,410	1,917	**25,972**
	06312500	Powder River Near Kaycee, WY	5,062	6,385	6,481	5,606	6,441	8,416	8,944	27,066	15,875	1,006	888	1,783	**93,950**
	06313000	South Fork Powder River Near Kaycee, WY	172	237	163	190	1,350	7,672	5,987	9,131	2,072	602	1,729	11	**29,316**
	06313400	Salt Creek Near Sussex, WY	2,257	1,820	1,706	1,849	2,577	4,243	3,003	5,395	4,120	3,062	1,940	1,853	**33,825**
	06313500	Powder River at Sussex, WY	10,088	8,646	7,430	7,200	10,592	17,746	17,475	38,478	26,121	9,211	4,476	4,899	**162,362**
	SEO Gage	Crazy Woman Creek at Trabing Bridge Near Buffalo, WY	329	223	218	196	150	189	1,697	8,924	13,287	3,211	1,242	978	**30,644**
	06316400	Crazy Woman Creek at Upper Station Near Arvada, WY	1,688	1,356	1,036	885	1,627	2,517	3,386	9,747	8,975	2,196	1,151	769	**35,333**
	06317000	Powder River at Arvada, WY	11,144	9,646	7,235	6,773	11,517	23,619	21,176	52,067	42,800	14,235	6,162	5,400	**211,773**
	06318500	Clear Creek Near Buffalo, WY	2,253	1,583	1,220	909	759	1,009	2,710	12,305	17,834	8,639	3,929	2,749	**55,899**
	SEO Gage	Clear Creek in Buffalo City Park, Buffalo, WY	1,886	1,397	1,138	947	1,277	1,972	2,407	9,746	14,070	4,659	1,414	1,254	**42,167**
	06320000	Rock Creek Near Buffalo, WY	894	653	587	525	437	490	993	7,108	9,142	3,800	2,729	1,558	**28,916**
	SEO Gage	Rock Creek at Mouth Near Buffalo, WY	1,572	1,322	1,026	927	1,272	2,245	1,360	5,460	7,121	1,755	929	918	**25,907**
	06320200	Clear Creek Below Rock Creek Near Buffalo, WY	3,672	3,132	2,571	2,386	2,774	4,084	5,349	17,212	23,059	7,586	3,034	3,074	**77,933**
	SEO Gage	Clear Creek below Healy Reservoir Near Buffalo, WY	2,601	1,730	1,299	1,079	1,454	2,483	3,739	14,926	20,747	7,964	3,380	2,772	**64,174**
	06321000	South Piney Creek Near Story, WY	2,068	1,539	1,514	1,257	961	1,032	1,555	5,964	20,205	12,621	9,042	5,535	**63,293**
	06323000	Piney Creek at Kearney, WY	1,886	2,307	2,059	1,875	1,607	2,038	4,072	15,796	23,765	6,122	2,061	1,265	**64,853**
	SEO Gage	Little Piney Creek, WY	784	751	591	583	709	964	945	1,620	1,489	881	602	689	**10,608**
	SEO Gage	Piney Creek below Lake DeSmet Tunnel Intake Near Story, WY	1,524	1,056	741	664	613	864	1,953	10,657	20,258	5,591	2,118	1,431	**47,470**
	06323500	Piney Creek at Ucross, WY	3,450	3,413	2,641	2,362	1,632	2,969	3,928	12,580	20,834	7,887	5,206	3,718	**70,620**
	SEO Gage	Clear Creek at Double Crossing Near Clearmont, WY	8,484	7,580	6,042	5,208	5,866	9,456	9,217	27,303	42,211	14,623	7,589	6,807	**150,386**
	SEO Gage	Clear Creek below P&F#3 Ditch Near Clearmont, WY	6,464	5,750	3,619	3,474	5,276	9,697	8,968	24,292	38,482	10,460	4,558	4,444	**125,484**
	06324000	Clear Creek Near Arvada, WY	7,050	6,494	4,356	4,151	5,773	9,919	10,332	25,700	38,174	11,742	5,498	5,462	**134,651**
	06324500	Powder River at Moorhead, MT	18,021	16,072	10,330	10,928	18,963	36,118	29,810	73,536	79,314	27,131	11,758	10,494	**342,475**
Little Powder	06324890	Little Powder River Below Corral Creek Near Weston, WY	8	16	23	57	182	1,022	138	1,239	103	267	38	0	**3,093**
	06324925	Little Powder River Near Weston, WY	637	128	74	360	2,640	4,275	1,982	3,093	1,600	463	275	161	**15,688**
	06324970	Little Powder River Above Dry Creek Near Weston, WY	823	260	174	580	2,501	4,299	1,602	4,205	1,992	748	404	284	**17,873**
Belle Fourche	06426500	Belle Fourche River Below Moorcroft, WY	682	203	149	420	1,761	4,664	2,268	5,169	2,134	997	515	281	**19,243**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Dayton
Sheridan
Clearmont
Arvada
Weston
Buffalo
Kaycee
Midwest
Edgerton
Miles
10 5 0 10 20 30
Legend
Ungaged Natural Flow Estimate Locations
Communities
WYOMING
Ungaged Model Nodes
HKM Engineering Inc.
Granite Tower Building
222 N. 32nd St., Suite 700
P.O. Box 31318
Billings, MT 59107-1318
(406) 656-6399, FAX (406) 656-6398
Figure III-6

The 1988 USGS report "Streamflows in Wyoming" presents regression equations, which rely on drainage area and average annual precipitation or mean basin elevation to estimate mean annual flow. The equation for the mountainous region is applicable for drainages with mean basin elevations from 5,000 to 10,800 feet. Only one ungaged model node has a mean basin elevation less than 5,000 feet (Prairie Dog Creek with a MBE of 4550). The USGS regression equation for the mountainous region was selected as the most appropriate alternative for estimating natural flow at most of the ungaged model nodes. The regression equation is as follows:

$$Q_a = 0.0015\ A^{1.01}\ (ELEV/1{,}000)^{2.88}$$

Where: Q_a is mean annual flow in cubic feet per second,
A is contributing drainage area in square miles, and
ELEV is mean basin elevation in feet.

The reasonableness of the estimates of average annual flow were evaluated by comparing the estimated unit runoff (acre-feet per square mile) to the recorded unit runoff at the nearest natural flow station during the 1970 to 1999 study period. The average annual natural flow was, in some instances, adjusted based on this comparison.

In addition to average annual natural flow at the ungaged model nodes, it is necessary to generate sequential monthly flows at these sites for all years of the study period. This was accomplished by selecting a natural flow gaging station having similar hydrologic characteristics and multiplying the sequential monthly flows at the gaged location by the ratio of the ungaged average annual natural flow to the gaged average annual natural flow. The time distribution of monthly flows at the ungaged sites is, therefore, represented by the streamflow at similar gaged sites. The average monthly and annual streamflows for the 1970 to 1999 study period, for the ungaged model nodes are summarized in Table III-4. The estimated monthly natural flows for each year of the 1970 to 1999 study period are provided in the "Surface Water Hydrology" technical memorandum.

Streamflows During Wet, Dry, and Normal Years

The water availability models represent dry year, normal year, and wet year hydrologic conditions throughout the Powder/Tongue River Basin. To this end, the annual streamflows for the 1970 to 1999 study period developed through the surface water hydrology work are ranked and divided into these three hydrologic categories. Indicator gages are selected for this purpose, to represent hydrologic conditions for the entire geographic area of the Powder/Tongue River Basin. To the extent possible, natural flow stations, free from transbasin diversion, irrigation depletions, or storage regulation are selected. One exception, Little Powder River above Dry Creek (#06324970) which is impacted by irrigation depletions was selected to represent hydrologic conditions in the Little Powder drainage. The nine indicator gages are shown on Figure III-7.

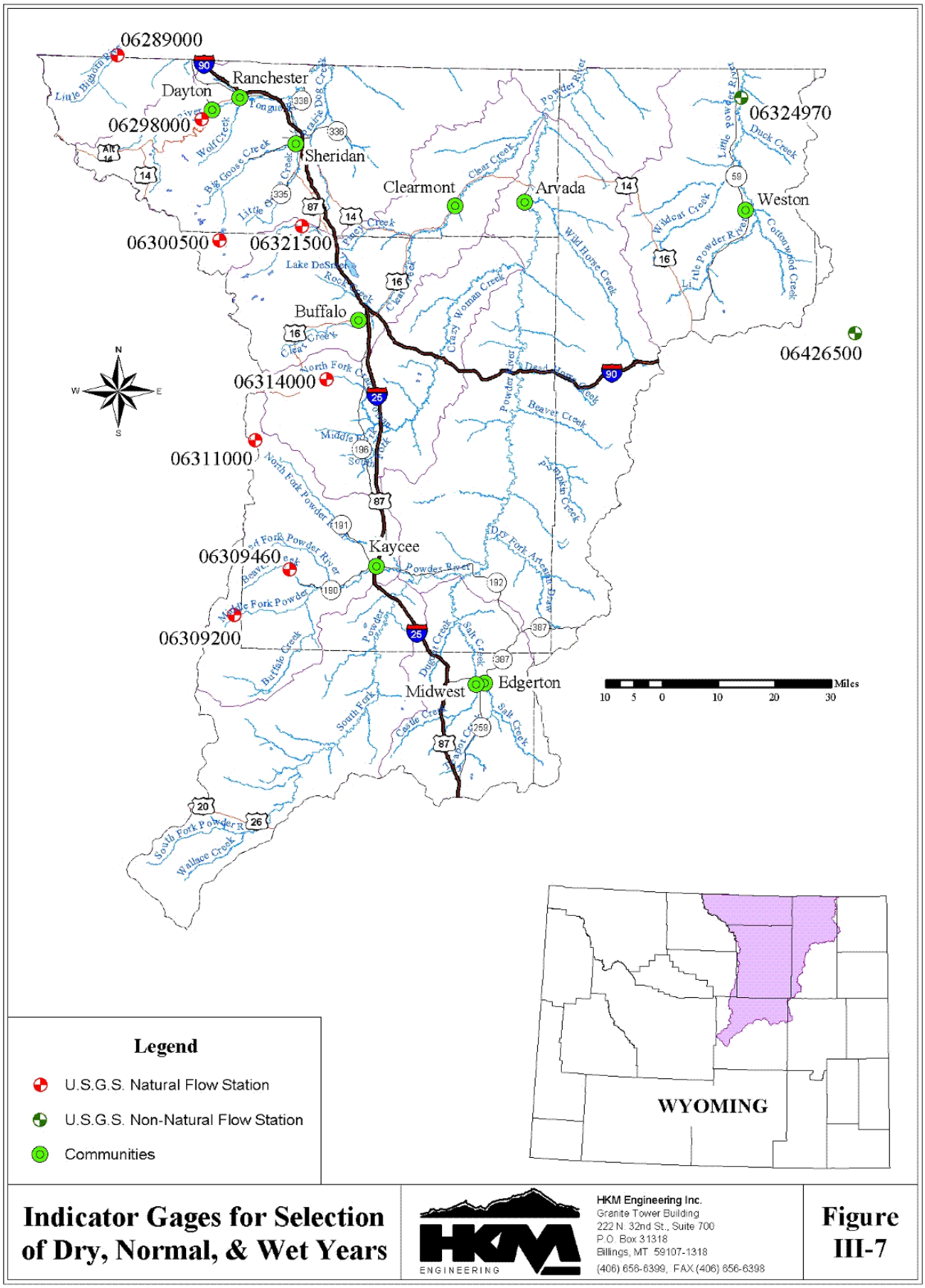
Table III-4

Summary of Average Monthly and Annual Flows (1970-1999)

Ungaged Natural Flow Nodes

Basin	Station Name	Estimated Average Streamflow for 1970-1999 in Acre-Feet												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tongue	Rapid Creek Just Below Little Rapid Creek in Section 32, T55N, R85W	98	73	65	58	49	54	156	1,050	1,453	407	169	110	**3,742**
	Beaver Creek at Bottom of Section 26, T55N, R85W	27	20	18	16	14	15	43	290	402	113	47	30	**1,034**
	Soldier Creek at Right Edge of Section 28, T56N, R85W	60	44	39	35	30	33	95	640	886	248	103	67	**2,281**
	Prairie Dog Creek Just Above Dutch Creek in Section 34, T57N, R83W	487	1,314	3,453	2,229	3,493	2,296	1,963	1,560	1,253	886	725	673	**20,332**[1]
Powder	Red Fork Powder River Just Below North & South Forks Red Fork Powder River in Section 29, T44N, R84W	2,706	2,511	2,415	2,290	2,104	2,477	4,405	9,771	7,396	4,024	3,071	2,695	**45,866**
	Kelly Creek at Top of Section 21, T49N, R82W	73	55	45	36	30	35	132	629	646	228	106	75	**2,092**
	Little North Fork Crazy Woman Creek Just Below Grossett Canyon in Section 14, T49N, R83W	166	125	103	82	69	80	299	1,425	1,463	516	240	170	**4,737**
	Muddy Creek at Diversion Near East Side of Section 35, T49N, R83W	153	115	94	75	63	73	275	1,309	1,344	474	220	156	**4,351**
	Billy Creek at Diversion to O'Malley Draw in Section 13, T48N, R83W	96	79	69	59	52	59	151	481	477	212	125	98	**1,957**
	Little Piney Creek Just Below Bear Gulch in Section 28, T53N, R83W	324	421	625	676	1,295	1,250	811	544	470	309	338	273	**7,336**[1]
	North & South Forks Shell Creek (Combined), at Confluence of Little North Fork Shell Creek and North Fork Shell Creek in Section 11, and Confluence of Unnamed Tributary & South Fork Shell Creek in Section 14; all in T52N, R83W	56	42	35	28	23	27	114	701	745	219	90	62	**2,141**
	Johnson Creek at Top of Section 22, T51N, R83W	53	41	33	27	22	26	109	672	714	210	86	59	**2,052**
	French Creek at Penrose Ditch Diversion in Section 27, T51N, R83W	128	98	80	64	53	62	262	1,614	1,715	504	207	142	**4,928**

Note: 1. The monthly and annual flows for Prairie Dog Creek and Little Piney Creek are the average of the dry, normal, and wet year monthly and annual flows



Indicator Gages for Selection of Dry, Normal, & Wet Years

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Figure III-7

Water use in the Tongue River and Powder River are interrelated through transbasin diversions including the Mead Coffeen Ditch, Piney Cruse Ditch, and the Prairie Dog Ditch. Because of this interrelationship, the years selected to represent the various hydrologic conditions must be consistent for all locations within each of these two river basins. Water use in the Little Bighorn River is essentially independent of water use in the other river basins. Similarly, water use in the Little Powder River drainage is also independent of water use in the other drainages. The years with non-exceedance probabilities of 20 percent or less (the driest 20 percent) and the years with exceedance probabilities of 20 percent or less (the wettest 20 percent) at each of the indicator gages are shown in Figure III-8. The remaining 60 percent of the years represent normal years. The years selected to represent dry years, wet years, and normal years for the Little Bighorn River basin, the Tongue and Powder River basins, and the Little Powder River basin are also summarized in Figure III-8.

The average monthly and annual streamflow for the natural flow stations for dry years, normal years, and wet years are provided in Tables III-5, III-6, and III-7 respectively. The average monthly and annual streamflow for the non-natural flow stations for dry years, normal years, and wet years are provided in Tables III-8, III-9, and III-10 respectively. Finally, the average monthly and annual streamflow for the ungaged model nodes for dry years, normal years, and wet years are provided in Tables III-11, III-12, and III-13 respectively.

Spreadsheet Model Development and Calibration

Water availability spreadsheet models were developed for the following six sub-basins within the Powder/Tongue River Basin planning area:

- Little Bighorn River sub-basin
- Tongue River sub-basin
- Clear Creek sub-basin
- Crazy Woman Creek sub-basin
- Powder River sub-basin
- Little Powder River sub-basin

The models do not explicitly account for water rights, appropriations, or compact allocations nor are the models operated based on these legal constraints. Further, the models do not associate supplemental reservoir releases to the specific water users. However, by calibrating the models to historical streamflows at gaged locations, the models can be used to generally represent existing operations.

The models developed for this plan are intended to simulate water use and availability under existing conditions. For each Powder/Tongue River sub-basin, three models were developed, reflecting each of the three hydrologic conditions (dry, normal, and wet years). The models each represent one calendar year of flows, on a monthly time step. Streamflow, estimated actual diversions, full supply diversions, irrigation returns, and reservoir conditions are the basic input data to the models. For all of these data, average values drawn from the dry, normal, or wet years of the study period were computed for use in the spreadsheets.

FIGURE III-8

SELECTION OF WET, DRY, AND NORMAL YEARS FOR MODELING

INDICATOR STATIONS FOR THE POWDER/TONGUE RIVER BASIN

		Little Bighorn	
		Little Bighorn River at State Line, Near Wyola, MT	
Rank	Weibull Plotting Position	Year	06289000
1	3.23%	1989	68,060
2	6.45%	1985	72,360
3	9.68%	1987	77,020
4	12.90%	1980	81,830
5	16.13%	1992	90,470
6	19.35%	1979	93,400
7	22.58%	1988	93,900
8	25.81%	1981	95,510
9	29.03%	1993	96,740
10	32.26%	1982	97,200
11	35.48%	1994	98,000
12	38.71%	1986	101,170
13	41.94%	1990	103,430
14	45.16%	1983	106,830
15	48.39%	1998	107,010
16	51.61%	1991	110,400
17	54.84%	1972	111,430
18	58.06%	1996	113,090
19	61.29%	1977	115,910
20	64.52%	1997	121,120
21	67.74%	1971	121,810
22	70.97%	1976	123,370
23	74.19%	1995	126,540
24	77.42%	1999	127,190
25	80.65%	1974	130,710
26	83.87%	1973	133,310
27	87.10%	1984	136,970
28	90.32%	1970	159,600
29	93.55%	1978	170,730
30	96.77%	1975	182,880

		Tongue River Basin				Powder River Basin									
		Tongue River Near Dayton, WY		East Fork Big Goose Creek Near Big Horn, WY		Middle Fork Powder River Near Barnum, WY		Beaver Creek Above White Panther Ditch, Near Barnum, WY		North Fork Powder River Near Hazelton, WY		North Fork Crazy Woman Creek Near Buffalo, WY		North Piney Creek Near Story, WY	
Rank	Weibull Plotting Position	Year	06298000	Year	06300500	Year	06309200	Year	06309460	Year	06311000	Year	06314000	Year	06321500
1	3.23%	1989	76,527	1985	15,754	1989	9,469	1989	6,634	1985	6,974	1977	10,122	1985	18,786
2	6.45%	1985	88,393	1988	17,616	1985	10,915	1981	7,204	1981	7,608	1981	11,608	1980	19,694
3	9.68%	1987	91,860	1994	17,717	1980	11,564	1980	7,893	1988	7,889	1985	12,404	1988	21,032
4	12.90%	1980	97,481	1987	18,242	1981	12,890	1985	8,016	1980	7,931	1988	13,511	1994	21,652
5	16.13%	1979	107,713	1977	18,318	1994	13,243	1982	8,040	1974	8,001	1994	13,978	1979	21,655
6	19.35%	1994	113,240	1980	18,340	1979	13,665	1986	8,325	1994	8,105	1989	14,551	1982	22,230
7	22.58%	1998	115,427	1989	18,387	1992	13,731	1988	8,506	1989	8,693	1974	14,671	1989	23,038
8	25.81%	1982	118,780	1991	19,455	1982	15,847	1987	8,963	1972	8,818	1972	14,752	1981	24,199
9	29.03%	1988	120,159	1981	20,437	1974	16,281	1994	9,036	1977	8,882	1973	15,375	1990	24,437
10	32.26%	1981	122,507	1998	20,660	1976	16,609	1974	9,387	1973	9,131	1990	15,464	1987	25,989
11	35.48%	1992	122,866	1979	20,850	1987	16,928	1992	9,635	1990	9,213	1982	15,982	1976	26,899
12	38.71%	1993	126,667	1982	21,839	1988	18,445	1991	9,722	1987	9,735	1970	16,319	1972	27,025
13	41.94%	1986	129,213	1993	22,222	1990	20,436	1990	10,269	1970	10,137	1980	16,411	1971	27,648
14	45.16%	1977	133,134	1983	22,330	1991	20,530	1976	10,299	1979	10,405	1979	16,564	1986	28,593
15	48.39%	1991	133,469	1970	23,062	1986	20,626	1979	10,329	1986	10,860	1987	16,707	1977	29,148
16	51.61%	1976	134,000	1996	23,340	1998	20,860	1998	10,491	1971	11,584	1986	17,730	1974	31,480
17	54.84%	1983	135,628	1990	23,717	1996	20,941	1996	10,511	1976	12,204	1971	18,160	1998	32,568
18	58.06%	1971	136,242	1992	24,316	1972	21,715	1971	10,558	1998	12,443	1998	19,877	1992	33,073
19	61.29%	1996	136,583	1971	24,586	1993	22,499	1972	10,609	1992	12,580	1991	20,064	1991	33,574
20	64.52%	1972	138,031	1997	24,639	1971	22,626	1993	10,710	1991	12,926	1976	20,131	1983	34,423
21	67.74%	1990	138,184	1976	24,826	1997	23,239	1997	10,875	1983	13,118	1992	20,391	1996	35,321
22	70.97%	1997	144,068	1986	24,899	1977	24,757	1973	10,877	1996	13,603	1996	21,093	1993	36,058
23	74.19%	1974	145,021	1973	25,555	1973	26,807	1977	11,016	1982	13,633	1983	21,296	1970	36,073
24	77.42%	1999	145,292	1999	25,853	1970	29,218	1970	11,042	1993	13,847	1993	21,679	1975	36,325
25	80.65%	1973	149,701	1972	27,268	1975	29,477	1983	11,976	1984	14,335	1995	23,013	1984	37,158
26	83.87%	1995	157,750	1974	28,147	1983	30,407	1975	12,565	1995	15,254	1975	23,229	1973	37,710
27	87.10%	1984	170,772	1978	28,491	1984	30,471	1995	12,975	1997	15,384	1997	23,681	1995	39,315
28	90.32%	1970	170,984	1975	30,620	1978	35,430	1999	13,206	1975	15,883	1984	24,218	1997	39,885
29	93.55%	1978	197,249	1995	38,229	1995	36,855	1984	13,707	1999	17,182	1999	25,986	1999	44,332
30	96.77%	1975	198,294	1984	44,963	1999	37,229	1978	17,984	1978	18,963	1978	28,477	1978	45,924

		Little Powder	
		Little Powder River Above Dry Creek, Near Weston, WY	
Rank	Weibull Plotting Position	Year	06324970
1	3.23%	1992	1,084
2	6.45%	1991	2,905
3	9.68%	1989	2,924
4	12.90%	1988	4,005
5	16.13%	1973	4,062
6	19.35%	1980	4,155
7	22.58%	1981	4,414
8	25.81%	1977	6,511
9	29.03%	1985	6,953
10	32.26%	1998	7,776
11	35.48%	1979	7,949
12	38.71%	1976	9,241
13	41.94%	1990	10,057
14	45.16%	1970	10,277
15	48.39%	1975	10,586
16	51.61%	1974	11,634
17	54.84%	1987	11,882
18	58.06%	1983	13,608
19	61.29%	1986	13,884
20	64.52%	1993	17,653
21	67.74%	1982	19,220
22	70.97%	1999	19,251
23	74.19%	1994	21,031
24	77.42%	1984	24,547
25	80.65%	1971	37,031
26	83.87%	1997	39,292
27	87.10%	1972	40,495
28	90.32%	1996	40,534
29	93.55%	1995	41,091
30	96.77%	1978	92,138

LEGEND	
	WET
	DRY

SELECTION OF WET, DRY, & NORMAL YEARS			
Hydrologic Condition	MODEL AREA		
	Little Bighorn Model	Tongue & Powder Models	Little Powder Model
WET	1970, 1973, 1974, 1975, 1978, 1984	1975, 1978, 1984, 1995, 1997, 1999	1971, 1972, 1978, 1995, 1996, 1997
DRY	1979, 1980, 1985, 1987, 1989, 1992	1980, 1981, 1985, 1988, 1989, 1994	1973, 1980, 1988, 1989, 1991, 1992
AVERAGE	All Other Years Between 1970 and 1999	All Other Years Between 1970 and 1999	All Other Years Between 1970 and 1999

Table III-5

Summary of Dry Year Monthly and Annual Flows (1970 to 1999)

Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	**06288600**	Little Bighorn River Below Dayton Gulch Near Burgess Junction, WY	383	293	270	230	186	199	396	2,737	2,400	1,220	631	406	**9,348**
	06288700	Dry Fork Little Bighorn River Below Lick Creek Near Burgess Junction, WY	1,781	1,540	1,467	1,330	1,157	1,254	1,685	4,567	4,393	2,990	2,106	1,666	**25,935**
	06288960	Little Bighorn River near Parkman, WY	3,804	3,159	2,990	2,746	2,375	2,648	3,934	12,923	11,513	6,948	4,513	3,536	**61,087**
	06288975	Elkhorn Creek Above Fuller Ranch Ditch Near Parkman, WY	104	97	90	81	70	83	145	327	258	145	119	101	**1,621**
	06288990	West Fork Little Bighorn River Near Parkman, WY	911	765	710	645	563	627	872	2,647	2,377	1,526	1,041	824	**13,505**
	06289000	Little Bighorn River at State Line Near Wyola, MT	5,168	4,347	4,130	3,815	3,330	3,687	5,332	16,225	14,538	9,057	6,063	4,832	**80,523**
	06289100	Red Canyon Creek Near Parkman, WY	23	24	19	21	16	23	126	260	103	34	20	21	**689**
	06289800	East Pass Creek Near Parkman, WY	450	377	359	329	293	315	616	1,506	1,362	863	587	468	**7,524**
	06291200	Lodge Grass Creek at State Line Near Wyola, MT	445	356	322	284	238	262	607	2,835	2,606	1,242	690	464	**10,349**
Tongue	**06297000**	South Fork Tongue River Near Dayton, WY	1,253	926	859	714	604	671	2,638	15,853	9,285	2,993	1,616	1,228	**38,639**
	06297480	Tongue River at Tongue Canyon Campground Near Dayton, WY	4,618	3,659	3,455	2,989	2,624	2,850	8,122	32,437	20,874	8,460	5,619	4,552	**100,258**
	06298000	Tongue River Near Dayton, WY	4,654	3,681	3,473	3,002	2,633	2,862	8,224	33,196	21,910	9,160	5,672	4,587	**103,051**
	06298480	Little Tongue River at Steamboat Point Near Dayton, WY	119	85	79	65	54	60	335	2,105	1,413	441	190	128	**5,073**
	06298490	Little Tongue River Above South Fork Little Tongue River Near Dayton, WY	85	59	54	44	36	41	209	1,748	926	239	115	83	**3,639**
	06298500	Little Tongue River Near Dayton, WY	200	143	132	108	90	101	528	3,159	2,144	692	306	208	**7,811**
	06299480	Wolf Creek Below Alden Creek Near Wolf, WY	423	313	291	241	205	227	1,036	5,941	4,067	1,352	610	419	**15,122**
	06299490	Wolf Creek Above Red Canyon Creek Near Wolf, WY	499	380	355	300	258	284	1,025	5,696	3,926	1,334	610	423	**15,089**
	06299500	Wolf Creek at Wolf, WY	496	370	344	287	244	270	1,106	5,662	3,972	1,426	678	478	**15,331**
	06300500	East Fork Big Goose Creek Near Big Horn, WY	355	243	221	176	143	163	918	6,291	6,407	1,855	700	573	**18,042**
	06301480	Coney Creek Above Twin Lakes Near Big Horn, WY	25	15	13	10	8	9	88	1,282	1,059	153	46	38	**2,746**
Powder	**06309200**	Middle Fork Powder River Near Barnum, WY	366	344	335	299	259	320	2,163	5,973	1,485	523	351	336	**12,754**
	06309260	Buffalo Creek Above North Fork Buffalo Creek Near Arminto, WY	23	22	21	18	15	20	211	755	132	36	22	21	**1,294**
	06309270	North Fork Buffalo Creek Near Arminto, WY	70	65	64	57	50	61	387	1,033	269	98	67	64	**2,284**
	06309280	Buffalo Creek Below North Fork Buffalo Creek Near Arminto, WY	0	0	0	0	0	0	10	932	123	3	0	0	**1,067**
	06309450	Beaver Creek Below Bayer Creek Near Barnum, WY	167	145	128	110	89	119	461	804	454	252	180	153	**3,060**
	06309460	Beaver Creek Above White Panther Ditch Near Barnum, WY	600	544	538	521	456	513	889	1,247	860	647	558	508	**7,882**
	06311000	North Fork Powder River Near Hazelton, WY	271	200	155	121	97	116	961	2,983	1,847	587	305	226	**7,867**
	06313950	North Fork Crazy Woman Creek Below Pole Creek Near Buffalo, WY	596	463	368	276	227	260	1,652	4,799	3,037	1,122	596	451	**13,847**
	06314000	North Fork Crazy Woman Creek Near Buffalo, WY	599	475	373	285	232	264	1,648	4,661	3,031	1,127	598	451	**13,744**
	06314500	North Fork Crazy Woman Creek Below Spring Draw Near Buffalo, WY	510	374	287	222	177	212	1,878	6,015	3,677	1,130	577	423	**15,483**
	06315480	Poison Creek Below Tetley Spring Near Mayoworth, WY	209	173	145	117	100	111	453	1,024	717	339	209	169	**3,766**
	06315490	Poison Creek Near Mayoworth, WY	241	202	171	139	120	133	502	1,091	777	382	242	197	**4,195**
	06315500	Middle Fork Crazy Woman Creek Near Greub, WY	659	513	416	339	282	327	1,881	4,814	3,223	1,256	730	569	**15,009**
	06317300	Sourdough Creek Near Buffalo, WY	64	45	36	25	22	28	153	457	433	152	75	56	**1,545**
	06317340	Little Sourdough Creek Near Buffalo, WY	16	11	3	1	1	2	106	95	55	12	5	8	**314**
	06319470	South Rock Creek at Forest Boundary Near Buffalo, WY	414	308	240	189	152	181	1,425	4,299	2,691	882	466	347	**11,594**
	06319480	South Rock Creek Above Red Canyon Near Buffalo, WY	395	293	227	178	143	170	1,383	4,239	2,637	850	445	330	**11,288**
	06321500	North Piney Creek Near Story, WY	751	587	459	371	295	342	2,571	8,859	4,307	1,475	776	606	**21,400**

Table III-6

Summary of Normal Year Monthly and Annual Flows (1970 to 1999)

Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	**06288600**	Little Bighorn River Below Dayton Gulch Near Burgess Junction, WY	422	303	267	237	196	220	361	3,862	6,199	1,629	778	463	**14,937**
	06288700	Dry Fork Little Bighorn River Below Lick Creek Near Burgess Junction, WY	1,854	1,591	1,477	1,379	1,227	1,329	1,722	6,442	9,677	4,367	2,630	2,024	**35,720**
	06288960	Little Bighorn River near Parkman, WY	4,002	3,337	3,079	2,837	2,458	2,766	3,732	17,480	27,873	10,893	6,005	4,414	**88,877**
	06288975	Elkhorn Creek Above Fuller Ranch Ditch Near Parkman, WY	116	101	92	86	75	88	139	470	602	186	136	123	**2,213**
	06288990	West Fork Little Bighorn River Near Parkman, WY	932	790	731	671	589	675	901	3,871	5,812	2,315	1,355	1,037	**19,677**
	06289000	Little Bighorn River at State Line Near Wyola, MT	5,412	4,543	4,226	3,927	3,465	3,879	5,112	21,438	33,132	13,750	7,872	5,948	**112,704**
	06289100	Red Canyon Creek Near Parkman, WY	35	31	25	27	23	42	214	545	241	64	31	27	**1,304**
	06289800	East Pass Creek Near Parkman, WY	474	391	365	339	303	331	552	1,928	2,318	1,057	644	510	**9,211**
	06291200	Lodge Grass Creek at State Line Near Wyola, MT	466	351	310	282	238	273	581	3,838	5,310	1,658	784	529	**14,620**
Tongue	**06297000**	South Fork Tongue River Near Dayton, WY	1,462	1,069	976	816	655	749	1,756	14,632	20,914	5,932	2,554	1,700	**53,216**
	06297480	Tongue River at Tongue Canyon Campground Near Dayton, WY	5,140	3,987	3,650	3,349	2,827	3,124	5,922	31,052	40,989	14,721	7,889	5,768	**128,419**
	06298000	Tongue River Near Dayton, WY	5,232	4,031	3,687	3,369	2,853	3,163	6,003	31,944	41,798	15,382	8,019	5,825	**131,306**
	06298480	Little Tongue River at Steamboat Point Near Dayton, WY	137	96	85	74	59	71	239	2,024	2,889	689	280	176	**6,819**
	06298490	Little Tongue River Above South Fork Little Tongue River Near Dayton, WY	102	70	60	52	40	47	133	1,615	2,453	532	202	121	**5,427**
	06298500	Little Tongue River Near Dayton, WY	228	162	140	127	111	124	392	3,153	4,156	1,074	427	278	**10,372**
	06299480	Wolf Creek Below Alden Creek Near Wolf, WY	481	347	306	269	221	261	757	5,691	8,097	2,060	859	561	**19,909**
	06299490	Wolf Creek Above Red Canyon Creek Near Wolf, WY	537	404	362	330	272	308	753	5,442	7,717	2,019	857	564	**19,565**
	06299500	Wolf Creek at Wolf, WY	543	405	355	321	281	301	827	5,443	7,591	2,118	934	627	**19,746**
	06300500	East Fork Big Goose Creek Near Big Horn, WY	434	279	208	210	153	169	516	4,890	10,683	3,453	1,208	777	**22,980**
	06301480	Coney Creek Above Twin Lakes Near Big Horn, WY	31	19	13	10	7	9	46	1,069	1,782	423	84	55	**3,548**
Powder	**06309200**	Middle Fork Powder River Near Barnum, WY	458	392	362	328	296	434	2,192	9,883	4,450	1,052	528	430	**20,805**
	06309260	Buffalo Creek Above North Fork Buffalo Creek Near Arminto, WY	31	26	23	20	18	29	229	1,337	562	91	37	28	**2,429**
	06309270	North Fork Buffalo Creek Near Arminto, WY	87	74	68	61	55	81	383	1,674	775	195	102	83	**3,639**
	06309280	Buffalo Creek Below North Fork Buffalo Creek Near Arminto, WY	0	0	0	0	0	0	51	1,904	700	41	3	1	**2,700**
	06309450	Beaver Creek Below Bayer Creek Near Barnum, WY	183	160	144	127	117	163	545	1,824	1,026	395	238	186	**5,106**
	06309460	Beaver Creek Above White Panther Ditch Near Barnum, WY	603	555	539	513	479	566	1,040	2,191	1,524	876	673	595	**10,154**
	06311000	North Fork Powder River Near Hazelton, WY	305	230	190	148	127	143	546	3,946	3,634	1,076	481	347	**11,173**
	06313950	North Fork Crazy Woman Creek Below Pole Creek Near Buffalo, WY	670	487	403	316	261	305	1,062	5,365	5,452	1,909	946	698	**17,873**
	06314000	North Fork Crazy Woman Creek Near Buffalo, WY	681	494	412	327	273	313	1,079	5,238	5,249	1,878	934	700	**17,577**
	06314500	North Fork Crazy Woman Creek Below Spring Draw Near Buffalo, WY	581	430	358	268	229	273	1,081	7,809	7,212	2,176	946	671	**22,032**
	06315480	Poison Creek Below Tetley Spring Near Mayoworth, WY	224	179	155	129	114	128	321	1,133	1,112	490	290	233	**4,508**
	06315490	Poison Creek Near Mayoworth, WY	256	207	181	153	134	152	362	1,195	1,174	541	331	268	**4,954**
	06315500	Middle Fork Crazy Woman Creek Near Greub, WY	728	568	492	398	350	426	1,222	5,982	5,545	2,015	1,045	796	**19,565**
	06317300	Sourdough Creek Near Buffalo, WY	73	56	47	36	30	33	96	822	847	265	115	84	**2,504**
	06317340	Little Sourdough Creek Near Buffalo, WY	34	20	7	3	2	5	188	201	133	35	16	25	**668**
	06319470	South Rock Creek at Forest Boundary Near Buffalo, WY	461	353	296	234	199	220	818	5,550	5,256	1,631	730	520	**16,268**
	06319480	South Rock Creek Above Red Canyon Near Buffalo, WY	439	336	278	216	186	208	790	5,473	5,219	1,595	706	502	**15,949**
	06321500	North Piney Creek Near Story, WY	829	650	535	441	374	472	1,688	10,668	9,908	2,619	1,137	897	**30,217**

Table III-7
Summary of Wet Year Monthly and Annual Flows (1970 to 1999)
Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06288600	Little Bighorn River Below Dayton Gulch Near Burgess Junction, WY	406	293	265	246	199	212	299	3,733	10,128	2,551	981	538	**19,851**
	06288700	Dry Fork Little Bighorn River Below Lick Creek Near Burgess Junction, WY	1,921	1,678	1,583	1,455	1,301	1,407	1,696	7,747	15,057	7,010	3,406	2,525	**46,785**
	06288960	Little Bighorn River near Parkman, WY	4,222	3,588	3,245	3,076	2,707	2,977	3,723	21,474	45,028	18,889	8,210	5,703	**122,841**
	06288975	Elkhorn Creek Above Fuller Ranch Ditch Near Parkman, WY	118	102	95	89	81	92	136	715	1,125	327	159	157	**3,196**
	06288990	West Fork Little Bighorn River Near Parkman, WY	984	836	764	707	647	710	901	5,327	10,134	4,021	1,785	1,335	**28,152**
	06289000	Little Bighorn River at State Line Near Wyola, MT	5,667	4,890	4,467	4,217	3,748	4,120	5,097	26,348	52,728	23,118	10,465	7,502	**152,367**
	06289100	Red Canyon Creek Near Parkman, WY	55	48	40	44	36	66	346	1,002	424	109	51	42	**2,263**
	06289800	East Pass Creek Near Parkman, WY	464	387	372	344	313	330	455	2,223	3,454	1,392	706	557	**10,995**
	06291200	Lodge Grass Creek at State Line Near Wyola, MT	466	344	322	308	257	270	427	3,807	8,850	2,869	913	624	**19,456**
Tongue	06297000	South Fork Tongue River Near Dayton, WY	1,479	1,030	923	856	690	786	1,288	14,366	39,809	11,430	3,358	1,954	**77,970**
	06297480	Tongue River at Tongue Canyon Campground Near Dayton, WY	5,280	4,056	3,710	3,440	3,012	3,311	4,758	29,952	68,799	25,483	9,988	6,407	**168,195**
	06298000	Tongue River Near Dayton, WY	5,301	3,998	3,673	3,465	2,930	3,237	4,697	30,887	68,594	25,504	10,027	6,591	**168,904**
	06298480	Little Tongue River at Steamboat Point Near Dayton, WY	139	97	84	74	62	72	194	2,648	5,358	1,124	339	177	**10,367**
	06298490	Little Tongue River Above South Fork Little Tongue River Near Dayton, WY	98	65	56	52	41	49	90	1,614	4,929	1,122	280	141	**8,538**
	06298500	Little Tongue River Near Dayton, WY	240	161	143	132	104	120	303	3,874	7,901	1,805	548	296	**15,626**
	06299480	Wolf Creek Below Alden Creek Near Wolf, WY	488	351	314	284	228	267	617	7,299	14,248	3,542	1,089	585	**29,311**
	06299490	Wolf Creek Above Red Canyon Creek Near Wolf, WY	568	429	380	357	304	332	636	6,999	13,552	3,453	1,068	586	**28,664**
	06299500	Wolf Creek at Wolf, WY	568	412	369	336	272	317	683	6,843	13,155	3,405	1,153	657	**28,171**
	06300500	East Fork Big Goose Creek Near Big Horn, WY	471	342	254	217	169	187	320	5,517	16,433	6,483	1,155	587	**32,133**
	06301480	Coney Creek Above Twin Lakes Near Big Horn, WY	33	19	15	12	9	11	21	965	2,498	1,252	116	37	**4,987**
Powder	06309200	Middle Fork Powder River Near Barnum, WY	543	561	427	373	329	497	1,886	13,410	11,223	1,624	703	542	**32,117**
	06309260	Buffalo Creek Above North Fork Buffalo Creek Near Arminto, WY	38	40	27	22	19	33	194	1,984	1,426	194	58	36	**4,070**
	06309270	North Fork Buffalo Creek Near Arminto, WY	102	109	81	70	60	91	313	2,141	1,981	317	143	111	**5,518**
	06309280	Buffalo Creek Below North Fork Buffalo Creek Near Arminto, WY	0	0	0	0	0	0	7	2,947	2,525	133	1	0	**5,612**
	06309450	Beaver Creek Below Bayer Creek Near Barnum, WY	209	204	155	138	118	174	499	2,662	2,173	708	343	251	**7,634**
	06309460	Beaver Creek Above White Panther Ditch Near Barnum, WY	652	633	577	531	487	593	975	3,236	2,937	1,278	898	756	**13,553**
	06311000	North Fork Powder River Near Hazelton, WY	286	213	174	157	120	169	415	4,497	7,433	1,738	607	360	**16,167**
	06313950	North Fork Crazy Woman Creek Below Pole Creek Near Buffalo, WY	542	449	359	315	272	329	874	7,018	9,478	3,068	1,159	683	**24,544**
	06314000	North Fork Crazy Woman Creek Near Buffalo, WY	557	448	366	314	275	331	875	7,077	9,409	3,174	1,220	724	**24,767**
	06314500	North Fork Crazy Woman Creek Below Spring Draw Near Buffalo, WY	539	398	324	291	221	314	798	9,188	15,384	3,455	1,171	684	**32,766**
	06315480	Poison Creek Below Tetley Spring Near Mayoworth, WY	192	165	140	130	116	136	314	1,436	1,721	642	318	222	**5,530**
	06315490	Poison Creek Near Mayoworth, WY	222	191	167	153	139	165	350	1,485	1,805	704	365	253	**5,997**
	06315500	Middle Fork Crazy Woman Creek Near Greub, WY	692	540	460	422	338	447	903	6,697	10,221	3,060	1,289	838	**25,906**
	06317300	Sourdough Creek Near Buffalo, WY	66	50	41	37	29	40	94	953	1,555	379	137	83	**3,462**
	06317340	Little Sourdough Creek Near Buffalo, WY	65	39	13	5	3	9	359	373	242	62	28	43	**1,242**
	06319470	South Rock Creek at Forest Boundary Near Buffalo, WY	437	337	274	244	187	244	621	6,203	10,264	2,837	914	545	**23,106**
	06319480	South Rock Creek Above Red Canyon Near Buffalo, WY	417	325	262	238	180	232	599	6,175	10,222	2,742	882	516	**22,788**
	06321500	North Piney Creek Near Story, WY	763	595	490	422	353	437	1,450	11,665	17,560	4,334	1,506	916	**40,490**

Table III-8
Summary of Dry Year Monthly and Annual Flows (1970-1999)
Non-Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06289600	West Pass Creek Near Parkman, WY	522	485	460	421	377	469	647	1,126	1,038	584	406	415	**6,949**
	06289820	East Pass Creek Near Dayton, WY	620	578	551	506	458	592	790	1,407	1,317	673	398	475	**8,364**
	06289870	Twin Creek Near Parkman, WY	71	64	81	213	155	472	573	664	160	93	70	59	**2,676**
Tongue	06302000	Big Goose Creek Near Sheridan, WY	2,116	1,637	1,536	1,310	1,136	1,244	2,545	14,220	14,547	5,167	3,833	2,937	**52,227**
	06303500	Little Goose Creek in Canyon Near Big Horn, WY	1,738	1,352	1,271	1,087	945	1,033	2,160	9,517	7,440	5,127	3,802	2,395	**37,866**
	06305500	Goose Creek Below Sheridan, WY	6,048	5,421	4,763	4,009	3,664	6,136	6,965	20,947	16,605	3,094	2,118	2,882	**82,651**
	06305700	Goose Creek Near Acme, WY	6,185	5,536	4,858	4,084	3,730	6,277	7,133	21,677	17,157	3,147	2,146	2,927	**84,857**
	06306250	Prairie Dog Creek Near Acme, WY	2,437	1,924	1,611	1,129	2,253	5,008	2,043	1,678	1,279	878	1,552	1,928	**23,719**
	06306300	Tongue River at State Line Near Decker, MT	14,045	12,138	8,888	8,018	8,497	16,247	19,902	61,280	43,982	10,638	6,433	7,775	**217,843**
Powder	06309500	Middle Fork Powder River Above Kaycee, WY	2,616	2,537	2,419	2,362	2,125	2,471	5,738	10,427	4,480	2,483	2,065	2,177	**41,898**
	06311060	North Fork Powder River Below Bull Creek Near Hazelton, WY	238	137	131	117	104	134	415	2,289	2,342	2,011	1,313	719	**9,949**
	06311400	North Fork Powder River Below Pass Creek Near Mayoworth, WY	1,348	1,128	1,160	1,145	1,008	1,105	1,672	3,450	2,843	2,598	2,122	1,548	**21,128**
	06312500	Powder River Near Kaycee, WY	3,984	5,116	5,210	4,358	5,231	6,568	7,052	18,405	10,431	643	850	1,268	**69,116**
	06313000	South Fork Powder River Near Kaycee, WY	86	118	116	102	1,136	3,680	2,856	5,383	1,170	269	1,000	6	**15,923**
	06313400	Salt Creek Near Sussex, WY	1,962	1,848	1,795	1,885	2,721	2,888	2,282	2,930	2,355	2,618	1,773	1,885	**26,941**
	06313500	Powder River at Sussex, WY	6,572	7,446	7,294	6,924	9,824	12,733	11,749	17,875	6,632	5,191	3,572	2,639	**98,450**
	SEO Gage	Crazy Woman Creek at Trabing Bridge Near Buffalo, WY	330	204	221	210	153	193	1,013	1,442	1,788	852	607	293	**7,307**
	06316400	Crazy Woman Creek at Upper Station Near Arvada, WY	1,073	1,174	1,125	1,024	1,198	1,904	2,181	3,773	2,521	792	423	278	**17,466**
	06317000	Powder River at Arvada, WY	7,643	8,622	7,085	7,065	10,102	18,663	13,967	21,182	9,420	5,767	2,810	2,314	**114,639**
	06318500	Clear Creek Near Buffalo, WY	1,806	1,397	1,062	778	621	912	2,633	9,770	11,330	5,321	2,680	1,977	**40,287**
	SEO Gage	Clear Creek in Buffalo City Park, Buffalo, WY	1,168	1,174	1,195	949	1,419	1,700	2,507	6,059	5,297	1,360	525	600	**23,951**
	06320000	Rock Creek Near Buffalo, WY	826	623	581	489	419	461	1,248	5,991	4,429	2,886	2,113	990	**21,055**
	SEO Gage	Rock Creek at Mouth Near Buffalo, WY	1,054	1,042	961	822	1,067	1,851	1,141	3,790	1,495	616	506	708	**15,052**
	06320200	Clear Creek Below Rock Creek Near Buffalo, WY	3,157	2,766	2,312	1,853	2,020	3,282	4,667	9,945	7,571	2,407	1,211	1,518	**42,708**
	SEO Gage	Clear Creek below Healy Reservoir Near Buffalo, WY	1,647	1,448	1,248	1,052	1,480	2,101	3,662	8,955	6,790	3,071	1,722	1,527	**34,703**
	06321000	South Piney Creek Near Story, WY	1,735	1,225	1,214	1,033	803	895	1,370	4,880	16,184	9,925	7,096	4,360	**50,719**
	06323000	Piney Creek at Kearney, WY	1,401	1,985	1,785	1,713	1,514	1,740	4,029	12,630	8,558	2,033	784	497	**38,670**
	SEO Gage	Little Piney Creek, WY	766	760	636	627	589	941	809	1,082	623	660	538	586	**8,616**
	SEO Gage	Piney Creek below Lake DeSmet Tunnel Intake Near Story, WY	974	552	422	387	356	458	2,180	8,305	6,194	2,871	1,073	1,094	**24,865**
	06323500	Piney Creek at Ucross, WY	3,235	3,416	3,367	3,181	1,307	1,717	3,657	7,110	8,503	7,061	4,634	3,715	**50,904**
	SEO Gage	Clear Creek at Double Crossing Near Clearmont, WY	7,063	7,196	6,881	6,323	5,321	6,584	7,413	15,042	12,668	8,499	6,054	5,085	**94,127**
	SEO Gage	Clear Creek below P&F#3 Ditch Near Clearmont, WY	10,045	7,190	3,181	3,300	7,712	9,831	10,268	38,389	61,603	13,948	5,051	4,132	**174,649**
	06324000	Clear Creek Near Arvada, WY	6,687	6,744	5,449	5,313	4,172	8,956	8,859	13,104	9,400	4,922	3,449	3,796	**80,849**
	06324500	Powder River at Moorhead, MT	15,447	16,172	10,265	11,567	13,510	27,822	22,040	33,420	20,735	10,368	6,822	5,603	**193,770**
Little Powder	06324890	Little Powder River Below Corral Creek Near Weston, WY	2	12	16	22	89	278	41	296	39	63	9	0	**868**
	06324925	Little Powder River Near Weston, WY	19	26	30	24	319	399	284	474	220	64	169	13	**2,041**
	06324970	Little Powder River Above Dry Creek Near Weston, WY	41	54	69	60	481	630	480	737	383	127	111	17	**3,189**
Belle Fourche	06426500	Belle Fourche River Below Moorcroft, WY	26	70	61	41	464	1,460	299	443	212	1,189	183	71	**4,517**

Table III-9
Summary of Normal Year Monthly and Annual Flows (1970-1999)
Non-Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06289600	West Pass Creek Near Parkman, WY	504	467	437	411	417	498	799	2,160	2,006	825	529	501	**9,554**
	06289820	East Pass Creek Near Dayton, WY	596	562	544	528	542	635	982	2,882	2,855	883	494	512	**12,016**
	06289870	Twin Creek Near Parkman, WY	124	105	137	370	270	783	909	1,820	398	173	129	98	**5,316**
Tongue	06302000	Big Goose Creek Near Sheridan, WY	2,326	1,735	1,570	1,430	1,194	1,339	2,282	12,149	25,660	7,537	4,754	3,721	**65,698**
	06303500	Little Goose Creek in Canyon Near Big Horn, WY	1,847	1,384	1,250	1,126	945	1,057	2,189	10,298	14,356	6,323	5,629	3,521	**49,924**
	06305500	Goose Creek Below Sheridan, WY	6,814	5,975	5,231	4,636	5,507	5,947	8,728	23,311	37,384	8,686	4,240	6,047	**122,506**
	06305700	Goose Creek Near Acme, WY	6,974	6,107	5,341	4,729	5,627	6,080	8,953	24,129	38,842	8,919	4,325	6,185	**126,210**
	06306250	Prairie Dog Creek Near Acme, WY	2,839	2,208	1,848	1,309	2,689	5,514	2,968	2,928	2,289	1,335	1,630	2,521	**30,078**
	06306300	Tongue River at State Line Near Decker, MT	16,788	14,097	12,116	12,437	15,372	19,950	22,686	66,751	92,276	27,317	11,874	14,461	**326,123**
Powder	06309500	Middle Fork Powder River Above Kaycee, WY	2,833	2,582	2,475	2,381	2,258	2,727	5,709	15,043	9,203	3,998	2,751	2,576	**54,536**
	06311060	North Fork Powder River Below Bull Creek Near Hazelton, WY	240	178	167	130	119	141	363	3,099	3,867	1,850	1,470	1,096	**12,720**
	06311400	North Fork Powder River Below Pass Creek Near Mayoworth, WY	1,303	1,116	1,119	1,084	971	1,069	1,688	4,781	5,035	2,692	2,343	1,915	**25,116**
	06312500	Powder River Near Kaycee, WY	4,911	6,163	6,250	5,456	6,193	8,182	8,671	27,220	16,087	1,025	811	1,775	**92,743**
	06313000	South Fork Powder River Near Kaycee, WY	159	215	149	166	1,198	7,158	5,540	8,230	1,974	608	1,676	11	**27,086**
	06313400	Salt Creek Near Sussex, WY	2,235	1,706	1,580	1,726	2,412	3,985	3,012	4,564	4,661	2,916	1,876	1,750	**32,423**
	06313500	Powder River at Sussex, WY	8,804	8,411	7,030	6,999	11,096	18,936	19,424	33,736	24,225	8,661	4,715	5,703	**157,741**
	SEO Gage	Crazy Woman Creek at Trabing Bridge Near Buffalo, WY	324	221	215	186	144	182	1,589	8,734	10,816	2,724	959	1,084	**27,177**
	06316400	Crazy Woman Creek at Upper Station Near Arvada, WY	1,419	1,319	961	811	1,793	2,626	3,724	8,073	7,100	2,075	1,083	974	**31,956**
	06317000	Powder River at Arvada, WY	9,874	9,343	6,922	6,424	12,141	24,059	23,302	44,564	38,014	13,330	6,608	6,543	**201,124**
	06318500	Clear Creek Near Buffalo, WY	2,258	1,534	1,184	881	742	970	2,622	11,564	17,291	7,889	3,941	2,840	**53,714**
	SEO Gage	Clear Creek in Buffalo City Park, Buffalo, WY	1,413	1,131	871	736	924	1,738	2,159	9,095	13,292	4,229	1,565	1,501	**38,653**
	06320000	Rock Creek Near Buffalo, WY	893	651	578	519	431	485	946	6,726	8,800	3,682	2,774	1,684	**28,169**
	SEO Gage	Rock Creek at Mouth Near Buffalo, WY	1,401	1,292	952	870	1,214	2,267	1,322	4,706	6,204	1,592	957	925	**23,702**
	06320200	Clear Creek Below Rock Creek Near Buffalo, WY	3,910	3,267	2,698	2,618	3,170	4,190	5,369	16,040	22,192	7,063	3,307	3,584	**77,409**
	SEO Gage	Clear Creek below Healy Reservoir Near Buffalo, WY	1,916	1,373	996	831	1,044	2,262	3,532	13,057	19,113	7,319	3,615	3,025	**58,083**
	06321000	South Piney Creek Near Story, WY	2,011	1,524	1,491	1,217	908	968	1,493	5,891	19,901	11,386	8,790	5,621	**61,201**
	06323000	Piney Creek at Kearney, WY	1,866	2,259	2,118	1,854	1,603	2,138	4,087	15,123	22,767	4,996	1,897	1,497	**62,203**
	SEO Gage	Little Piney Creek, WY	744	722	580	549	707	950	954	1,428	1,428	803	584	718	**10,166**
	SEO Gage	Piney Creek below Lake DeSmet Tunnel Intake Near Story, WY	1,463	1,057	713	642	595	861	1,678	9,173	18,866	4,704	2,047	1,432	**43,231**
	06323500	Piney Creek at Ucross, WY	3,045	3,150	2,126	1,851	1,543	2,979	3,926	12,380	17,789	5,885	4,958	3,896	**63,527**
	SEO Gage	Clear Creek at Double Crossing Near Clearmont, WY	7,147	6,939	5,087	4,263	5,128	9,624	9,332	24,775	37,299	11,948	7,645	7,449	**136,634**
	SEO Gage	Clear Creek below P&F#3 Ditch Near Clearmont, WY	6,599	5,483	4,320	4,630	6,173	10,641	7,800	19,529	38,577	12,655	6,281	5,376	**128,064**
	06324000	Clear Creek Near Arvada, WY	6,461	6,176	4,147	3,680	5,852	10,041	10,320	23,374	34,407	9,106	5,364	6,169	**125,097**
	06324500	Powder River at Moorhead, MT	16,672	14,954	10,739	10,319	20,648	36,869	31,922	62,461	71,190	23,837	11,879	12,535	**324,023**
Little Powder	06324890	Little Powder River Below Corral Creek Near Weston, WY	8	14	21	60	187	713	138	837	84	296	41	0	**2,399**
	06324925	Little Powder River Near Weston, WY	283	144	65	405	1,109	1,553	1,119	1,970	1,683	625	309	246	**9,511**
	06324970	Little Powder River Above Dry Creek Near Weston, WY	450	254	142	548	1,493	2,209	1,519	2,318	2,026	812	453	360	**12,582**
Belle Fourche	06426500	Belle Fourche River Below Moorcroft, WY	846	276	205	494	1,513	3,406	2,128	2,920	1,675	804	418	376	**15,059**

Table III-10
Summary of Wet Year Monthly and Annual Flows (1970-1999)
Non-Natural Flow Stations

Basin	Station Number	Station Name	Average Streamflow for 1970-1999 in Acre-Feet												
			Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Little Bighorn	06289600	West Pass Creek Near Parkman, WY	580	489	427	437	397	554	790	2,821	3,336	1,121	468	608	**12,027**
	06289820	East Pass Creek Near Dayton, WY	710	600	520	549	484	684	1,035	3,727	4,598	1,411	517	721	**15,555**
	06289870	Twin Creek Near Parkman, WY	201	171	218	631	444	1,621	1,779	3,801	735	309	233	170	**10,314**
Tongue	06302000	Big Goose Creek Near Sheridan, WY	2,438	1,792	1,633	1,532	1,276	1,423	1,844	15,206	43,642	15,021	5,115	4,027	**94,948**
	06303500	Little Goose Creek in Canyon Near Big Horn, WY	1,998	1,477	1,349	1,267	1,059	1,178	1,681	13,765	23,622	8,813	5,493	4,168	**65,872**
	06305500	Goose Creek Below Sheridan, WY	6,969	5,930	5,088	4,932	4,673	7,138	8,270	43,156	71,740	21,424	5,397	6,955	**191,672**
	06305700	Goose Creek Near Acme, WY	7,133	6,062	5,193	5,033	4,767	7,306	8,477	44,499	75,198	22,253	5,480	7,142	**198,542**
	06306250	Prairie Dog Creek Near Acme, WY	3,018	2,448	2,050	1,394	2,556	7,069	3,027	8,112	3,531	2,223	2,239	2,303	**39,972**
	06306300	Tongue River at State Line Near Decker, MT	16,527	14,165	11,352	10,340	10,940	21,038	21,378	108,313	171,233	55,478	16,727	15,543	**473,035**
Powder	06309500	Middle Fork Powder River Above Kaycee, WY	2,946	2,927	2,605	2,432	2,273	2,817	5,514	18,856	15,840	5,414	3,479	3,002	**68,105**
	06311060	North Fork Powder River Below Bull Creek Near Hazelton, WY	241	175	161	139	133	159	332	4,356	6,662	2,508	1,899	1,134	**17,899**
	06311400	North Fork Powder River Below Pass Creek Near Mayoworth, WY	1,370	1,215	1,178	1,153	1,048	1,133	1,330	6,663	9,603	3,500	2,898	2,293	**33,386**
	06312500	Powder River Near Kaycee, WY	6,596	8,318	8,443	7,304	8,391	10,965	11,653	35,264	20,683	1,310	1,157	2,323	**122,407**
	06313000	South Fork Powder River Near Kaycee, WY	277	394	234	331	1,879	12,398	9,830	14,619	3,052	854	2,431	15	**46,315**
	06313400	Salt Creek Near Sussex, WY	2,618	2,134	1,994	2,179	2,928	6,372	3,697	10,353	4,264	3,944	2,299	2,130	**44,913**
	06313500	Powder River at Sussex, WY	17,455	10,548	8,768	8,082	9,846	19,191	17,354	73,310	51,299	14,882	4,663	4,747	**240,144**
	SEO Gage	Crazy Woman Creek at Trabing Bridge Near Buffalo, WY	342	248	227	213	167	205	2,705	16,980	32,197	7,031	2,723	1,346	**64,382**
	06316400	Crazy Woman Creek at Upper Station Near Arvada, WY	3,113	1,647	1,174	970	1,556	2,802	3,577	20,742	21,055	3,967	2,082	646	**63,330**
	06317000	Powder River at Arvada, WY	18,455	11,577	8,322	7,527	11,060	27,253	22,005	105,460	90,540	25,422	8,175	5,057	**340,852**
	06318500	Clear Creek Near Buffalo, WY	2,683	1,917	1,485	1,122	948	1,224	3,052	17,066	25,968	14,208	5,142	3,249	**78,065**
	SEO Gage	Clear Creek in Buffalo City Park, Buffalo, WY	4,025	2,420	1,881	1,577	2,194	2,946	3,054	15,386	25,177	9,248	1,853	1,168	**70,930**
	06320000	Rock Creek Near Buffalo, WY	964	688	622	579	474	535	878	9,368	14,881	5,068	3,209	1,747	**39,012**
	SEO Gage	Rock Creek at Mouth Near Buffalo, WY	2,602	1,694	1,311	1,205	1,650	2,571	1,691	9,391	15,501	3,386	1,269	1,104	**43,372**
	06320200	Clear Creek Below Rock Creek Near Buffalo, WY	3,474	3,091	2,449	2,224	2,341	4,567	5,969	27,998	41,149	14,336	4,037	3,100	**114,733**
	SEO Gage	Clear Creek below Healy Reservoir Near Buffalo, WY	5,612	3,084	2,263	1,852	2,658	3,530	4,435	26,501	39,607	14,794	4,335	3,255	**111,926**
	06321000	South Piney Creek Near Story, WY	2,333	1,720	1,708	1,457	1,168	1,244	1,749	6,581	22,873	17,609	10,733	5,829	**75,004**
	06323000	Piney Creek at Kearney, WY	2,432	2,775	2,159	2,103	1,710	2,037	4,070	20,980	41,967	13,590	3,830	1,340	**98,991**
	SEO Gage	Little Piney Creek, WY	925	830	582	642	833	1,030	1,054	2,734	2,540	1,336	722	707	**13,933**
	SEO Gage	Piney Creek below Lake DeSmet Tunnel Intake Near Story, WY	2,259	1,558	1,144	1,004	927	1,280	2,549	17,464	38,497	10,973	3,374	1,762	**82,791**
	06323500	Piney Creek at Ucross, WY	4,880	4,201	3,459	3,078	2,221	4,190	4,203	18,650	42,300	14,719	6,525	3,190	**111,616**
	SEO Gage	Clear Creek at Double Crossing Near Clearmont, WY	13,916	9,888	8,067	6,929	8,629	11,825	10,678	47,150	86,491	28,773	8,955	6,602	**247,901**
	SEO Gage	Clear Creek below P&F#3 Ditch Near Clearmont, WY	5,842	5,553	2,924	2,797	4,373	12,829	12,513	17,547	3,355	2,034	589	1,452	**71,807**
	06324000	Clear Creek Near Arvada, WY	9,179	7,200	3,891	4,404	7,135	10,514	11,838	45,277	78,252	26,470	7,949	5,007	**217,115**
	06324500	Powder River at Moorhead, MT	24,643	19,325	9,172	12,118	19,360	42,163	31,243	146,877	162,267	53,775	16,330	9,263	**546,537**
Little Powder	06324890	Little Powder River Below Corral Creek Near Weston, WY	11	27	37	83	261	2,693	233	3,385	225	387	58	1	**7,400**
	06324925	Little Powder River Near Weston, WY	2,316	180	143	562	9,553	16,317	6,268	9,079	2,733	377	279	53	**47,860**
	06324970	Little Powder River Above Dry Creek Near Weston, WY	2,722	485	375	1,195	7,548	14,241	2,977	13,336	3,498	1,177	553	323	**48,430**
Belle Fourche	06426500	Belle Fourche River Below Moorcroft, WY	850	118	70	577	3,802	11,643	4,656	16,641	5,432	1,384	1,138	208	**46,519**

Table III-11
Summary of Dry Year Monthly and Annual Flows (1970-1999)
Ungaged Natural Flow Nodes

Basin	Station Name	Estimated Average Streamflow for 1970-1999 in Acre-Feet												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tongue	Rapid Creek Just Below Little Rapid Creek in Section 32, T55N, R85W	90	67	63	52	44	49	201	1,031	723	260	123	87	**2,792**
	Beaver Creek at Bottom of Section 26, T55N, R85W	25	19	17	14	12	14	56	285	200	72	34	24	**771**
	Soldier Creek at Right Edge of Section 28, T56N, R85W	55	41	38	32	27	30	123	628	441	158	75	53	**1,702**
	Prairie Dog Creek Just Above Dutch Creek in Section 34, T57N, R83W	462	1,322	3,269	2,125	1,827	1,432	1,401	1,314	1,134	748	612	610	**16,255**
Powder	Red Fork Powder River Just Below North & South Forks Red Fork Powder River in Section 29, T44N, R84W	24	24	19	20	15	23	118	335	105	33	18	17	**752**
	Kelly Creek at Top of Section 21, T49N, R82W	49	37	28	22	18	21	173	531	330	106	56	41	**1,414**
	Little North Fork Crazy Woman Creek Just Below Grossett Canyon in Section 14, T49N, R83W	156	123	97	74	60	68	428	1,210	787	292	155	117	**3,568**
	Muddy Creek at Diversion Near East Side of Section 35, T49N, R83W	143	113	89	68	55	63	393	1,111	723	269	143	108	**3,277**
	Billy Creek at Diversion to O'Malley Draw in Section 13, T48N, R83W	2,116	1,637	1,536	1,310	1,136	1,244	2,545	14,220	14,547	5,167	3,833	2,937	**52,227**
	Little Piney Creek Just Below Bear Gulch in Section 28, T53N, R83W	332	336	601	616	820	626	564	407	341	245	309	282	**5,480**
	North & South Forks Shell Creek (Combined), at Confluence of Little North Fork Shell Creek & North Fork Shell Creek in Section 11, and Confluence of Unnamed Tributary & South Fork Shell Creek in Section 14; all in T52N, R83W	52	38	30	23	19	22	181	554	345	111	58	43	**1,475**
	Johnson Creek at Top of Section 22, T51N, R83W	49	37	28	22	18	21	173	531	330	106	56	41	**1,414**
	French Creek at Penrose Ditch Diversion in Section 27, T51N, R83W	119	88	68	53	43	51	416	1,275	793	256	134	99	**3,395**

Table III-12
Summary of Normal Year Monthly and Annual Flows (1970-1999)
Ungaged Natural Flow Nodes

Basin	Station Name	Estimated Average Streamflow for 1970-1999 in Acre-Feet												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tongue	Rapid Creek Just Below Little Rapid Creek in Section 32, T55N, R85W	99	74	65	58	51	55	151	991	1,382	386	170	114	**3,596**
	Beaver Creek at Bottom of Section 26, T55N, R85W	27	20	18	16	14	15	42	274	382	107	47	32	**994**
	Soldier Creek at Right Edge of Section 28, T56N, R85W	60	45	39	36	31	33	92	604	843	235	104	70	**2,192**
	Prairie Dog Creek Just Above Dutch Creek in Section 34, T57N, R83W	559	1,529	3,372	2,321	2,368	2,074	1,852	1,470	1,202	1,066	830	752	**19,396**
Powder	Red Fork Powder River Just Below North & South Forks Red Fork Powder River in Section 29, T44N, R84W	34	31	25	27	23	41	215	515	238	64	32	28	**1,272**
	Kelly Creek at Top of Section 21, T49N, R82W	55	42	35	27	23	26	99	685	654	200	88	63	**1,998**
	Little North Fork Crazy Woman Creek Just Below Grossett Canyon in Section 14, T49N, R83W	177	128	107	85	71	81	280	1,360	1,363	488	243	182	**4,563**
	Muddy Creek at Diversion Near East Side of Section 35, T49N, R83W	162	118	98	78	65	75	257	1,249	1,252	448	223	167	**4,191**
	Billy Creek at Diversion to O'Malley Draw in Section 13, T48N, R83W	2,326	1,735	1,570	1,430	1,194	1,339	2,282	12,149	25,660	7,537	4,754	3,721	**65,698**
	Little Piney Creek Just Below Bear Gulch in Section 28, T53N, R83W	289	422	610	672	1,086	1,143	678	483	465	271	309	264	**6,691**
	North & South Forks Shell Creek (Combined), at Confluence of Little North Fork Shell Creek & North Fork Shell Creek in Section 11, and Confluence of Unnamed Tributary & South Fork Shell Creek in Section 14; all in T52N, R83W	57	44	36	28	24	27	103	715	682	208	92	66	**2,084**
	Johnson Creek at Top of Section 22, T51N, R83W	55	42	35	27	23	26	99	685	654	200	88	63	**1,998**
	French Creek at Penrose Ditch Diversion in Section 27, T51N, R83W	132	101	84	65	56	63	237	1,646	1,570	480	212	151	**4,797**

Table III-13
Summary of Wet Year Monthly and Annual Flows (1970-1999)
Ungaged Natural Flow Nodes

Basin	Station Name	Estimated Average Streamflow for 1970-1999 Acre-Feet												
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Tongue	Rapid Creek Just Below Little Rapid Creek in Section 32, T55N, R85W	103	75	67	61	50	58	124	1,246	2,396	620	210	120	**5,130**
	Beaver Creek at Bottom of Section 26, T55N, R85W	29	21	19	17	14	16	34	344	662	171	58	33	**1,418**
	Soldier Creek at Right Edge of Section 28, T56N, R85W	63	46	41	37	30	35	76	760	1,460	378	128	73	**3,127**
	Prairie Dog Creek Just Above Dutch Creek in Section 34, T57N, R83W	439	1,090	3,718	2,241	6,284	3,382	2,637	1,896	1,423	845	733	657	**25,344**
Powder	Red Fork Powder River Just Below North & South Forks Red Fork Powder River in Section 29, T44N, R84W	50	44	36	41	33	60	316	925	390	100	46	39	**2,081**
	Kelly Creek at Top of Section 21, T49N, R82W	52	41	33	30	23	29	75	773	1,280	343	110	65	**2,854**
	Little North Fork Crazy Woman Creek Just Below Grossett Canyon in Section 14, T49N, R83W	145	116	95	81	71	86	227	1,837	2,442	824	317	188	**6,429**
	Muddy Creek at Diversion Near East Side of Section 35, T49N, R83W	133	107	87	75	66	79	209	1,687	2,243	757	291	173	**5,905**
	Billy Creek at Diversion to O'Malley Draw in Section 13, T48N, R83W	2,438	1,792	1,633	1,532	1,276	1,423	1,844	15,206	43,642	15,021	5,115	4,027	**94,948**
	Little Piney Creek Just Below Bear Gulch in Section 28, T53N, R83W	351	505	664	740	1,979	1,982	1,190	741	604	411	397	271	**9,837**
	North & South Forks Shell Creek (Combined), at Confluence of Little North Fork Shell Creek & North Fork Shell Creek in Section 11, and Confluence of Unnamed Tributary & South Fork Shell Creek in Section 14; all in T52N, R83W	54	42	34	31	24	30	78	807	1,336	358	115	67	**2,978**
	Johnson Creek at Top of Section 22, T51N, R83W	52	41	33	30	23	29	75	773	1,280	343	110	65	**2,854**
	French Creek at Penrose Ditch Diversion in Section 27, T51N, R83W	125	98	79	71	54	70	180	1,857	3,074	825	265	155	**6,854**

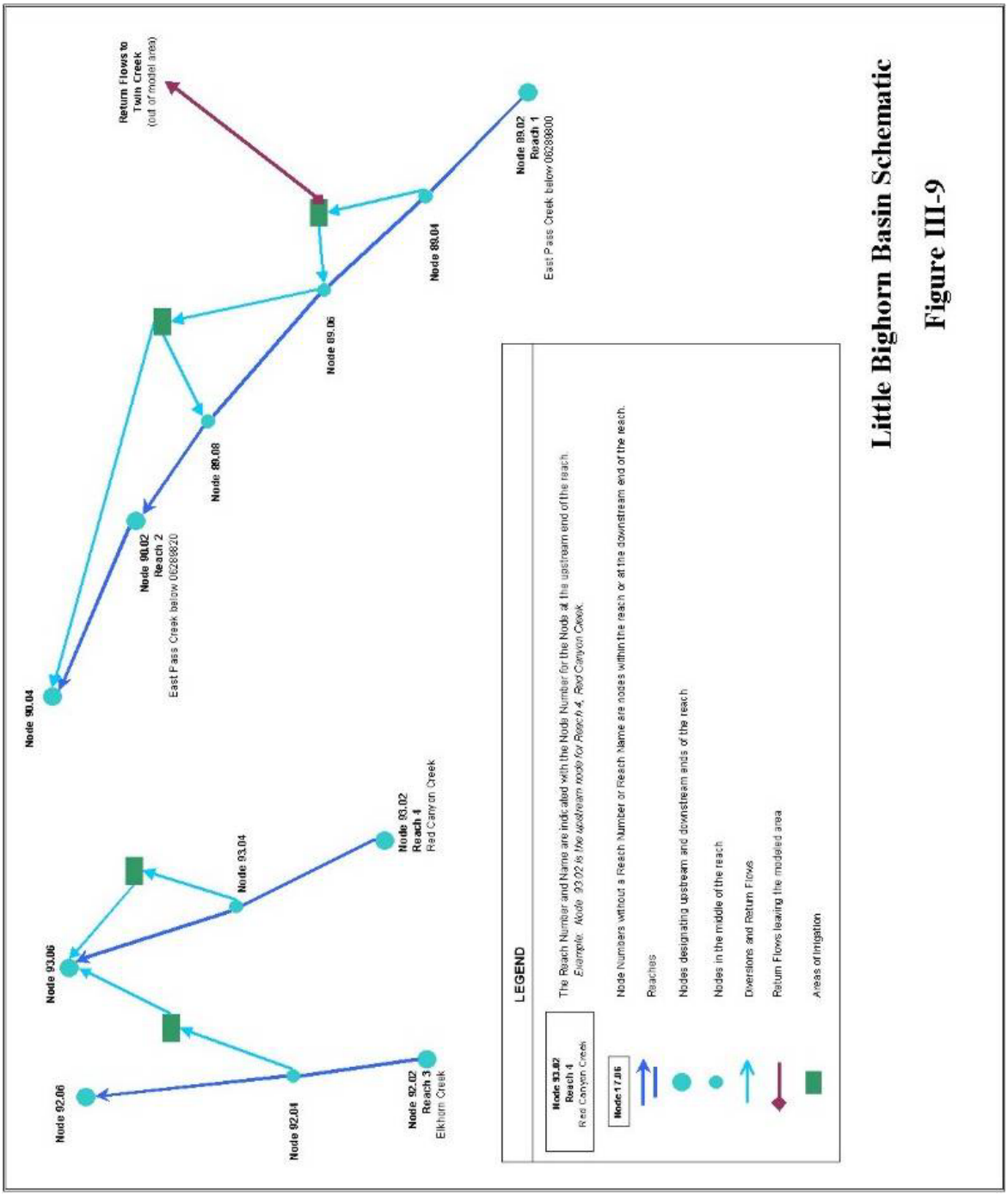
Theoretical Maximum Diversion Requirements were calculated using the acreage of irrigated lands mapped through this study and the consumptive irrigation requirements (CIR) provided by Dr. Larry Pochop. The historical diversion records were then compared to the Theoretical Maximum Diversions yielding mathematical relationships used to calculate the Estimated Actual Diversions and the Full Supply Diversion Requirements for all modeled irrigated lands. A more detailed discussion of this process is offered in the "Agricultural Use" technical memorandum.

Development of the model and the model inputs (primarily streamflows, estimated actual diversions and the interrelated irrigation efficiencies and irrigation return flows) progressed somewhat concurrently in order to achieve calibration. The model representation of the physical system and the various model inputs were adjusted as necessary through a trial and error process until the models were reasonably well calibrated.

To mathematically represent each sub-basin, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach was then sub-divided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. The resulting network is a simplified representation of actual conditions. Figures III-9 through III-14 present node diagrams of the sub-basin models developed for the planning area.

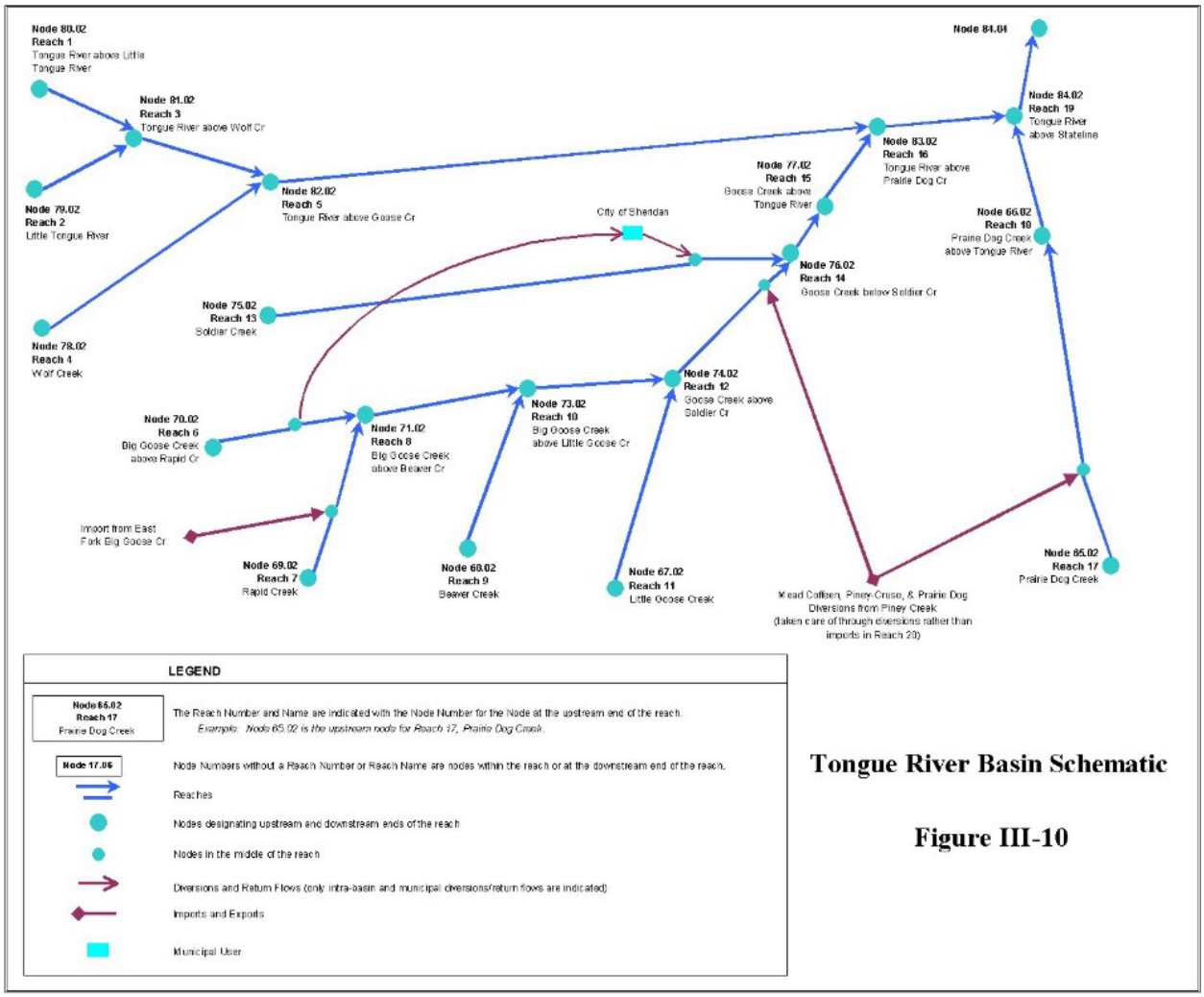
Historical or virgin flow for each month is supplied to the model at the uppermost node. Where available, upper basin gages were selected as the uppermost model nodes; in their absence, flow at the ungaged headwater point was estimated as discussed in a preceding section. For each reach, incremental stream gains (e.g., ungaged tributaries, ground water inflow, and inflow resulting from man-induced but unmodeled processes) and losses (e.g. seepage, evaporation, and unspecified diversions) are computed by the spreadsheet. These are calculated by adding the net modeled effects (diversions and increases in storage less return flows and decreases in storage) within the basin back into the difference between the upstream and downstream historical gage flows.

At each node, a water budget computation is completed to determine the amount of water that bypasses the node. At non-storage nodes, the difference between inflow, including upstream inflows, return flows, imports and basin gains, and outflows, including diversions, basin losses and exports, is the amount of flow available to the next node downstream. For storage nodes, an additional loss calculation for evaporation and the change in storage is evaluated. Also at storage nodes, any uncontrolled spill that occurs is added to the scheduled release to determine total outflow. Diverted amounts at diversion nodes are the minimum of demand (the full supply diversion at the structure) and physically available streamflow. The mass balance, or water budget calculations, is performed for all nodes in a reach.



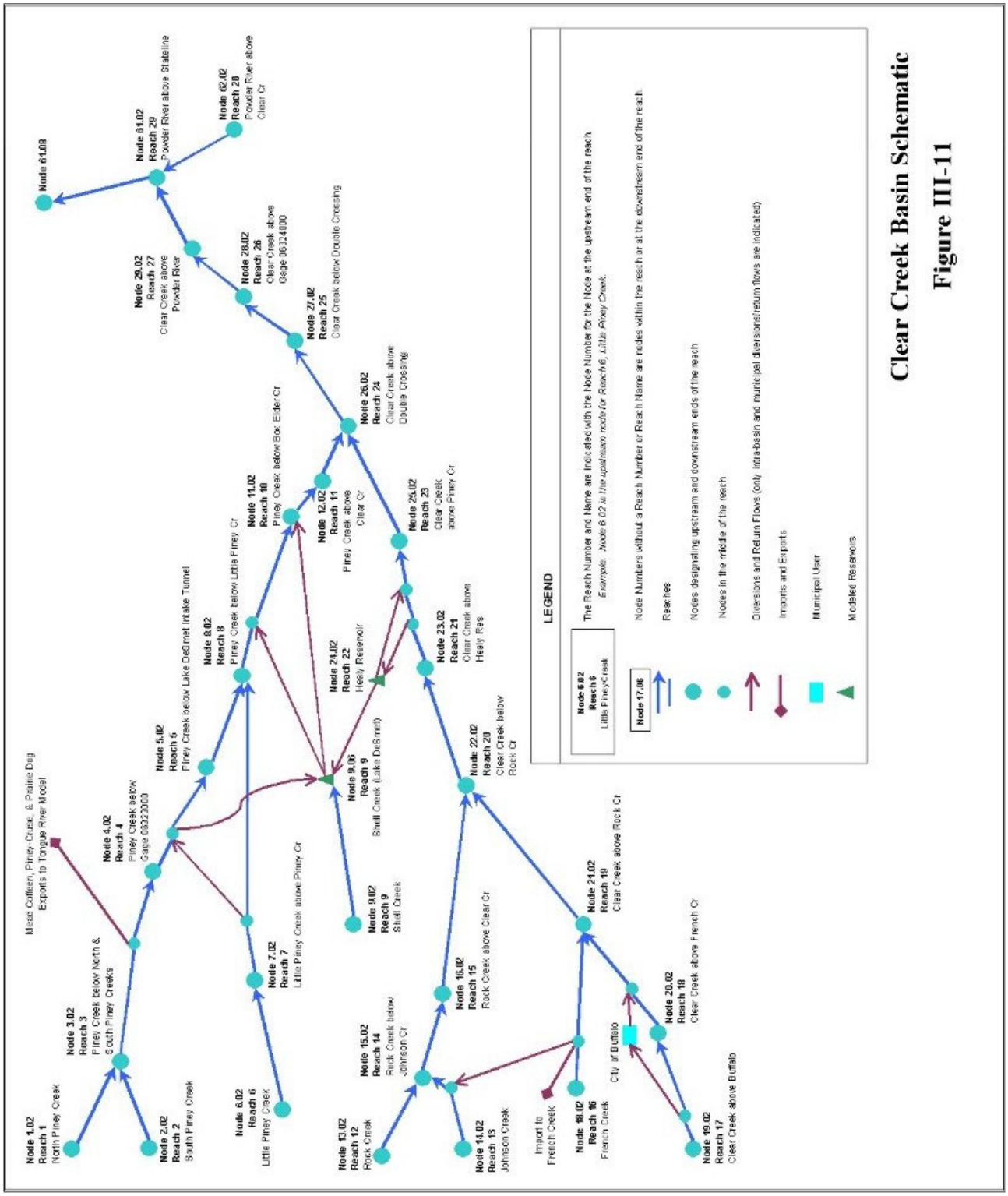
Little Bighorn Basin Schematic

Figure III-9



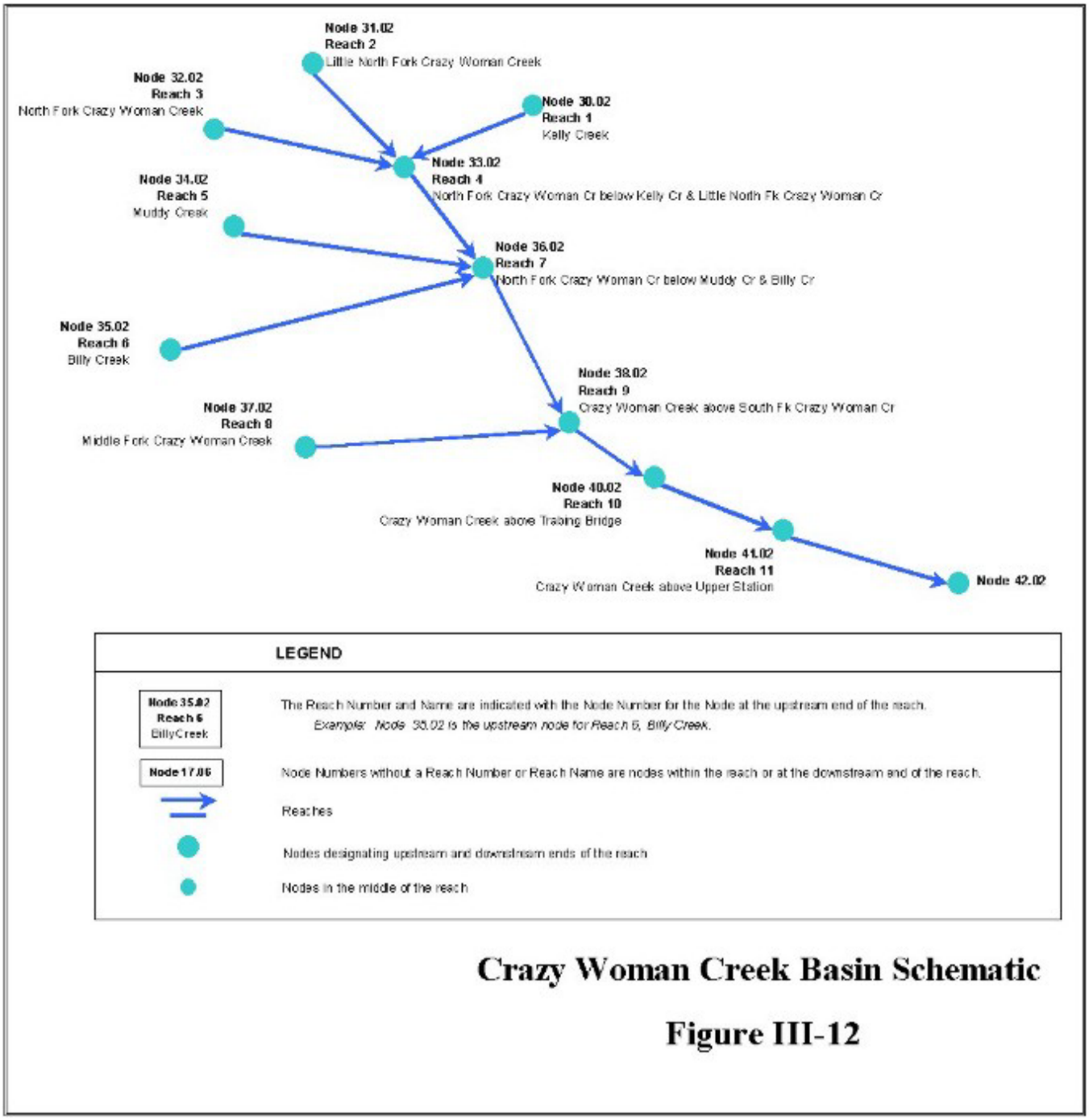
Tongue River Basin Schematic

Figure III-10



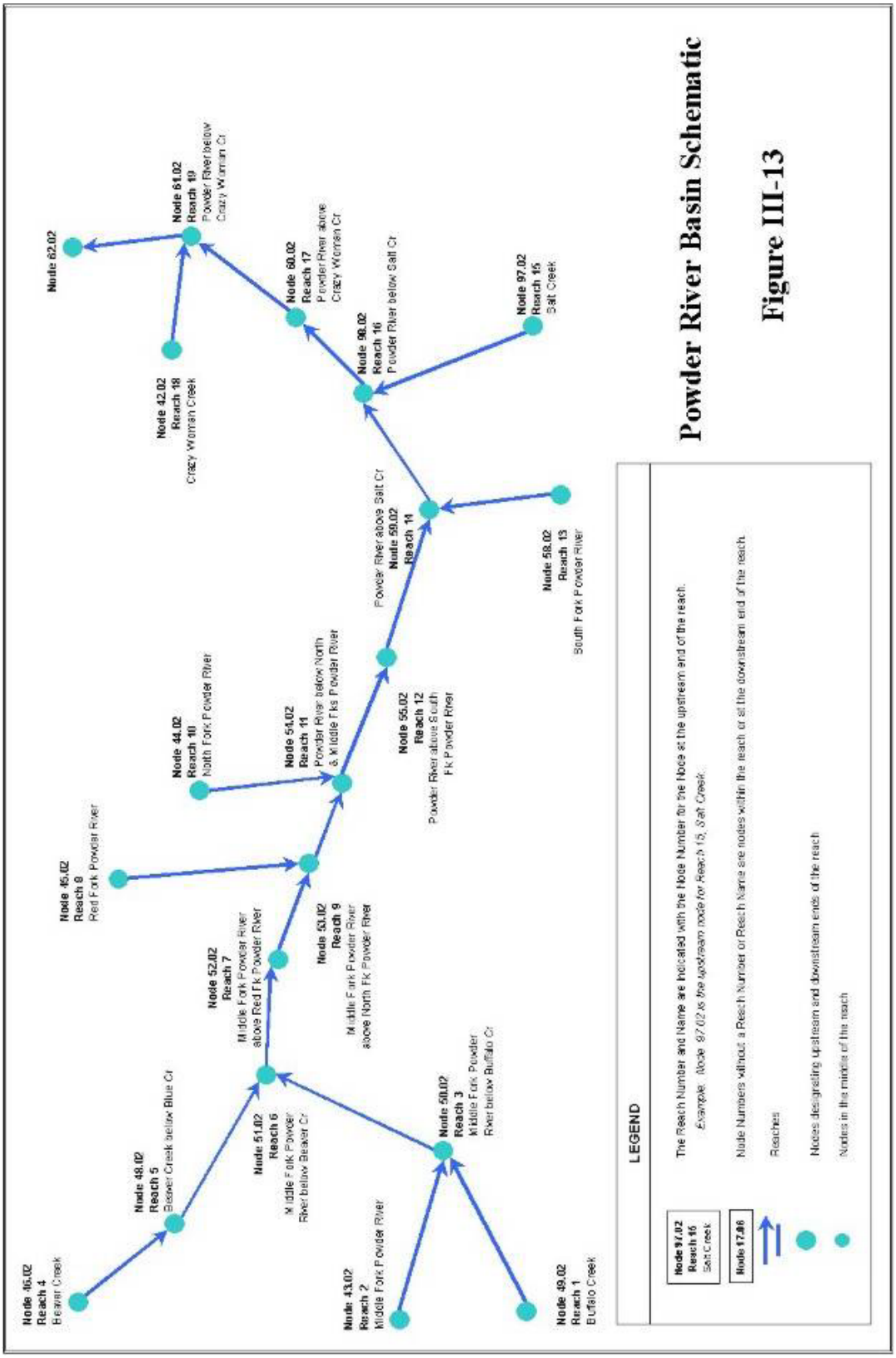
Clear Creek Basin Schematic

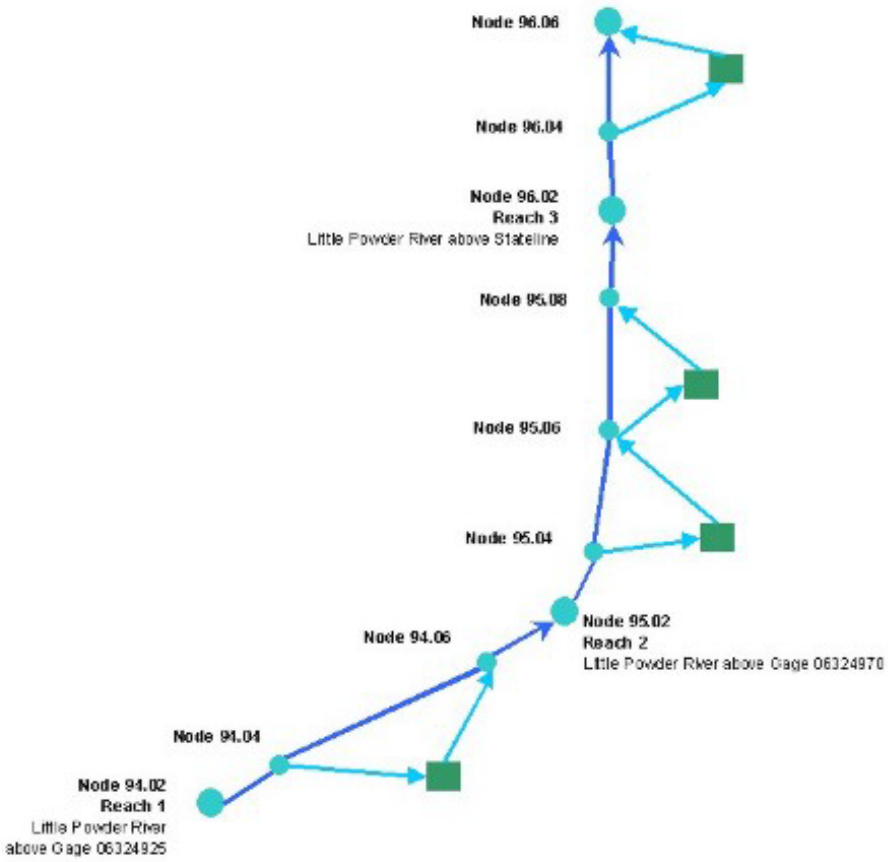
Figure III-11

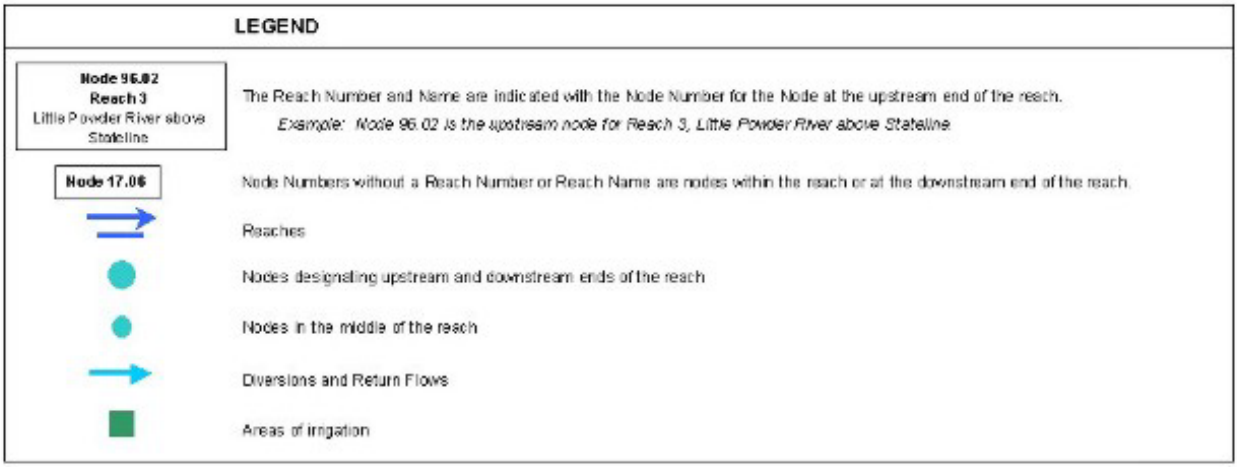


Crazy Woman Creek Basin Schematic

Figure III-12


Powder River Basin Schematic
Figure III-13
Node 62.02
Node 64.02
Reach 19
Powder River below
Crazy Woman Cr
Node 60.02
Reach 17
Powder River above
Crazy Woman Cr
Node 42.02
Reach 18
Crazy Woman Creek
Node 98.02
Reach 16
Powder River below Salt Cr
Node 97.02
Reach 15
Salt Creek
Powder River above Salt Cr
Node 59.02
Reach 14
Node 58.02
Reach 13
South Fork Powder River
Node 54.02
Reach 11
Powder River below North
& Middle Frks Powder River
Node 44.02
Reach 10
North Fork Powder River
Node 55.02
Reach 12
Powder River above South
Fk Powder River
Node 45.02
Reach 8
Red Fork Powder River
Node 52.02
Reach 7
Middle Fork Powder River
above Red Fk Powder River
Node 53.02
Reach 9
Middle Fork Powder River
above North Fk Powder River
Node 51.02
Reach 6
Middle Fork Powder
River below Beaver Cr
Node 48.02
Reach 5
Beaver Creek below Blue Cr
Node 46.02
Reach 4
Beaver Creek
Node 50.02
Reach 3
Middle Fork Powder
River below Buffalo Cr
Node 43.02
Reach 2
Middle Fork Powder River
Node 49.02
Reach 1
Buffalo Creek
LEGEND
Node 97.02
Reach 15
Salt Creek
Node 17.#6
The Reach Number and Name are indicated with the Node Number for the Node at the upstream end of the reach.
Example: Node 97.02 is the upstream node for Reach 15, Salt Creek.
Node Numbers without a Reach Number or Reach Name are nodes within the reach or at the downstream end of the reach.
Reaches
Nodes designating upstream and downstream ends of the reach
Nodes in the middle of the reach





Little Powder River Basin Schematic

Figure III-14

Model output includes the full-supply diversion demand and model simulated diversions at each of the diversion points, and streamflow at each of the Powder/Tongue River sub-basin model nodes. Estimates of impacts associated with various water projects can be analyzed by changing input data, as decreases in available streamflow or as changes to diversions occur. New storage projects that alter the timing of streamflows or shortages may also be evaluated.

Model Development and Structure

The model was developed using Microsoft® Excel 97. The workbooks contain macros written in the Microsoft® Visual Basic for Applications programming language. The primary function of the macros is to facilitate navigation within the workbook.

Each of the Powder/Tongue River sub-basin 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:** Graphical User Interfaces (GUIs) containing buttons used to move within the workbook;
- **Input Worksheets:** Raw data entry worksheets (USGS Gage data or headwater inflow data, Diversion Data, etc.);
- **Computation Worksheets:** Compute various components of the model (reservoir evaporation, irrigation return flows, etc.);
- **Reach/Node Worksheets:** Calculate node by node computations of the water budget; and
- **Results Worksheets:** Tabulate and present the model output.

A more detailed description of the development of the spreadsheet models is provided in the "Spreadsheet Model Development and Calibration" technical memorandum.

Determination of Available Surface Water

The estimated amount of water flowing through each of the various model reaches, as previously described, provides the primary basis for determining how much water is physically available for future development. Reaches are typically defined by gages or confluences, and represent tributary basins or subsections of the mainstem. A Reach Outflow worksheet is provided in each model, summarizing the monthly flow at the downstream end of each reach. The information provided in these summaries is used for this analysis.

While simulated flow at the reach terminus indicates the estimated amount of water physically present, it does not fully reflect availability. Downstream demands relying on the water physically available at any given location must first be accounted for. These downstream demands fall into three general categories:

1. Existing irrigation, or municipal diversions
2. Instream flow constraints
3. Compact constraints

Available Flow in Excess of Existing Diversion Demands

To determine how much of the physical supply is actually available in excess of existing demands, "available flow" at each reach terminus is defined as the minimum of the physically available flow at that point, and the "available flow" at all downstream reaches. Thus available flow must be defined first at the most downstream point, with upstream availability calculated in stream order. These calculations are made on a monthly basis, and annual water availability is computed as the sum of monthly values.

Instream Flow Constraints

Instream flow rights exert a demand on the river but do not affect physical supply, because the water is not removed from the stream. Sufficient flow must be bypassed through upstream reaches to satisfy downstream instream flow requirements. The available flow for reaches located upstream from permitted instream flows are determined as the minimum of physical flow at that point, and available flow in excess of existing diversion demands less the instream flow requirement at the downstream reach.

With only one exception, all of the six instream flow rights within the planning area are located above the most upstream reach explicitly simulated in the model. The available flow for future development reported herein, therefore, is downstream from most of these instream flow constraints. The exception is a 9.86-mile long reach of the Middle Fork Powder River with a 1987 priority instream flow requirement of 12 to 25 cfs. The available flow in Reach 2 of the Powder River sub-basin was calculated taking this instream flow demand into consideration.

The reach by reach results of the monthly available flow determination, accounting for the instream flow constraints, are provided in Tables III-15 through III-32 for each of the six sub-basins and for each of the three hydrologic conditions (wet, normal, and dry years). The total annual available flow is summarized in Table III-14 for each sub-basin and hydrologic condition. The locations of these available flows are also shown graphically on Figures III-15 through III-20 for the limiting dry year conditions.

Table III-14
Total Annual Available Flow

Subbasin	Hydrologic Condition		
	Wet Years	**Normal Years**	**Dry Years**
Little Bighorn River	152,000	113,000	81,000
Tongue River	473,000	326,000	218,000
Clear Creek	213,000	124,000	80,000
Crazy Woman Creek	69,000	32,000	16,000
Powder River	547,000	324,000	194,000
Little Powder River	48,000	12,000	3,000

Table III-15
Available Flow for Little Bighorn Basin (Acre-Feet)
Wet Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	East Pass Cr below USGS gage 06289800	549	484	684	1,035	3,727	4,598	1,411	517	721	710	600	520	15,555
2	East Pass Cr below USGS gage 06289820	568	496	690	1,035	3,741	4,636	1,458	573	788	760	638	549	15,931
3	Elkhorn Creek below USGS gage 06288975	89	81	92	136	711	1,115	315	147	150	118	102	95	3,153
4	Red Canyon Creek below USGS gage 06289100	46	37	66	346	1,001	421	105	48	44	60	52	42	2,268

Table III-16
Available Flow for Little Bighorn Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	East Pass Cr below USGS gage 06289800	528	542	635	982	2,882	2,855	883	494	512	596	562	544	12,016
2	East Pass Cr below USGS gage 06289820	549	556	643	988	2,906	2,902	937	556	589	654	605	575	12,461
3	Elkhorn Creek below USGS gage 06288975	86	75	88	137	464	592	174	124	114	116	101	92	2,164
4	Red Canyon Creek below USGS gage 06289100	29	24	43	213	544	238	61	29	28	40	35	28	1,313

Table III-17
Available Flow for Little Bighorn Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	East Pass Cr below USGS gage 06289800	506	458	592	790	1,407	1,317	673	398	475	620	578	551	8,364
2	East Pass Cr below USGS gage 06289820	527	472	600	804	1,455	1,387	743	470	565	688	628	586	8,926
3	Elkhorn Creek below USGS gage 06288975	81	70	83	141	317	246	133	109	91	104	97	90	1,562
4	Red Canyon Creek below USGS gage 06289100	23	17	24	125	258	101	32	20	23	29	28	22	702

Table III-18
Available Flow for Tongue River Basin (Acre-Feet)
Wet Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Tongue River above Little Tongue River	3,493	3,099	4,101	5,652	34,863	69,125	25,201	8,354	5,454	5,369	4,132	3,715	172,557
2	Little Tongue River	132	109	151	334	4,235	7,620	1,320	56	0	238	164	143	14,502
3	Tongue River above Wolf Creek	3,826	3,343	4,325	5,986	39,098	76,744	26,521	8,410	5,454	6,123	4,689	4,156	188,675
4	Wolf Creek	507	395	456	736	7,343	12,285	2,000	0	10	1,014	765	630	26,141
5	Tongue River above Goose Creek	4,443	3,889	4,866	6,723	46,441	89,029	28,521	8,410	5,464	7,481	5,891	4,915	216,074
6	Big Goose Creek above Rapid Creek	904	1,286	2,907	3,434	20,500	45,977	15,058	2,911	3,258	1,898	1,341	1,169	100,643
7	Rapid Creek	69	73	140	48	622	1,269	914	0	0	113	91	79	3,418
8	Big Goose Creek above Beaver Creek	1,124	1,461	3,103	3,483	21,123	47,246	15,972	2,911	3,258	2,218	1,725	1,471	105,095
9	Beaver Creek	93	60	52	73	492	715	180	88	71	220	186	142	2,373
10	Big Goose Creek above Little Goose Creek	1,400	1,633	3,209	3,561	21,649	48,030	16,152	2,998	3,329	2,438	2,037	1,704	108,141
11	Little Goose Creek	2,224	2,093	3,152	3,297	17,881	21,368	4,782	1,962	3,047	3,462	2,966	2,478	68,712
12	Goose Creek above Soldier Creek	3,931	3,983	6,542	7,735	41,796	70,136	20,934	4,960	6,376	5,901	5,002	4,182	181,477
13	Soldier Creek	975	690	596	535	1,360	1,604	490	436	579	1,013	928	806	10,013
14	Goose Creek below Soldier Creek	4,906	4,767	7,306	8,477	44,499	75,198	22,253	5,480	7,142	6,914	6,062	4,988	197,990
15	Goose Creek above Tongue River	4,906	5,011	9,233	10,526	51,560	78,270	24,483	5,840	7,566	6,914	6,182	4,988	215,479
16	Tongue River above Prairie Dog Creek	9,349	8,940	14,121	17,249	98,002	167,299	53,003	14,251	13,030	14,395	12,185	9,903	431,727
17	Prairie Dog Creek above USGS gage 06306250	991	1,816	5,423	3,027	8,112	3,531	2,223	2,239	2,303	2,132	1,815	1,449	35,063
18	Prairie Dog Creek above Tongue River	991	1,909	6,853	3,768	9,419	3,687	2,475	2,476	2,513	2,132	1,851	1,449	39,522
19	Tongue River above State Line	10,340	10,940	21,038	21,378	108,313	171,233	55,478	16,727	15,543	16,527	14,165	11,352	473,035

Table III-19
Available Flow for Tongue River Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Tongue River above Little Tongue River	4,097	3,785	4,287	6,797	31,196	40,228	14,135	5,834	4,768	5,298	4,087	3,729	128,239
2	Little Tongue River	153	146	167	389	2,860	3,579	524	0	0	224	162	140	8,344
3	Tongue River above Wolf Creek	4,440	4,054	4,518	7,186	34,055	43,806	14,659	5,834	4,768	6,046	4,654	4,166	138,186
4	Wolf Creek	549	469	459	779	4,696	6,156	603	0	66	1,000	763	615	16,155
5	Tongue River above Goose Creek	5,203	4,663	5,051	7,965	38,751	49,962	15,262	5,834	5,061	7,484	5,868	5,113	156,217
6	Big Goose Creek above Rapid Creek	1,167	1,996	2,534	3,506	12,104	24,197	4,773	2,016	1,844	1,864	1,365	1,191	58,558
7	Rapid Creek	71	105	122	0	0	1,735	104	0	0	99	90	76	2,402
8	Big Goose Creek above Beaver Creek	1,383	2,196	2,705	3,506	12,104	25,933	4,877	2,016	2,077	2,219	1,758	1,491	62,264
9	Beaver Creek	98	71	51	62	292	386	117	74	132	247	207	154	1,890
10	Big Goose Creek above Little Goose Creek	1,663	2,378	2,808	3,568	12,431	26,426	5,152	2,090	2,604	2,466	2,129	1,877	65,590
11	Little Goose Creek	2,131	2,441	2,613	3,370	9,008	9,619	1,226	1,802	2,081	3,388	2,962	2,569	43,210
12	Goose Creek above Soldier Creek	3,957	4,959	5,472	8,222	22,407	36,483	8,086	3,892	5,273	5,854	5,091	4,446	114,140
13	Soldier Creek	679	548	475	507	905	901	600	348	774	960	884	786	8,366
14	Goose Creek below Soldier Creek	4,729	5,627	6,080	8,953	24,129	38,842	8,919	4,325	6,185	6,832	6,107	5,341	126,069
15	Goose Creek above Tongue River	5,712	7,430	8,224	10,623	24,604	39,850	9,845	4,327	6,513	6,832	6,107	5,341	135,408
16	Tongue River above Prairie Dog Creek	10,970	12,129	13,293	18,588	63,356	89,813	25,107	10,161	11,574	14,317	12,091	10,471	291,870
17	Prairie Dog Creek above USGS gage 06306250	1,174	2,419	4,913	2,968	2,928	2,289	1,335	1,630	2,521	2,471	1,977	1,644	28,268
18	Prairie Dog Creek above Tongue River	1,418	3,193	6,645	3,535	3,000	2,364	1,511	1,713	2,727	2,471	1,977	1,644	32,198
19	Tongue River above State Line	12,437	15,372	19,950	22,686	66,751	92,276	27,317	11,874	14,461	16,788	14,097	12,116	326,123

Table III-20
Available Flow for Tongue River Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Tongue River above Little Tongue River	3,004	2,653	3,226	7,848	31,008	19,377	5,581	3,057	2,722	4,730	3,749	3,259	90,215
2	Little Tongue River	107	90	113	353	2,579	1,392	0	0	0	193	143	122	5,092
3	Tongue River above Wolf Creek	3,111	2,773	3,408	8,201	33,587	20,768	5,581	3,057	2,722	5,505	4,368	3,381	96,462
4	Wolf Creek	394	313	348	606	4,271	2,173	0	0	26	969	747	503	10,350
5	Tongue River above Goose Creek	3,505	3,086	3,840	8,807	37,857	22,941	5,581	3,057	3,017	6,474	5,283	3,884	107,333
6	Big Goose Creek above Rapid Creek	1,019	1,132	2,622	2,573	13,498	9,327	84	0	0	1,631	1,265	1,154	34,305
7	Rapid Creek	64	64	123	0	0	584	0	0	0	74	87	76	1,073
8	Big Goose Creek above Beaver Creek	1,216	1,276	2,789	2,573	13,498	9,911	97	102	202	1,773	1,656	1,281	36,374
9	Beaver Creek	52	29	37	0	282	192	48	12	0	174	175	100	1,101
10	Big Goose Creek above Little Goose Creek	1,312	1,341	2,868	2,573	13,779	10,333	373	376	526	1,947	1,831	1,381	38,641
11	Little Goose Creek	1,661	1,581	2,723	1,357	6,347	1,038	887	932	1,042	2,661	2,468	1,789	24,485
12	Goose Creek above Soldier Creek	2,973	2,922	5,636	6,367	20,126	15,795	2,242	1,502	2,100	4,607	4,299	3,170	71,738
13	Soldier Creek	602	514	501	598	821	810	671	379	649	909	861	638	7,952
14	Goose Creek below Soldier Creek	3,575	3,436	6,277	7,133	21,677	17,157	2,912	1,880	2,749	5,517	5,160	3,808	81,280
15	Goose Creek above Tongue River	3,575	3,436	7,041	7,615	21,726	17,598	2,912	1,880	2,749	5,517	5,160	3,808	83,018
16	Tongue River above Prairie Dog Creek	7,080	6,522	10,881	16,422	59,584	40,540	8,494	4,938	5,765	11,990	10,443	7,692	190,351
17	Prairie Dog Creek above USGS gage 06306250	938	1,975	4,793	2,043	1,678	1,279	878	1,496	1,928	2,055	1,695	1,196	21,953
18	Prairie Dog Creek above Tongue River	938	1,975	5,366	2,208	1,696	1,335	878	1,496	1,928	2,055	1,695	1,196	22,765
19	Tongue River above State Line	8,018	8,497	16,247	19,902	61,280	43,982	10,638	6,433	7,775	14,045	12,138	8,888	217,843

Table III-21
Available Flow for Clear Creek Basin (Acre-Feet)
Wet Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Piney Creek	225	215	333	1,155	10,872	16,085	2,167	415	182	556	400	255	32,862
2	South Piney Creek	779	712	947	1,393	6,134	20,952	8,806	2,959	1,158	1,702	1,158	889	47,589
3	Piney Creek below North & South Piney Creeks	1,004	927	1,280	2,549	17,006	37,038	10,973	3,374	1,340	2,259	1,558	1,144	80,451
4	Piney Creek below USGS gage 06323000	1,004	927	1,280	2,549	17,006	37,038	10,973	3,374	1,762	2,259	1,558	1,144	80,873
5	Piney Creek below Lake DeSmet Intake Tunnel	1,655	1,142	2,336	3,204	17,006	37,038	12,311	4,386	1,852	2,655	2,529	1,150	87,264
6	Little Piney Creek above SEO gage	642	833	1,030	904	1,426	2,311	1,336	722	707	925	830	582	12,246
7	Little Piney Creek above Piney Creek	1,058	960	1,786	904	1,426	2,311	1,434	939	743	1,087	1,346	585	14,578
8	Piney Creek below Little Piney Creek	2,712	2,191	4,172	4,108	18,431	39,348	13,745	5,325	2,595	3,742	4,072	1,736	102,179
10	Piney Creek below Box Elder Creek	2,712	2,221	4,190	4,203	18,431	39,348	13,745	5,325	2,595	3,742	4,072	1,736	102,322
11	Piney Creek above Clear Creek	2,712	3,224	5,689	5,198	18,431	39,348	13,745	5,325	2,595	3,742	4,072	1,736	105,819
12	Rock Creek	524	815	1,408	1,274	8,173	12,220	2,799	769	615	1,008	863	330	30,798
13	Johnson Creek	48	50	83	38	326	456	0	0	0	122	134	45	1,304
14	Rock Creek below Johnson Creek	573	865	1,491	1,451	9,102	12,676	2,799	769	615	1,130	997	376	32,844
15	Rock Creek above Clear Creek	573	865	1,491	1,451	9,102	12,676	2,799	769	615	1,130	997	376	32,844
16	French Creek	73	53	57	55	1,135	1,981	1,672	182	0	118	141	55	5,523
17	Clear Creek above City of Buffalo	1,046	1,423	1,982	2,929	15,386	21,221	8,254	1,672	1,168	2,226	1,945	756	60,007
18	Clear Creek above French Creek	1,046	1,423	1,982	2,929	15,449	21,221	8,254	1,672	1,168	2,226	1,945	756	60,070
19	Clear Creek above Rock Creek	1,119	1,476	2,039	2,984	16,584	23,202	9,926	1,854	1,398	2,344	2,086	811	65,823
20	Clear Creek below Rock Creek	1,691	2,341	3,530	4,435	25,686	35,878	12,725	2,624	2,014	3,474	3,084	1,186	98,668
21	Clear Creek above Healy Reservoir	1,691	2,658	3,530	4,435	25,686	35,878	12,725	2,624	2,014	4,444	3,084	1,186	99,955
23	Clear Creek above Piney Creek	1,691	3,911	4,824	5,374	25,686	35,878	12,725	2,624	2,014	4,444	3,128	1,186	103,486
24	Clear Creek above Double Crossing	4,404	7,135	10,514	10,678	44,118	75,227	26,470	7,949	4,609	8,186	7,200	2,922	209,410
25	Clear Creek below Double Crossing	4,404	7,135	10,514	10,929	44,118	75,227	26,470	7,949	4,609	8,186	7,200	2,922	209,661
26	Clear Creek above USGS gage 06324000	4,404	7,135	10,514	10,929	44,118	75,227	26,470	7,949	4,609	8,186	7,200	2,922	209,661
27	Clear Creek above Powder River	4,440	7,568	11,728	10,929	44,118	75,227	27,431	8,047	4,609	8,186	7,345	2,922	212,547
28	Powder River above Clear Creek	7,589	11,731	30,400	20,315	102,759	87,040	26,344	8,276	4,655	16,458	11,810	6,250	333,625
29	Powder River above State Line	12,118	19,360	42,163	31,243	146,877	162,267	53,775	16,330	9,263	24,643	19,325	9,172	546,537

Table III-22
Available Flow for Clear Creek Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Piney Creek	171	173	282	891	5,910	5,342	714	217	197	427	316	188	14,829
2	South Piney Creek	472	422	578	788	3,263	10,730	3,104	1,680	1,235	1,036	741	525	24,574
3	Piney Creek below North & South Piney Creeks	642	595	861	1,678	9,173	16,073	3,818	1,897	1,432	1,463	1,057	713	39,403
4	Piney Creek below USGS gage 06323000	642	595	861	1,678	9,173	16,073	3,818	2,047	1,432	1,463	1,057	713	39,552
5	Piney Creek below Lake DeSmet Intake Tunnel	914	656	1,389	2,465	9,915	16,073	3,818	2,631	1,858	1,463	1,668	1,036	43,887
6	Little Piney Creek above SEO gage	549	707	950	954	904	828	652	584	718	744	722	580	8,892
7	Little Piney Creek above Piney Creek	781	781	1,533	1,339	904	828	652	750	931	744	1,139	842	11,224
8	Piney Creek below Little Piney Creek	1,823	1,524	2,971	3,804	10,819	16,901	4,470	3,504	3,595	3,045	3,091	2,080	57,629
10	Piney Creek below Box Elder Creek	1,851	1,543	2,979	3,926	10,819	16,901	4,470	3,504	3,595	3,045	3,150	2,126	57,910
11	Piney Creek above Clear Creek	2,483	2,956	5,419	4,932	10,819	16,901	4,470	3,504	3,595	3,823	4,018	2,659	65,579
12	Rock Creek	283	441	1,061	766	3,283	4,820	954	479	439	545	417	297	13,787
13	Johnson Creek	28	32	62	0	0	0	0	0	0	86	74	42	324
14	Rock Creek below Johnson Creek	311	474	1,123	1,203	3,283	4,820	954	479	514	631	491	339	14,623
15	Rock Creek above Clear Creek	311	474	1,123	1,203	3,283	4,820	954	479	514	631	491	339	14,623
16	French Creek	63	45	49	67	552	1,022	619	0	0	170	125	94	2,805
17	Clear Creek above City of Buffalo	457	526	1,090	2,159	6,836	11,079	3,063	1,339	1,501	1,115	757	563	30,483
18	Clear Creek above French Creek	457	526	1,090	2,261	6,836	11,079	3,063	1,339	1,501	1,115	757	563	30,586
19	Clear Creek above Rock Creek	520	571	1,138	2,329	7,388	12,101	3,682	1,339	1,614	1,285	882	656	33,504
20	Clear Creek below Rock Creek	831	1,044	2,262	3,532	10,670	16,921	4,636	1,818	2,127	1,916	1,373	996	48,127
21	Clear Creek above Healy Reservoir	831	1,044	2,262	3,532	10,670	16,921	4,636	1,818	2,127	1,916	1,373	996	48,127
23	Clear Creek above Piney Creek	1,197	2,062	4,148	4,253	10,670	16,921	4,636	1,818	2,127	2,638	1,933	1,364	53,768
24	Clear Creek above Double Crossing	3,680	5,128	9,624	9,332	21,489	33,822	9,106	5,322	5,723	6,461	5,951	4,023	119,660
25	Clear Creek below Double Crossing	3,680	5,673	9,946	9,798	21,489	33,822	9,106	5,322	5,723	6,461	5,951	4,023	120,994
26	Clear Creek above USGS gage 06324000	3,680	5,852	10,041	9,798	21,489	33,822	9,106	5,322	6,083	6,461	5,951	4,023	121,630
27	Clear Creek above Powder River	3,734	6,701	10,850	9,798	21,489	33,822	9,635	5,322	6,083	6,523	5,951	4,023	123,932
28	Powder River above Clear Creek	6,519	13,902	25,996	22,124	40,971	37,368	14,105	6,557	6,452	9,968	9,003	6,715	199,680
29	Powder River above State Line	10,319	20,648	36,869	31,922	62,461	71,190	23,837	11,879	12,535	16,672	14,954	10,739	324,023

Table III-23
Available Flow for Clear Creek Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Piney Creek	102	96	127	1,422	3,684	1,116	263	77	61	294	179	116	7,536
2	South Piney Creek	284	260	331	758	2,029	4,195	1,770	707	436	680	373	306	12,129
3	Piney Creek below North & South Piney Creeks	387	356	458	2,180	5,713	5,311	2,033	784	497	974	552	422	19,666
4	Piney Creek below USGS gage 06323000	387	356	458	2,180	5,713	5,311	2,871	1,073	1,094	974	552	422	21,391
5	Piney Creek below Lake DeSmet Intake Tunnel	1,168	464	548	2,517	5,713	5,311	3,138	1,668	1,621	974	1,305	1,262	25,688
6	Little Piney Creek above SEO gage	627	589	941	809	263	534	660	538	586	766	760	636	7,708
7	Little Piney Creek above Piney Creek	1,894	768	1,128	934	263	534	721	836	868	766	1,799	1,901	12,411
8	Piney Creek below Little Piney Creek	3,181	1,307	1,717	3,451	5,976	5,845	3,859	3,013	2,522	3,235	3,416	3,176	40,699
10	Piney Creek below Box Elder Creek	3,181	1,307	1,717	3,657	5,976	5,845	3,859	3,013	2,522	3,235	3,416	3,176	40,905
11	Piney Creek above Clear Creek	3,670	1,828	2,931	3,810	5,976	5,845	3,859	3,013	2,522	4,247	4,579	3,176	45,456
12	Rock Creek	315	485	904	173	2,269	617	0	0	0	409	379	342	5,890
13	Johnson Creek	28	30	47	0	0	0	0	0	0	59	60	39	263
14	Rock Creek below Johnson Creek	343	515	951	905	2,269	617	146	97	111	467	439	381	7,241
15	Rock Creek above Clear Creek	343	515	951	905	2,269	617	146	97	111	467	439	381	7,241
16	French Creek	66	47	44	0	410	161	240	0	0	180	138	90	1,376
17	Clear Creek above City of Buffalo	643	919	1,106	2,403	4,118	2,681	530	339	322	1,000	871	776	15,707
18	Clear Creek above French Creek	643	919	1,106	2,403	4,118	2,681	530	339	322	1,000	871	776	15,707
19	Clear Creek above Rock Creek	709	966	1,150	2,403	4,528	2,841	769	339	322	1,180	1,009	867	17,082
20	Clear Creek below Rock Creek	1,052	1,480	2,101	3,308	6,797	3,458	915	436	433	1,647	1,448	1,248	24,323
21	Clear Creek above Healy Reservoir	1,052	1,480	2,101	3,308	6,797	3,458	915	436	433	1,647	1,448	1,248	24,323
23	Clear Creek above Piney Creek	1,294	2,120	3,625	3,308	6,797	3,458	915	436	433	2,440	2,165	1,287	28,278
24	Clear Creek above Double Crossing	4,964	3,949	6,584	7,413	12,773	9,303	4,774	3,449	2,955	6,687	6,744	4,462	74,056
25	Clear Creek below Double Crossing	4,964	3,949	8,902	8,139	12,773	9,303	4,774	3,449	2,955	6,687	6,744	4,462	77,102
26	Clear Creek above USGS gage 06324000	4,964	3,949	8,956	8,554	12,773	9,400	4,774	3,449	3,482	6,687	6,744	4,462	78,194
27	Clear Creek above Powder River	4,964	3,949	9,016	8,554	12,773	10,282	4,774	3,698	3,482	7,125	7,038	4,462	80,118
28	Powder River above Clear Creek	6,602	9,561	18,787	13,486	20,647	10,304	5,594	3,013	2,122	8,145	8,998	5,803	113,062
29	Powder River above State Line	11,567	13,510	27,822	22,040	33,420	20,735	10,368	6,822	5,603	15,447	16,172	10,265	193,770

Table III-24
Available Flow for Crazy Woman Creek Basin (Acre-Feet)
Wet Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Kelly Creek	10	8	8	98	679	731	180	95	20	17	13	11	1,870
2	Little North Fork Crazy Woman Creek	22	18	19	214	1,499	1,602	371	182	36	38	29	25	4,055
3	North Fork Crazy Woman Creek	79	57	69	761	7,592	10,292	1,619	714	143	141	98	87	21,650
4	N Fk Crazy Woman Cr bel. Kelly & Little N Fk	111	84	96	1,073	9,769	12,626	2,170	990	199	195	139	124	27,575
5	Muddy Creek	17	14	16	198	1,347	1,398	318	150	19	27	20	18	3,541
6	Billy Creek	10	9	12	137	443	401	93	77	16	12	10	10	1,230
7	N Fk Crazy Woman Cr bel. Muddy & Billy Cr	137	107	123	1,408	11,559	14,425	2,581	1,217	234	234	169	152	32,346
8	Middle Fork Crazy Woman Creek	75	60	82	885	5,421	6,630	1,386	865	177	108	79	75	15,842
9	Crazy Woman Cr above S Fk Crazy Woman Cr	213	167	205	2,293	16,980	21,055	3,967	2,082	411	342	248	227	48,189
10	Crazy Woman Cr above Trabing Bridge	213	167	205	2,705	16,980	21,055	3,967	2,082	411	342	248	227	48,600
11	Crazy Woman Cr above Upper Station	792	1,494	2,802	3,472	20,742	21,055	3,967	2,082	411	2,439	1,522	720	61,498

Table III-25
Available Flow for Crazy Woman Creek Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Kelly Creek	9	7	8	64	279	283	86	37	20	17	11	11	831
2	Little North Fork Crazy Woman Creek	21	15	17	136	598	587	160	65	32	39	26	25	1,720
3	North Fork Crazy Woman Creek	67	49	58	538	3,544	3,251	780	279	133	128	87	82	8,995
4	N Fk Crazy Woman Cr bel. Kelly & Little N Fk	97	71	83	739	4,421	4,120	1,025	380	185	184	124	117	11,546
5	Muddy Creek	16	12	14	125	511	470	87	26	0	28	18	18	1,325
6	Billy Creek	9	8	10	74	179	143	39	39	8	12	9	9	539
7	N Fk Crazy Woman Cr bel. Muddy & Billy Cr	122	91	107	937	5,111	4,734	1,151	445	193	224	151	144	13,410
8	Middle Fork Crazy Woman Creek	64	53	75	652	2,684	2,366	667	344	90	100	70	70	7,235
9	Crazy Woman Cr above S Fk Crazy Woman Cr	186	144	182	1,589	7,795	7,100	1,818	789	283	324	221	215	20,645
10	Crazy Woman Cr above Trabing Bridge	186	144	182	1,589	7,795	7,100	2,075	959	812	324	221	215	21,602
11	Crazy Woman Cr above Upper Station	656	1,679	2,626	3,560	7,795	7,100	2,075	1,016	812	1,321	1,184	786	30,610

Table III-26
Available Flow for Crazy Woman Creek Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Kelly Creek	10	7	8	39	57	54	0	0	0	17	11	12	215
2	Little North Fork Crazy Woman Creek	24	16	19	79	121	99	0	0	0	38	24	27	446
3	North Fork Crazy Woman Creek	71	47	58	365	620	511	0	0	0	124	74	79	1,949
4	N Fk Crazy Woman Cr bel. Kelly & Little N Fk	105	71	84	483	798	663	0	0	0	179	109	118	2,610
5	Muddy Creek	19	14	17	68	104	33	0	0	0	30	19	20	325
6	Billy Creek	11	9	12	39	38	4	0	0	0	13	9	10	145
7	N Fk Crazy Woman Cr bel. Muddy & Billy Cr	135	94	114	590	941	700	0	0	0	222	137	148	3,080
8	Middle Fork Crazy Woman Creek	76	59	79	423	501	453	0	0	0	108	67	73	1,839
9	Crazy Woman Cr above S Fk Crazy Woman Cr	210	153	193	1,013	1,442	1,153	0	0	0	330	204	221	4,918
10	Crazy Woman Cr above Trabing Bridge	210	153	193	1,013	1,442	1,788	532	168	123	330	204	221	6,377
11	Crazy Woman Cr above Upper Station	836	1,031	1,904	2,113	3,540	2,361	532	168	123	1,022	1,135	754	15,520

Table III-27
Available Flow for Powder River Basin (Acre-Feet)
Wet Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Buffalo Creek	195	181	273	618	3,342	1,414	0	0	0	202	255	208	6,687
2	Middle Fork Powder River[1]	51	85	362	1,601	11,430	6,449	418	268	600	117	242	85	21,707
3	Middle Fork Powder River below Buffalo Creek	913	974	1,395	2,874	14,771	7,863	418	268	600	1,221	1,403	819	33,518
4	Beaver Creek	1,063	1,113	1,311	1,181	2,657	1,489	258	263	641	1,022	1,079	889	12,967
5	Beaver Creek below Blue Creek	1,063	1,187	1,355	1,181	2,657	1,489	258	263	641	1,212	1,283	889	13,479
6	Middle Fork Powder River below Beaver Creek	1,975	2,273	2,817	4,055	17,429	9,352	676	531	1,241	2,432	2,927	1,708	47,417
7	Middle Fk Powder River above Red Fk Powder	1,975	2,466	2,997	4,055	17,429	9,352	676	531	1,241	2,432	2,928	1,708	47,791
8	Red Fork Powder River	1,940	2,358	2,799	3,040	12,699	6,977	536	404	926	2,465	2,883	1,709	38,738
9	Middle Fk Powder River above N Fk Powder	3,915	4,824	5,796	7,095	30,128	16,330	1,212	935	2,167	4,898	6,001	3,418	86,718
10	North Fork Powder River	1,145	1,291	1,288	716	5,136	4,353	98	48	156	1,698	1,822	1,004	18,757
11	Powder River below N & Middle Fks Powder	5,060	6,115	7,085	7,811	35,264	20,683	1,310	983	2,323	6,596	7,823	4,422	105,474
12	Powder River above South Fork Powder	5,060	6,115	7,085	7,811	42,733	37,477	3,051	983	2,323	9,932	7,823	4,422	134,816
13	South Fork Powder River	229	1,369	8,011	6,589	17,715	5,530	1,989	2,067	15	418	370	123	44,427
14	Powder River above Salt Creek	5,290	7,484	15,096	14,400	60,729	43,564	5,694	3,051	2,642	10,350	8,193	4,544	181,036
15	Salt Creek	1,452	2,090	4,095	2,469	12,546	7,727	9,183	1,613	1,638	3,694	1,879	993	49,377
16	Powder River below Salt Creek	6,741	9,573	19,191	16,870	73,310	51,299	14,882	4,663	4,280	14,044	10,072	5,537	230,461
17	Powder River above Crazy Woman Creek	6,741	9,573	23,790	16,870	80,197	61,924	20,283	5,915	4,280	14,044	10,072	5,537	259,225
18	Crazy Woman Creek above Powder River	785	1,487	3,459	3,445	22,562	25,117	5,101	2,206	375	2,414	1,505	712	69,167
19	Powder River below Crazy Woman Creek	7,527	11,060	27,253	20,315	102,759	87,040	25,422	8,175	4,655	16,458	11,577	6,250	328,489

Note: [1] Constrained by Instream Flow Rights of 12 cfs (July 1 - March 31) and 25 cfs (April 1 - June 30).

Table III-28
Available Flow for Powder River Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Buffalo Creek	202	190	267	694	2,090	100	0	0	0	236	231	214	4,226
2	Middle Fork Powder River[1]	0	0	0	280	6,819	2,957	0	0	0	0	0	0	10,056
3	Middle Fork Powder River below Buffalo Creek	745	968	1,324	3,152	10,841	6,385	399	261	570	881	1,085	821	27,431
4	Beaver Creek	964	1,244	1,384	1,175	1,729	1,474	233	240	553	956	1,228	988	12,166
5	Beaver Creek below Blue Creek	964	1,290	1,402	1,175	1,729	1,566	233	240	553	956	1,228	988	12,322
6	Middle Fork Powder River below Beaver Creek	1,709	2,258	2,727	4,327	12,569	8,716	632	500	1,123	1,837	2,312	1,809	40,519
7	Middle Fk Powder River above Red Fk Powder	1,709	2,525	3,423	4,327	12,569	8,716	632	500	1,123	1,837	2,312	1,809	41,483
8	Red Fork Powder River	1,658	2,396	3,155	3,347	7,408	4,935	393	310	647	1,790	2,277	1,788	30,105
9	Middle Fk Powder River above N Fk Powder	3,367	4,922	6,579	7,674	19,977	13,651	1,025	811	1,770	3,627	4,589	3,597	71,587
10	North Fork Powder River	971	1,272	1,451	997	2,629	1,918	0	0	5	1,284	1,500	1,119	13,145
11	Powder River below N & Middle Fks Powder	4,338	6,193	8,029	8,671	22,606	16,087	1,025	811	1,775	4,911	6,089	4,716	85,251
12	Powder River above South Fork Powder	4,338	6,653	8,029	9,371	22,606	17,055	1,908	821	2,730	5,790	6,089	4,716	90,107
13	South Fork Powder River	132	1,287	7,025	5,987	6,835	2,093	1,132	1,699	17	188	213	112	26,720
14	Powder River above Salt Creek	4,470	7,940	15,054	15,358	29,441	19,403	3,580	3,010	3,353	6,189	6,302	4,828	118,929
15	Salt Creek	1,306	2,532	3,882	3,239	3,750	4,823	5,081	1,705	2,350	2,399	1,540	1,114	33,722
16	Powder River below Salt Creek	5,776	10,472	18,936	18,597	33,192	24,225	8,661	4,715	5,703	8,588	7,842	5,943	152,650
17	Powder River above Crazy Woman Creek	5,776	10,472	21,140	18,597	33,192	29,159	11,002	5,572	5,732	8,588	7,842	5,943	163,014
18	Crazy Woman Creek above Powder River	648	1,669	2,919	3,526	7,779	8,209	2,328	985	720	1,286	1,162	773	32,004
19	Powder River below Crazy Woman Creek	6,424	12,141	24,059	22,124	40,971	37,368	13,330	6,557	6,452	9,874	9,003	6,715	195,018

Note: [1] Constrained by Instream Flow Rights of 12 cfs (July 1 - March 31) and 25 cfs (April 1 - June 30).

Table III-29
Available Flow for Powder River Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Buffalo Creek	187	169	214	298	909	0	0	0	0	167	206	197	2,347
2	Middle Fork Powder River[1]	0	0	0	425	3,840	0	0	0	0	0	0	0	4,265
3	Middle Fork Powder River below Buffalo Creek	633	799	1,072	2,985	6,625	2,576	240	219	360	586	829	597	17,521
4	Beaver Creek	921	1,164	1,365	961	943	830	199	248	405	820	1,096	817	9,767
5	Beaver Creek below Blue Creek	921	1,164	1,399	961	943	846	199	248	405	820	1,096	817	9,817
6	Middle Fork Powder River below Beaver Creek	1,553	1,964	2,471	3,946	7,568	3,421	438	467	765	1,407	1,925	1,414	27,338
7	Middle Fk Powder River above Red Fk Powder	1,553	1,964	2,651	3,946	7,568	3,421	438	467	765	1,407	1,925	1,414	27,518
8	Red Fork Powder River	1,544	1,892	2,451	2,332	3,262	1,603	205	268	358	1,487	1,903	1,435	18,740
9	Middle Fk Powder River above N Fk Powder	3,097	3,856	5,101	6,278	10,831	5,024	643	735	1,123	2,894	3,828	2,849	46,258
10	North Fork Powder River	919	1,089	1,278	385	1,069	0	0	0	0	1,090	1,288	917	8,036
11	Powder River below N & Middle Fks Powder	4,016	4,945	6,379	6,662	11,900	5,024	643	735	1,123	3,984	5,116	3,766	54,294
12	Powder River above South Fork Powder	4,016	4,945	6,379	6,662	11,900	5,024	900	735	1,123	4,159	5,229	3,766	54,840
13	South Fork Powder River	94	1,074	3,574	2,698	3,480	564	377	864	6	90	121	84	13,026
14	Powder River above Salt Creek	4,110	6,019	9,953	9,360	15,380	5,588	1,886	1,599	1,129	4,674	5,648	3,850	69,196
15	Salt Creek	1,660	2,515	2,780	2,108	1,851	1,044	3,197	1,054	924	1,898	1,799	1,206	22,035
16	Powder River below Salt Creek	5,770	8,534	12,733	11,468	17,231	6,632	5,083	2,652	2,053	6,572	7,446	5,056	91,231
17	Powder River above Crazy Woman Creek	5,770	8,534	16,245	11,468	17,231	7,179	5,083	2,652	2,053	6,655	7,507	5,056	95,434
18	Crazy Woman Creek above Powder River	832	1,028	2,418	2,018	3,415	2,241	511	158	69	988	1,114	747	15,539
19	Powder River below Crazy Woman Creek	6,602	9,561	18,663	13,486	20,647	9,420	5,594	2,810	2,122	7,643	8,622	5,803	110,973

Note: [1] Constrained by Instream Flow Rights of 12 cfs (July 1 - March 31) and 25 cfs (April 1 - June 30).

Table III-30
Available Flow for Little Powder River Basin (Acre-Feet)
Wet Year Hydrologic Conditions

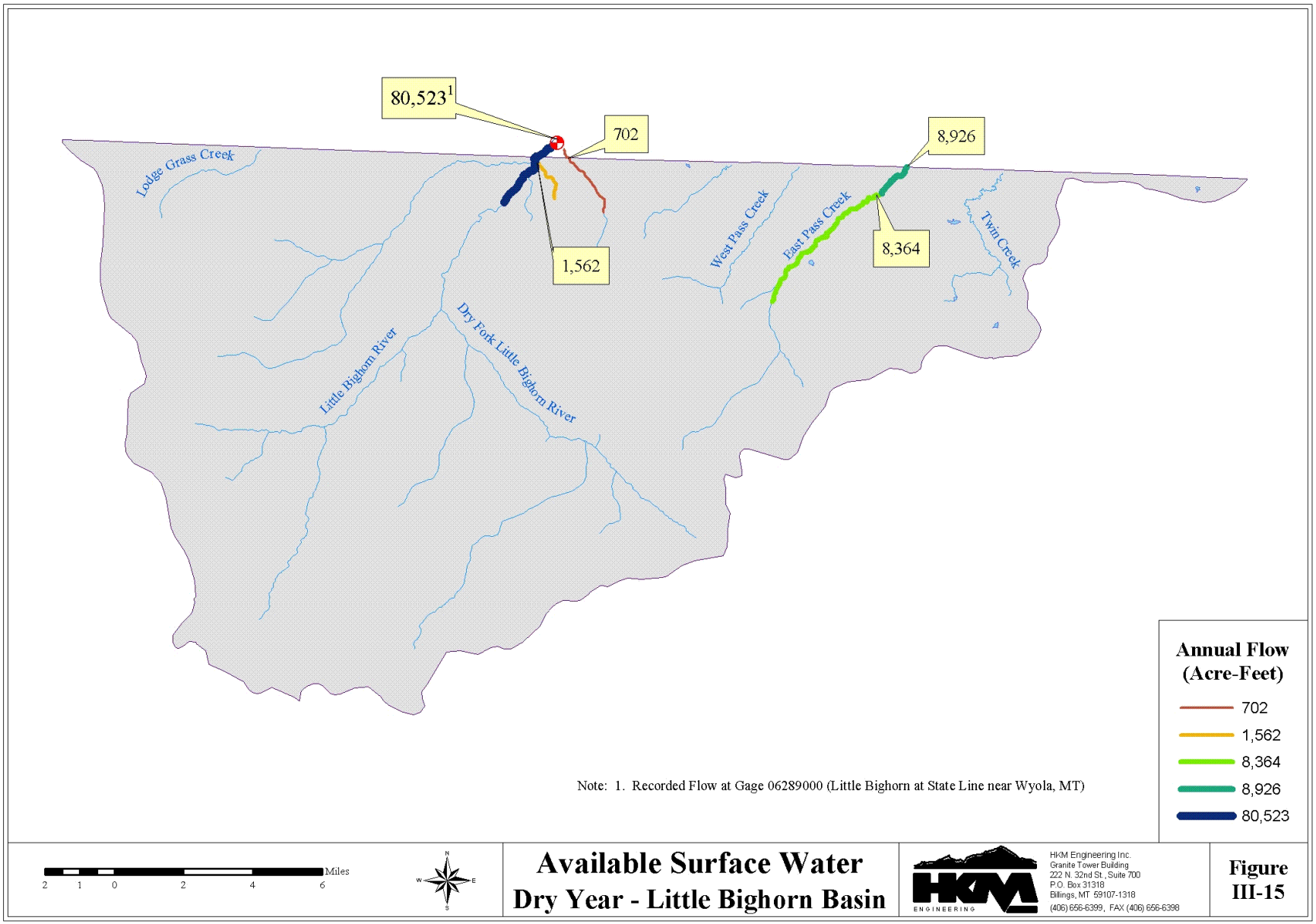
Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Little Powder River above USGS gage 06324925	562	7,548	14,241	2,860	9,079	2,733	377	279	53	2,316	180	143	40,372
2	Little Powder River above USGS gage 06324970	1,195	7,548	14,241	2,860	13,237	3,354	1,044	426	226	2,722	485	375	47,714
3	Little Powder River above State Line	1,203	7,553	14,243	2,860	13,237	3,354	1,044	426	226	2,782	520	391	47,838

Table III-31
Available Flow for Little Powder River Basin (Acre-Feet)
Normal Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Little Powder River above USGS gage 06324925	405	1,109	1,553	1,119	1,970	1,683	625	309	246	283	144	65	9,511
2	Little Powder River above USGS gage 06324970	548	1,493	2,209	1,396	2,190	1,894	674	337	268	450	254	142	11,853
3	Little Powder River above State Line	556	1,497	2,210	1,396	2,190	1,894	674	337	268	504	289	159	11,974

Table III-32
Available Flow for Little Powder River Basin (Acre-Feet)
Dry Year Hydrologic Conditions

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Little Powder River above USGS gage 06324925	24	319	399	284	474	220	64	74	13	19	26	30	1,946
2	Little Powder River above USGS gage 06324970	60	481	630	344	560	239	105	74	17	41	54	69	2,674
3	Little Powder River above State Line	63	482	630	344	560	239	105	74	43	53	69	75	2,737


80,523[1]
702
8,926
1,562
8,364
Lodge Grass Creek
West Pass Creek
East Pass Creek
Twin Creek
Little Bighorn River
Dry Fork Little Bighorn River
Annual Flow (Acre-Feet)
702
1,562
8,364
8,926
80,523
Note: 1. Recorded Flow at Gage 06289000 (Little Bighorn at State Line near Wyola, MT)
2 1 0 2 4 6 Miles
N
W
E
S
Available Surface Water
Dry Year - Little Bighorn Basin
HKM ENGINEERING
HKM Engineering Inc.
Granite Tower Building
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P.O. Box 31318
Billings, MT 59107-1318
(406) 656-6399, FAX (406) 656-6398
Figure III-15

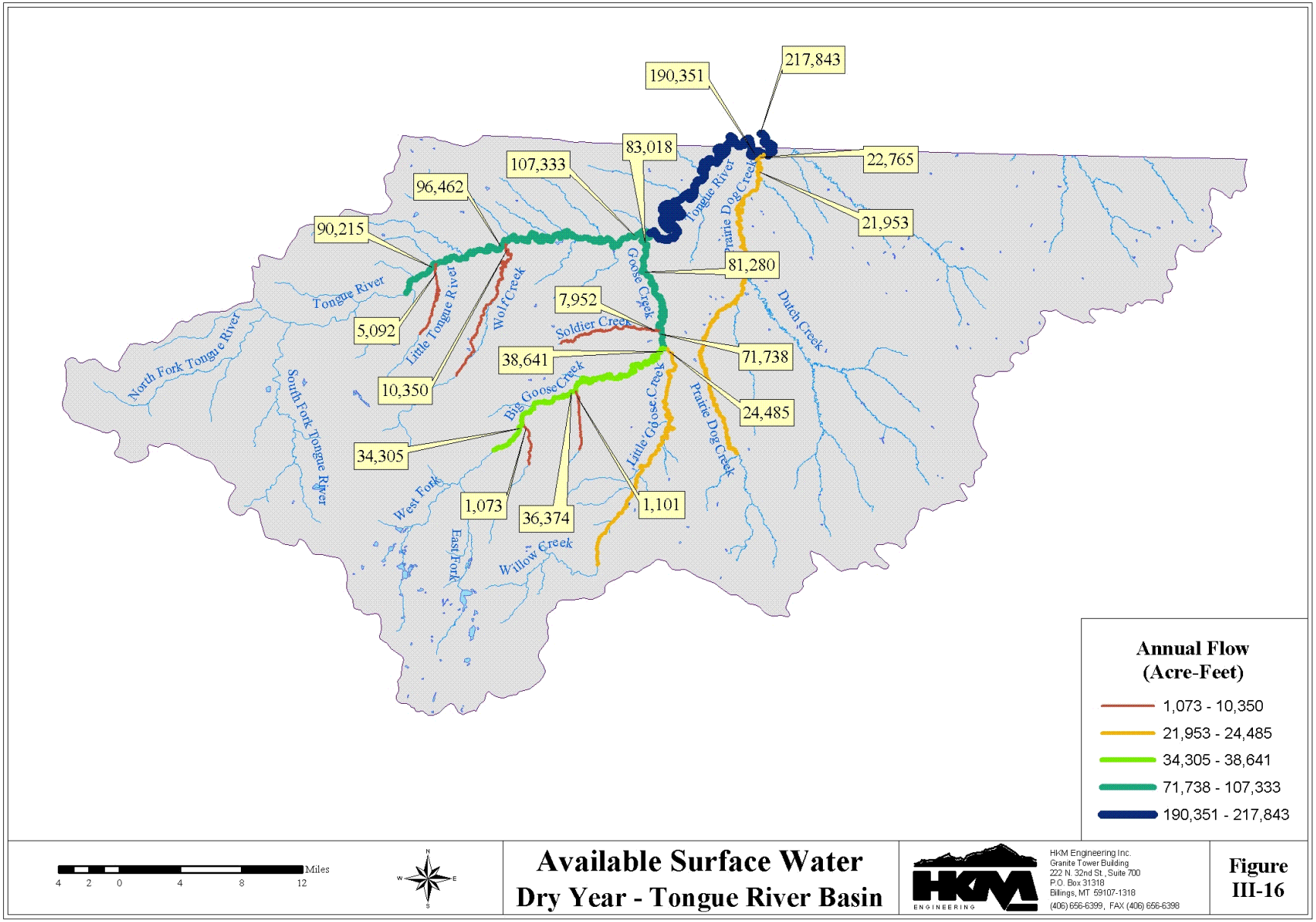
190,351
217,843
83,018
22,765
107,333
96,462
21,953
90,215
81,280
7,952
5,092
71,738
38,641
10,350
24,485
34,305
1,073
36,374
1,101
Tongue River
Little Tongue River
Wolf Creek
Goose Creek
Soldier Creek
Prairie Dog Creek
Dutch Creek
North Fork Tongue River
South Fork Tongue River
Big Goose Creek
Little Goose Creek
West Fork
East Fork
Willow Creek
Annual Flow
(Acre-Feet)
1,073 - 10,350
21,953 - 24,485
34,305 - 38,641
71,738 - 107,333
190,351 - 217,843
Miles
4 2 0 4 8 12
N
W E
S
Available Surface Water
Dry Year - Tongue River Basin
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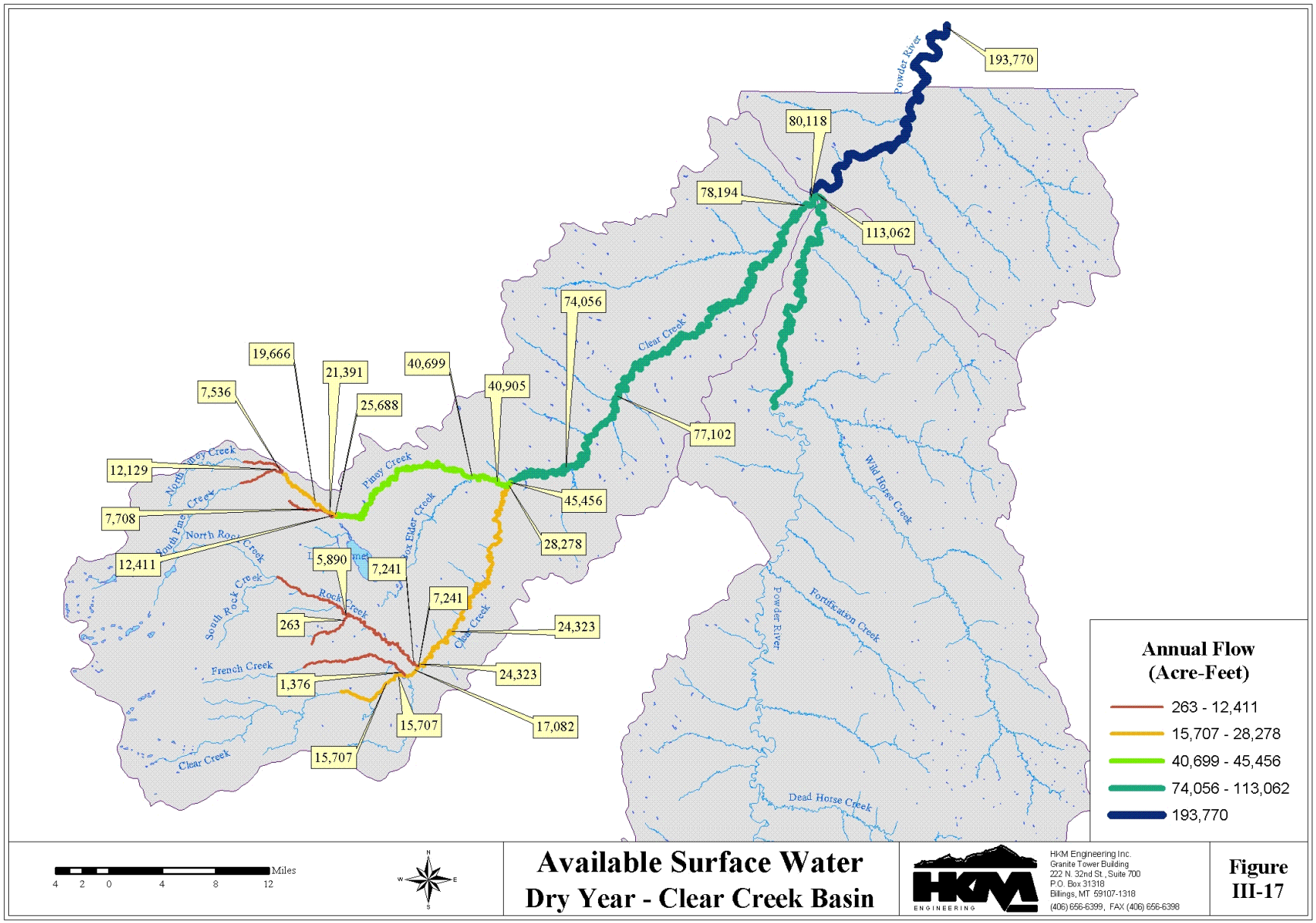
Figure
III-16


193,770
80,118
78,194
113,062
74,056
77,102
40,699
40,905
45,456
28,278
19,666
21,391
25,688
7,536
12,129
7,708
12,411
5,890
7,241
7,241
263
24,323
24,323
1,376
15,707
17,082
15,707
Powder River
Clear Creek
Piney Creek
Wild Horse Creek
Fortification Creek
Dead Horse Creek
French Creek
South Rock Creek
Rock Creek
Annual Flow
(Acre-Feet)
263 - 12,411
15,707 - 28,278
40,699 - 45,456
74,056 - 113,062
193,770
Miles
4 2 0 4 8 12
Available Surface Water
Dry Year - Clear Creek Basin
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Billings, MT 59107-1318
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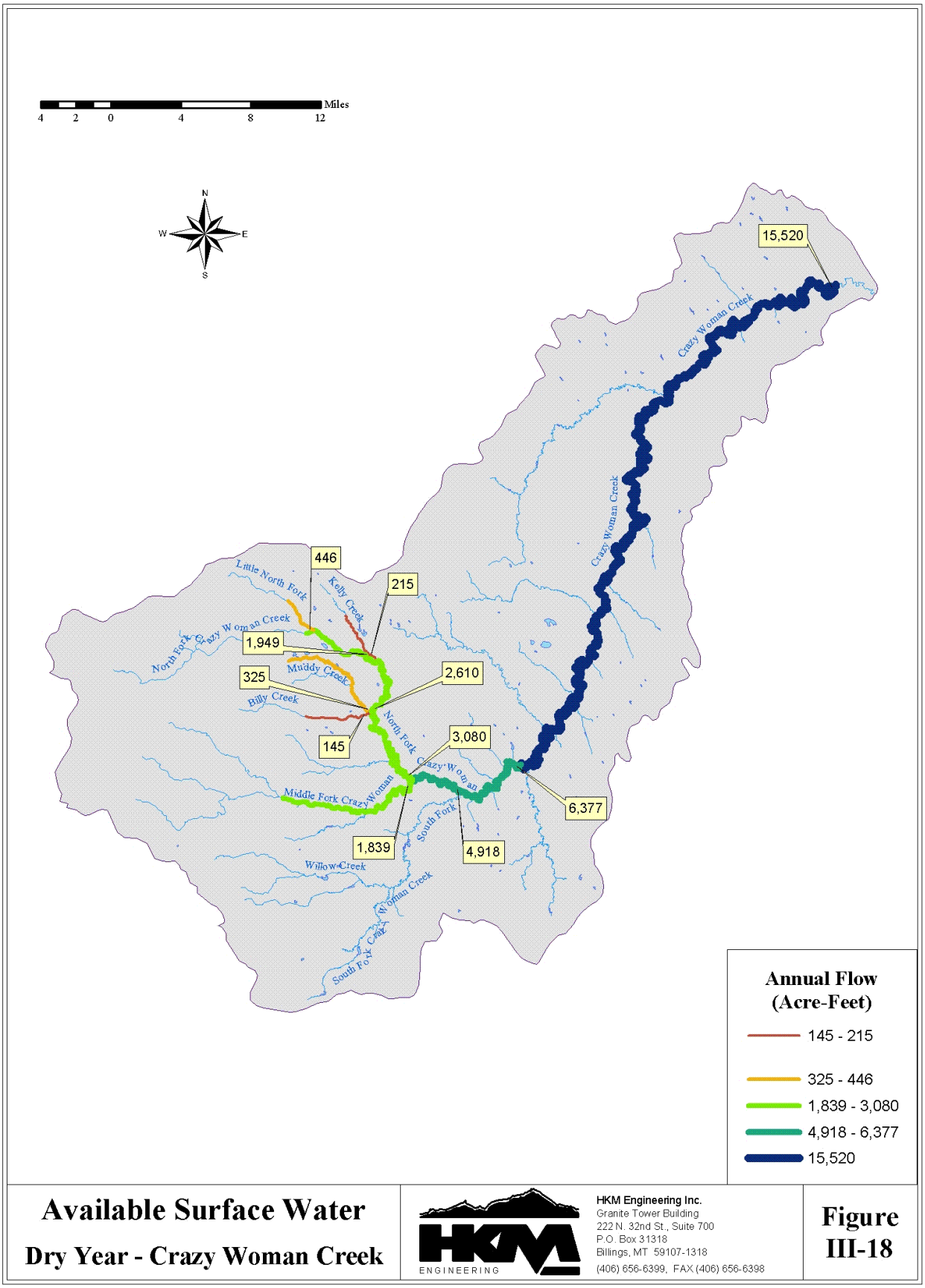
Figure
III-17



Available Surface Water

Dry Year - Crazy Woman Creek

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Figure III-18

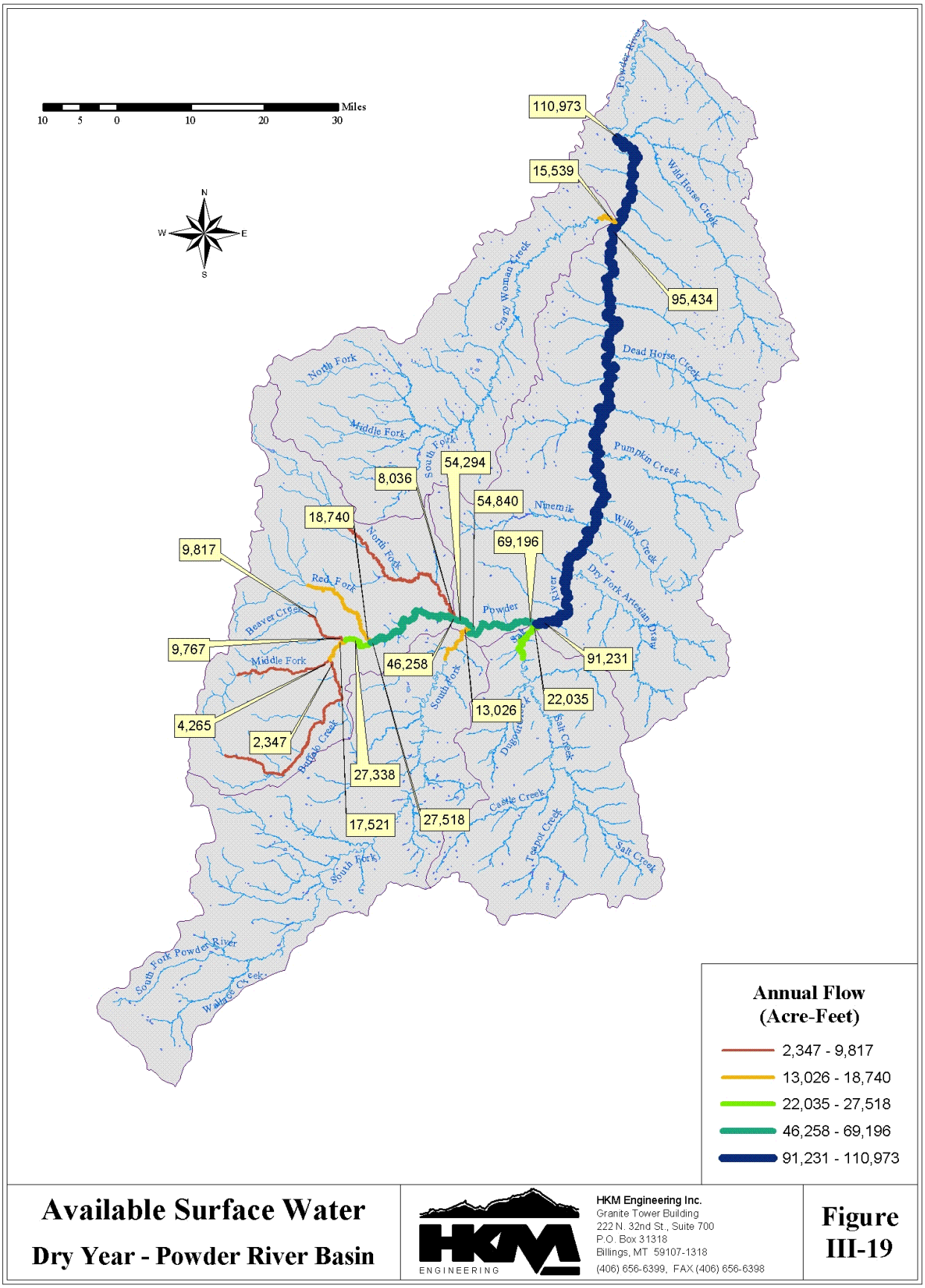
Miles
10 5 0 10 20 30
N
W
E
S
110,973
15,539
95,434
54,294
8,036
54,840
18,740
69,196
9,817
46,258
91,231
9,767
22,035
13,026
4,265
2,347
27,338
17,521
27,518
Powder River
Wild Horse Creek
Crazy Woman Creek
North Fork
Middle Fork
South Fork
Dead Horse Creek
Pumpkin Creek
Ninemile
Willow Creek
Dry Fork Antelope Draw
Red Fork
Beaver Creek
Middle Fork
Buffalo Creek
Dugout Creek
Salt Creek
Castle Creek
Teapot Creek
South Fork Powder River
Wallace Creek
Annual Flow (Acre-Feet)
2,347 - 9,817
13,026 - 18,740
22,035 - 27,518
46,258 - 69,196
91,231 - 110,973
Available Surface Water
Dry Year - Powder River Basin
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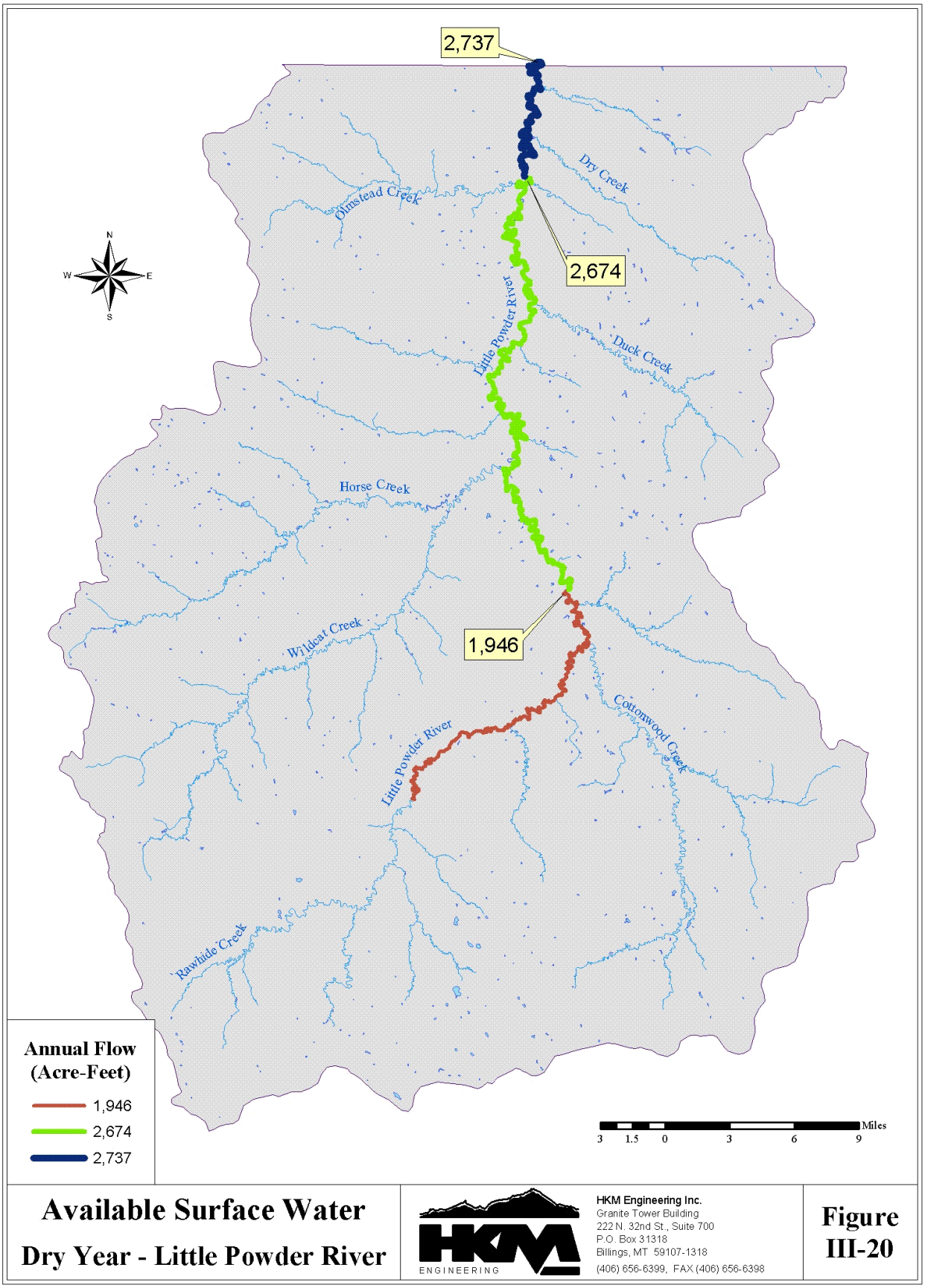
Figure III-19



Available Surface Water
Dry Year - Little Powder River

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Figure III-20

The yield potential of each of these basins is limited by the dry year conditions. Further, the timing of these available flows does not necessarily match the timing of the demand for this water. For example of the 218,000 acre feet of available flow from the Tongue River during a typical dry year, 65 percent of this occurs during the spring runoff months of March through June. Reservoir storage would be required to store this excess flow to satisfy demands throughout the year. The available flow presented in Table III-14 does not include the constraints of the Yellowstone River Compact. This will be discussed in the next section.

Compact Constraints

A determination of the amount of water available to Wyoming for future development is not complete without an evaluation of the constraints imposed by interstate compacts. 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 following is a brief summary of the rules for dividing the waters according to the Yellowstone River Compact:

1. *existing rights as of January 1, 1950 maintain their status quo;*
2. *no water may be diverted from the Yellowstone River Basin for use in another River Basin without consent from all states;*
3. *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 on a percentage basis

Nothing contained in the Compact is to be construed to adversely affect any rights to the use of the waters of the Yellowstone River by or for Indians, Indian tribes, and their reservations.

The methodology used in the current study to evaluate water availability under the Yellowstone River Compact was coordinated through the Wyoming State Engineer's Office and relies heavily on previous work performed by others on behalf of each of the two States. A more detailed, "from the ground up" evaluation is beyond the scope of the current planning effort. The methodology employed provides estimates of Wyoming's allocation under each of the three hydrologic conditions (wet, normal, and dry years).

Tongue River

The allocable flows of the Tongue River drainage are to be divided between the two States in accordance with the following percentages per the Yellowstone River Compact:

Wyoming	40%
Montana	60%

The State of Montana sponsored a study in 1990/1991 to determine the amount of water available for storage in the, then proposed, enlargement of Tongue River Reservoir. The State of Wyoming also made a determination of Wyoming's supplemental water needs for pre-1950 water rights during this same time frame. Information from both sources was utilized in evaluating Wyoming's share of Tongue River water.

This evaluation is based on the following assumptions:

- The allocation of the waters of the Tongue River is based on adjusted flow records from USGS Gage 06308500 (Tongue River at Miles City) during the study period 1970 through 1999.

- Any water use under post-1950 water rights that is reflected in Gage 06308500 has occurred in both States in the same proportion as the Compact allocation (40% Wyoming / 60% Montana). These depletions are therefore not added into the flow at Miles City. The results of this evaluation therefore represent the Remaining Allocable Flow.

- The enlargement to Tongue River Reservoir was completed in late 1998 and storage in the enlarged pool did not occur until June of 1999 and then only for a short time. The streamflow at Miles City is therefore essentially unaffected during the 1970 through 1999 study period by storage regulation under post-1950 storage rights and adjustments are not required.

The range of estimates of remaining allocable flow for the State of Wyoming then centers around what adjustments are to be made to the flows at Miles City to account for unused Tribal and Federal pre-1950 rights and supplemental supplies to pre-1950 Wyoming and Montana State rights. Only the remaining flow, after these adjustments are made, is available for allocation.

In a letter sent to the State of Montana in 1990, Wyoming has claimed a need for 18,702 acre-feet of additional water to supplement the supply of pre-1950 rights. To fully supply these needs, additional reservoir storage with pre-1950 storage rights would likely be required.

The work sponsored by the State of Montana in 1990/1991 makes the assumption that the following four adjustments should be made to the streamflow at Miles City to account for unused pre-1950 rights or supplemental supplies to pre-1950 rights.

1. Depletions for Northern Cheyenne tribal water rights (31,800 acre-feet),
2. Winter bypass flow at Tongue River Dam (23,800 acre-feet),
3. Depletions for the unused 1924 priority USDA irrigation project near Miles City (1,900 acre-feet),
4. Depletions for supplemental supplies to pre-1950 rights on tributaries to the Tongue River in Montana (9,500 acre-feet).

The winter bypass flow at Tongue River Dam is based on an agreement between the State of Montana and the Tongue River Water Users in the late 1930's to maintain adequate flow to keep the river free of ice and to allow for stock water use. Because this is not a formal water right, its validity under the Yellowstone River Compact is a matter of legal interpretation. Montana water law does not allow for supplemental water rights and, similar to Wyoming, development of supplemental water supplies would likely require reservoir storage under pre-1950 storage rights in order to be exempt from Compact constraints.

In order 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 III-33. For the liberal estimate, the flow at Miles City is only adjusted to reflect increased depletions for supplemental supply to pre-1950 rights in Wyoming. For the conservative estimate, all of the aforementioned adjustments are included. The actual remaining allocation, to finally be determined at some undefined time in the future, will likely fall somewhere in the middle of this range of estimates.

Table III-33
Wyoming's Remaining Allocation of Available Flow per Yellowstone River Compact

Hydrologic Condition	Tongue River Basin		Powder River Basin
	Conservative Estimate	Liberal Estimate	
Wet Years	163,000	189,000	211,500
Normal Years	90,000	117,000	131,100
Dry Years	40,000	67,000	74,300

Additional detail of the determination of available flows is provided in the "Available Surface Water Determination" technical memorandum. For comparative purposes, the Wyoming Water Planning Program estimated Wyoming's average annual unused and unappropriated portion of the Tongue River to be 96,400 acre-feet for the 1948 through 1968 study period.

Powder River

The allocable flows of the Powder River drainage are to be divided between the two States in accordance with the following percentages per the Yellowstone River Compact:

Wyoming	42%
Montana	58%

Wyoming's allocation of the Powder River is based on the estimate reported in the previous water plan as directed by the SEO. This estimate has, however, been adjusted to reflect the current study period. The water availability presented in the 1972 water plan was based on the 21-year study period of 1948 through 1968; whereas, the current study utilizes the 30-year period 1970 through 1999. The average annual flow of the Powder River near Locate for the 1948 – 1968 study period is 377,100. The corresponding average for the 1970 – 1999 study period is 424,400. Wyoming's average annual unused and unappropriated portion of the Powder River, estimated through the earlier study is 120,700 acre-feet. This value is adjusted upwards by

12.5% to 135,800 to reflect the somewhat wetter average annual flow during the current study period. Wyoming's allocation of the available flows of the Powder River is summarized in Table III-33 for each of the three hydrologic conditions.

B. Ground Water

A qualitative summary of the ground water resources of the Powder and Tongue River basins of northeastern Wyoming is presented herein. Collectively, these basins and the study area are referred to as the Powder/Tongue River Basin (planning area).

Study Objectives

The first objective of this task was to inventory and catalog the Wyoming State Engineer's Office (SEO) ground water permit database for various categories of ground water uses in the planning area, and incorporate the extracted information into six GIS data themes. This was accomplished through a cooperative effort of personnel of the SEO and Wyoming Water Development Commission (WWDC). GIS data layers prepared from information on file with the SEO as of December 31, 2000 included:

- Permitted active agricultural wells with production rates greater than 49 gpm
- Permitted active municipal wells with production rates greater than 49 gpm
- Permitted active industrial and miscellaneous wells with production rates greater than 49 gpm
- Active permitted domestic wells
- Active permitted stock wells
- Active permitted coalbed methane wells

Because of the dynamic nature of CBM development in the planning area, the permitted CBM well data was recollected from the SEO database near the end of this planning effort. The permitted CBM wells are therefore current as of December 31, 2001.

The second objective of this task was to inventory and document existing published data on ground water studies and ground water planning documents for the planning area. All of the planning area is located within the Powder River Structural Basin (PRSB). Some of the existing ground water studies and ground water planning documents overlap the geographic boundaries of the planning area and include the drainage basins of the Little Missouri, Belle Fourche, Cheyenne and Niobrara Rivers.

Other objectives are as follows:

- Summarize existing information on aquifers with regards to location, storage, yield and development potential within the planning area.

- Summarize the potential effects that ground water development might have on the ground water and surface water systems in the basins within the planning area.

- Characterize coalbed methane development and its short and long-term effects on ground water and surface water supplies within the river basins of the planning area.

It is intended that the information provided herein along with the GIS data layers and the bibliography of previous investigations will provide a starting point for site specific ground water investigations.

Study Methods

There were no original investigations performed as part of this task. The work consisted of performing an inventory, compilation, and review of published literature on the geology and ground water resources of the planning area.

There is a wealth of published and unpublished reports of investigations on the geology and ground water resources of the planning area. The geology of the PRSB has been the subject of investigation and exploration as a result of interest in the development of energy and natural resources for at least the last 40 to 50 years. Resources of interest have included oil and gas, coal, uranium, coalbed methane and water.

A bibliography of published ground water studies and ground water planning documents for the Basin Plan is included in the "Available Ground Water Determination" technical memorandum. The references included in the bibliography, provide sources for an overview of ground water resources, and of some of the interests and concerns that have arisen as a result of the various stages of development of energy and natural resources in the planning area.

Additional information in specific geographic areas within the planning area is available through the U.S. Geological Survey (USGS) and other federal agencies. Two additional federal agencies active in ground water related issues in the PRSB include the Bureau of Land Management (BLM) and the U. S. Environmental Protection Agency (USEPA).

Several Wyoming State agencies have site specific information available in the planning area. These agencies include the Department of Environmental Quality (Land Quality and Water Quality Divisions), the State Engineer's Office, the United States Geological Survey, the Oil and Gas Conservation Commission and the Water Development Commission.

Overview

The planning area lies in the central and northcentral part of the state and includes all or part of six Wyoming counties (Figure I-1). The planning area includes all of Sheridan and Johnson Counties, about sixty percent of Campbell County (north, centralwest and southwest) and a small portion of northeastern Natrona County. Very small parts of west and southeast Converse and Washakie Counties are also within the planning area. Figure III-21 shows the general location of the planning area with respect to regional structural elements in northcentral and northeastern Wyoming.

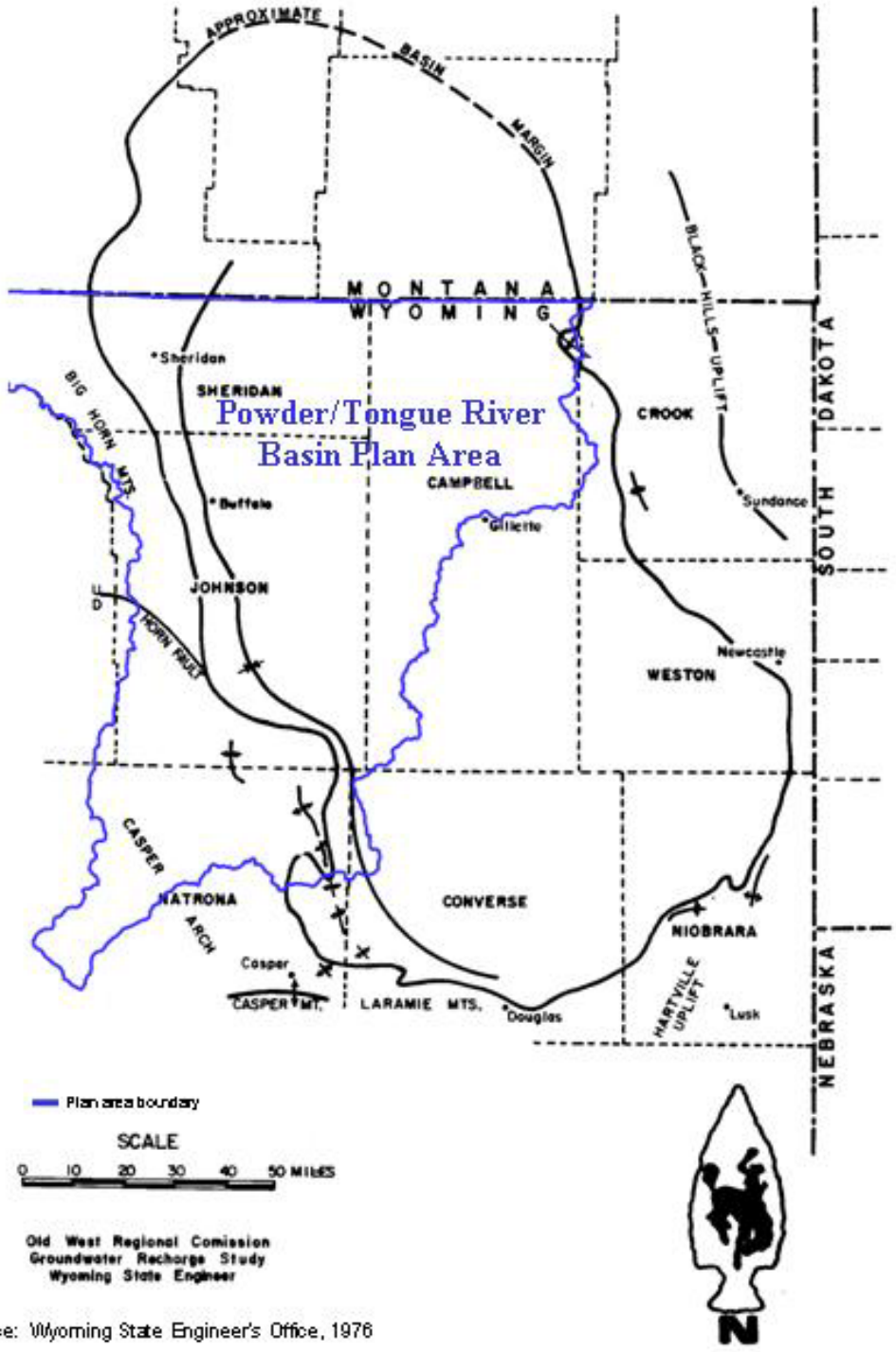


Figure Source: Wyoming State Engineer's Office, 1976

Investigation of Recharge to Groundwater Reservoirs of Northeastern Wyoming

Figure III-21. Location and Geologic Structure Map, Powder/Tongue River Basin Plan Area, Wyoming

Major communities in Sheridan and Johnson Counties include Arvada, Ucross, Clearmont, Dayton, Ranchester, Sheridan, Buffalo and Kaycee. Edgerton and Midwest are the primary towns in Natrona County. Gillette in Campbell County lies on the eastern edge of the planning area.

Regionally, the planning area lies within the Missouri River drainage system and covers an area of approximately 11,261 square miles in central and northcentral Wyoming. The principal surface water systems within the planning area include the Tongue, Powder, and Little Bighorn Rivers and their respective tributaries. These drainage systems form the boundary of the Basin Plan.

Altitudes are variable in the planning area and generally range from 3,460 feet where the Tongue River crosses the State line into Montana in Sheridan County to 13,165 feet at the summit of Cloud Peak in Johnson County. East of the Mountains in Johnson County, relief is about 2,000 feet with altitudes ranging from 3,700 feet to an average of about 5,700 feet in the foothills at the base of the Bighorn Mountains. Altitudes in Natrona County range from 9,800 feet in the northwest part of the County to 4,800 feet near Midwest.

Climate is typical of the northern High Plains with low precipitation, high evaporation and wide ranges of temperatures. Annual precipitation varies from 13 to 15 inches in the majority of the planning area (Figure I-2). Generally, about forty to fifty percent of the precipitation in the planning area occurs between April and June.

Geologic Setting

Geologic formations in the planning area range in geologic time from Precambrian crystalline rocks to recent alluvial and eolian deposits generally consisting of clays, silts, sands and gravels. The PRSB has over 17,000 feet of sedimentary strata. These sedimentary rocks have been divided into about 11,000 feet of Cambrian to Cretaceous pretectonic deposits and up to 7,000 feet of Tertiary deposits associated with the deformation of the PRSB.

The older strata, which are exposed only in the western part of the planning area, are economically important for oil production. The Tertiary deposits contain significant coal reserves and are subject to mining and coalbed methane development. Both the Early Cretaceous Fall River Formation and the Early Tertiary Wasatch Formation have been important as uranium deposit sources in the Black Hills and the PRSB outside the planning area. Figure III-22 presents a generalized geologic section of the PRSB typical of the planning area.

The Powder/Tongue River Basin encompasses several tectonic elements that influence the geology, and the occurrence and availability ground water. These structural features include the PRSB, mountain uplifts (Bighorn Mountains, the Laramie Range and Black Hills (outside and east of planning area)) and broad uplifts of lesser magnitude (Casper Arch and Hartville Hills).

Figures III-23 and III-24 present the generalized surficial and bedrock geology of the planning area.

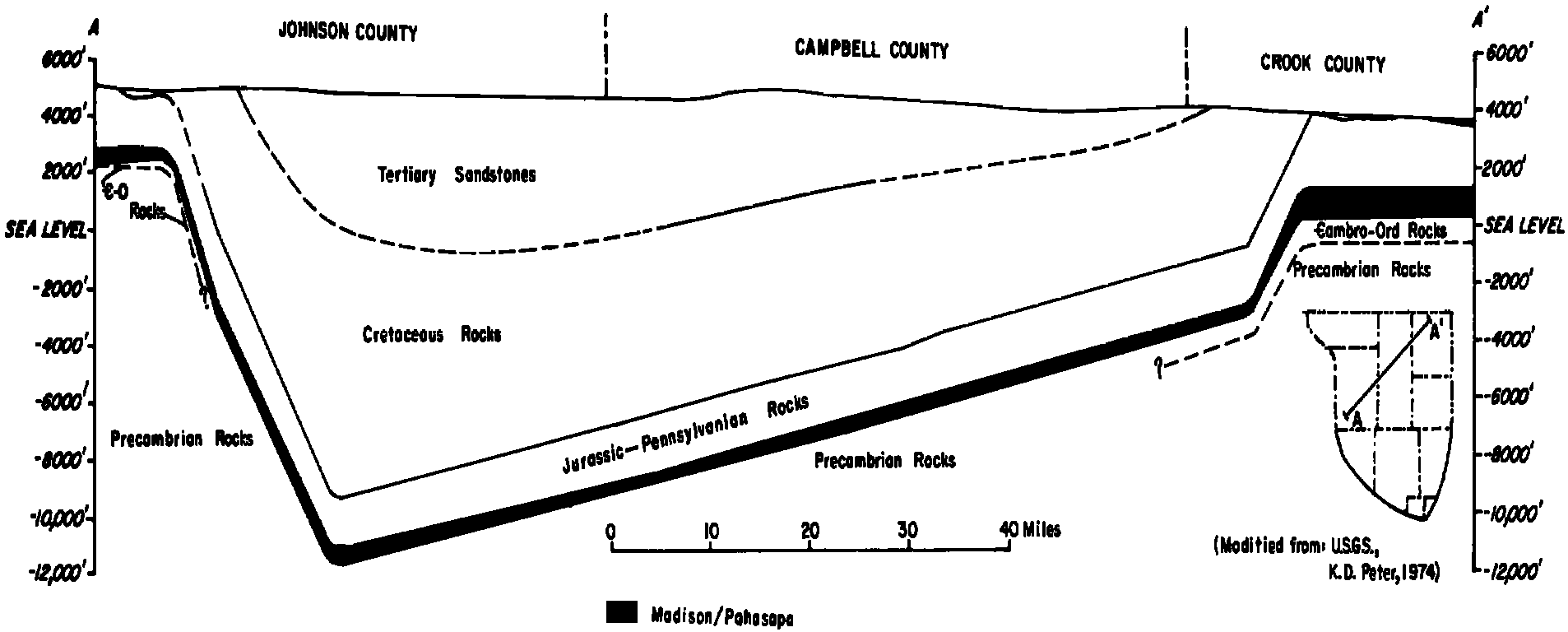
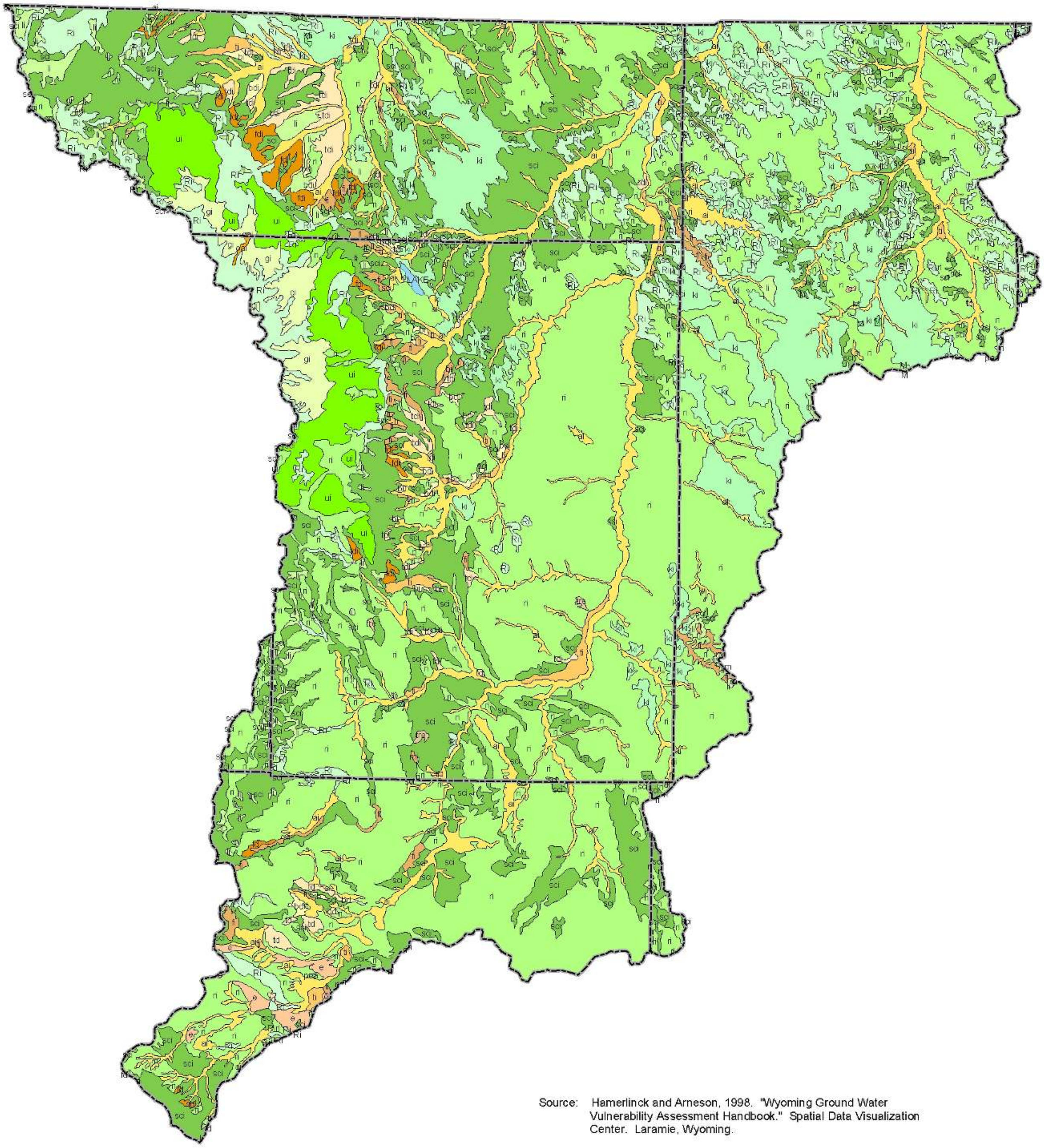


Figure Source: Wyoming State Engineer's Office, 1976
Investigation of Recharge to Groundwater Reservoirs Of Northeastern Wyoming

Figure III-22. Generalized Geologic Section in Northeastern Wyoming



Source: Hamerlinck and Arneson, 1998. "Wyoming Ground Water Vulnerability Assessment Handbook." Spatial Data Visualization Center. Laramie, Wyoming.

N
W
E
S

Legend

Lake	Body of Water	ei	Eolian Deposits
ai	Alluvium	oai	Glacial Outwash and Alluvium
bi	Bench Deposits	gi	Glacial Deposits
bdi	Dissected Bench Deposits	li	Landslide
tdi	Dissected Terrace Deposits	pea	Playa Deposits
ti	Terrace Deposits	sci	Slopewash and Colluvium
tre	Shallow Terrace Deposits	ri	Residuum
fi	Alluvial Fan and Gradational Fan Deposits	ui	Grus
fdi	Dissected Alluvial Fan and Gradational Fan Deposits	Ri	Bedrock and Glaciated Bedrock
mi	Mesa	Mi	Mined Areas
		ki	Clinker

6 3 0 6 12 18 Miles

Surficial Geology

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Figure III-23

N

W E

S

Source: Hamerlinck and Arneson, 1998. "Wyoming Ground Water Vulnerability Assessment Handbook." Spatial Data Visualization Center. Laramie, Wyoming.

Legend

- Lake — Bodies of Water
- Qa — ALLUVIUM AND COLLUVIUM
- Qt — GRAVEL, PEDIMENT, AND FAN DEPOSITS
- Qg — GLACIAL DEPOSITS
- Qls — LANDSLIDE DEPOSITS
- Qs — DUNE SAND AND LOESS
- Qu — UNDIVIDED SURFICIAL DEPOSITS
- QTb — BUG FORMATION (PLEISTOCENE OR PLIOCENE)
- QTg — TERRACE GRAVEL (PLEISTOCENE AND / OR PLIOCENE)
- Tmu — UPPER MIOCENE ROCKS 2
- Tm — MIOCENE ROCKS 2
- Tml — LOWER MIOCENE ROCKS
- Tmo — LOWER MIOCENE AND UPPER OLIGOCENE ROCKS OR ROCKS EQUIVALENT TO UPPER AND LOWER MIOCENE ROCKS AND WHITE RIVER FORMATION
- Twru — Upper conglomerate member
- Twr — WHITE RIVER FORMATION
- Tid — DACITE AND QUARTZ LATITE INTRUSIVE AND EXTRUSIVE IGNEOUS ROCKS
- Tai — ALKALIC INTRUSIVE AND EXTRUSIVE IGNEOUS ROCKS
- Twb — WAGON BED FORMATION
- Tie — INTRUSIVE AND EXTRUSIVE IGNEOUS ROCKS
- Twdr — WIND RIVER FORMATION
- Twmo — Moncrief Member
- Twk — Kingsbury Conglomerate Member
- Tw — WASATCH FORMATION
- Tim — INDIAN MEADOWS FORMATION
- Tftr — Tongue River Member
- Tftl — Tongue River and Lebo Members
- Tfl — Lebo Member
- Tflt — Lebo and Tullock Members
- Tft — Tullock Member
- Tfu — FORT UNION FORMATION
- Kl — LANCE FORMATION
- Klm — LAND FORMATION, FOX HILLS SANDSTONE, MEETEETSE FORMATION, AND BEARPAW AND LEWIS SHALES
- Kfh — FOX HILLS SANDSTONE
- Kfl — FOX HILLS SANDSTONE AND LEWIS SHALE
- Kfb — FOX HILLS SANDSTONE AND BEARPAW SHALE
- Kml — MEETEESTE FORMATION AND LEWIS SHALE
- Kle — LEWIS SHALE
- Kmv — MESAVERDE FORMATION
- Kp — PIERRE SHALE
- Ks — STEELE SHALE
- Kc — CODY SHALE
- Kn — NIOBRARA FORMATION
- Knc — NIOBRARA FORMATION AND CARLILE SHALE
- Kcl — CARLILE SHALE
- Kf — FRONTIER FORMATION
- Kgb — GREENHORN FORMATION AND BELLE FOURCHE SHALE
- Kgbm — GREENHORN FORMATION AND BELLE FOURCHE AND MOWRY SHALES
- Kmr — MOWRY FORMATION
- Kft — FRONTIER FORMATION AND MOWRY AND THERMOPOLIS SHALES
- Kmt — MOWRY AND THERMOPOLIS SHALE
- Kns — NEWCASTLE SANDSTONE AND SKULL CREEK SHALE
- KJ — CLOVERLY FORMATION (HARTVILLE UPLIFT) OR INYAN KARA GROUP (BLACK HILLS) AND MORRISON FORMATION
- KJs — CLOVERLY, MORRISON, AND SUNDANCE FORMATIONS
- KJg — CLOVERLY, MORRISON, SUNDANCE, AND GYPSUM SPRING FORMATIONS
- Js — SUNDANCE FORMATION
- Jsg — SUNDANCE AND GYPSUM SPRING FORMATIONS
- @c — CHUGWATER FORMATION
- @cd — CHUGWATER AND DINWOODY FORMATIONS
- @Ps — SPEARFISH FORMATION
- @Pcg — CHUGWATER AND GOOSE EGG FORMATIONS
- @Pg — GOOSE EGG FORMATION
- Pmo — MINNEKAHTA LIMESTONE AND OPECHE SHALE
- Pp — PHOSPHORIA FORMATION AND RELATED ROCKS
- MzPz — MESOZOIC AND PALEOZOIC ROCKS
- P&c — CASPER FORMATION
- P&h — HARTVILLE FORMATION
- P&m — MINNELUSA FORMATION
- P&M — CASPER FORMATION AND MADISON LIMESTONE
- PM — TENSLEEP SANDSTONE AND AMSDEN FORMATION
- Pzr — MINNEKAHTA LIMESTONE, OPECHE SHALE, MINNELUSA FORMATION, PAHASAPA AND ENGLEWOOD LIMESTONES, WHITEWOOD DOLOMITE, AND WINNIPEG AND DEADWOOD FORMATIONS
- Mm — MADISON LIMESTONE OR GROUP
- MD — MADISON LIMESTONE AND DARBY FORMATION
- MDe — PAHASAPA AND ENGLEWOOD LIMESTONES
- MDg — GUERNSEY FORMATION
- MO — MADISON LIMESTONE AND BIGHORN DOLOMITE
- Ob — BIGHORN DOLOMITE
- O_ — WHITEWOOD DOLOMITE, AND WINNIPEG AND DEADWOOD FORMATIONS
- _r — GALLATIN LIMESTONE, GROS VENTRE FORMATION AND EQUIVALENTS, AND FLATHEAD SANDSTONE
- Xsv — METASEDIMENTARY AND METAVOLCANIC ROCKS
- Xgy — GRANITIC ROCKS OF 1,700-Ma AGE GROUP
- Xgo — GRANITIC ROCKS OF 2,600-Ma AGE GROUP
- Wg — GRANITIC ROCKS OF 2,600-Ma AGE GROUP
- Wgn — GRANITE GNEISS
- Ws — Metasedimentary rocks
- Wmu — Metamorphosed mafic and ultramafic rocks
- WVsv — METASEDIMENTARY AND METAVOLCANIC ROCKS
- WVg — PLUTONIC ROCKS
- Ugn — OLDEST GNEISS COMPLEX

6 3 0 6 12 18 Miles

Bedrock Geology

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Figure III-24

Geologic Units and Ground Water

A geologic formation is a body or group of rock strata that consist dominantly of a certain lithologic type or combination of types. A general definition of an aquifer is a geologic formation or group of formations that are capable of yielding a significant quantity of water to wells or springs.

There are more than 30 geologic formations exposed on the western margin of the planning area. For this report, the formations were grouped into five principal aquifer systems that have historically been the major ground water sources of interest in the planning area. The grouping was based on that presented in the 1981 report on the "Occurrence And Characteristics of Ground Water in The Powder River Basin, Wyoming", by the Water Resources Research Institute (WWRI) of Wyoming. Figure III-25 graphically summarizes the geologic formations and their hydrogeologic role in the PRSB.

The WWRI aquifer system division and the grouping used herein were based on aquifer hydrogeologic similarity and aquitard identification. The grouping allows for a simplified presentation of the principal sources of ground water in the planning area. The five major aquifer systems within the planning area are (oldest to youngest):

- Madison Aquifer System
- Dakota Aquifer System
- Fox Hills/Lance Aquifer System
- Fort Union/Wasatch Aquifer System
- Quaternary Aquifer System

More detailed information on the hydrogeology and hydrologic characteristics of the major aquifer systems are provided in the “Available Ground Water Determination” memorandum.

Ground Water Quality

Ground water quality data contained in USGS ground water reports for the planning area were reviewed and provide an overview of the general quality of water from the aquifer systems within the planning area.

The review included selected USGS analyses available from USGS data files as of March 26,1982 (Larson and Daddow, 1984). The 2000 USGS publication on water co-produced with coalbed methane in the PRSB was also reviewed (Rice, Ellis and Miller, W*ater Co-produced with Coalbed Methane in the Powder River Basin, Wyoming: Preliminary Data*).

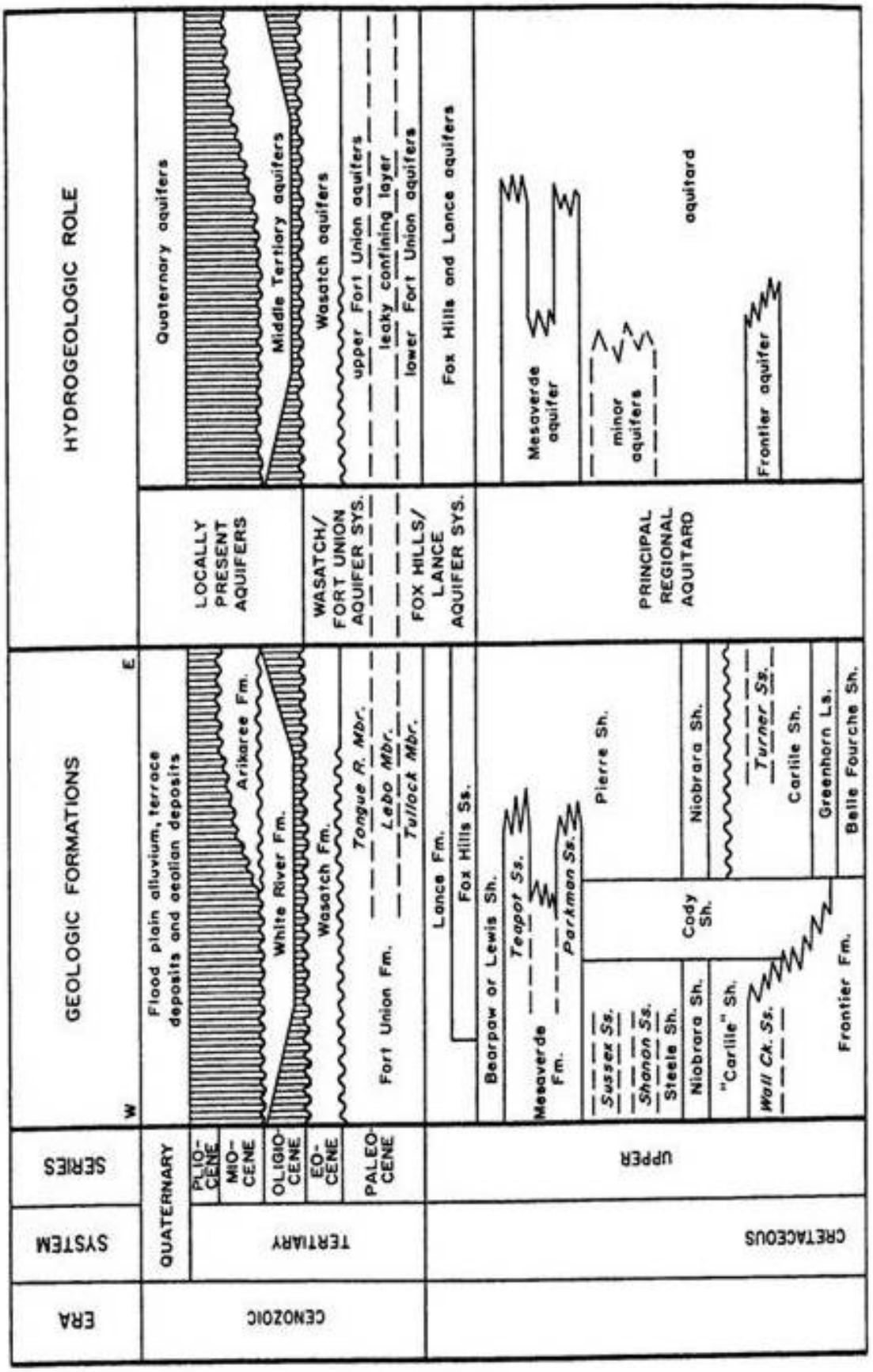

Figure III-25. Diagrammatic Hydrostratigraphy of the Powder River Structural Basin within the Powder/Tongue River Basin Plan Area.

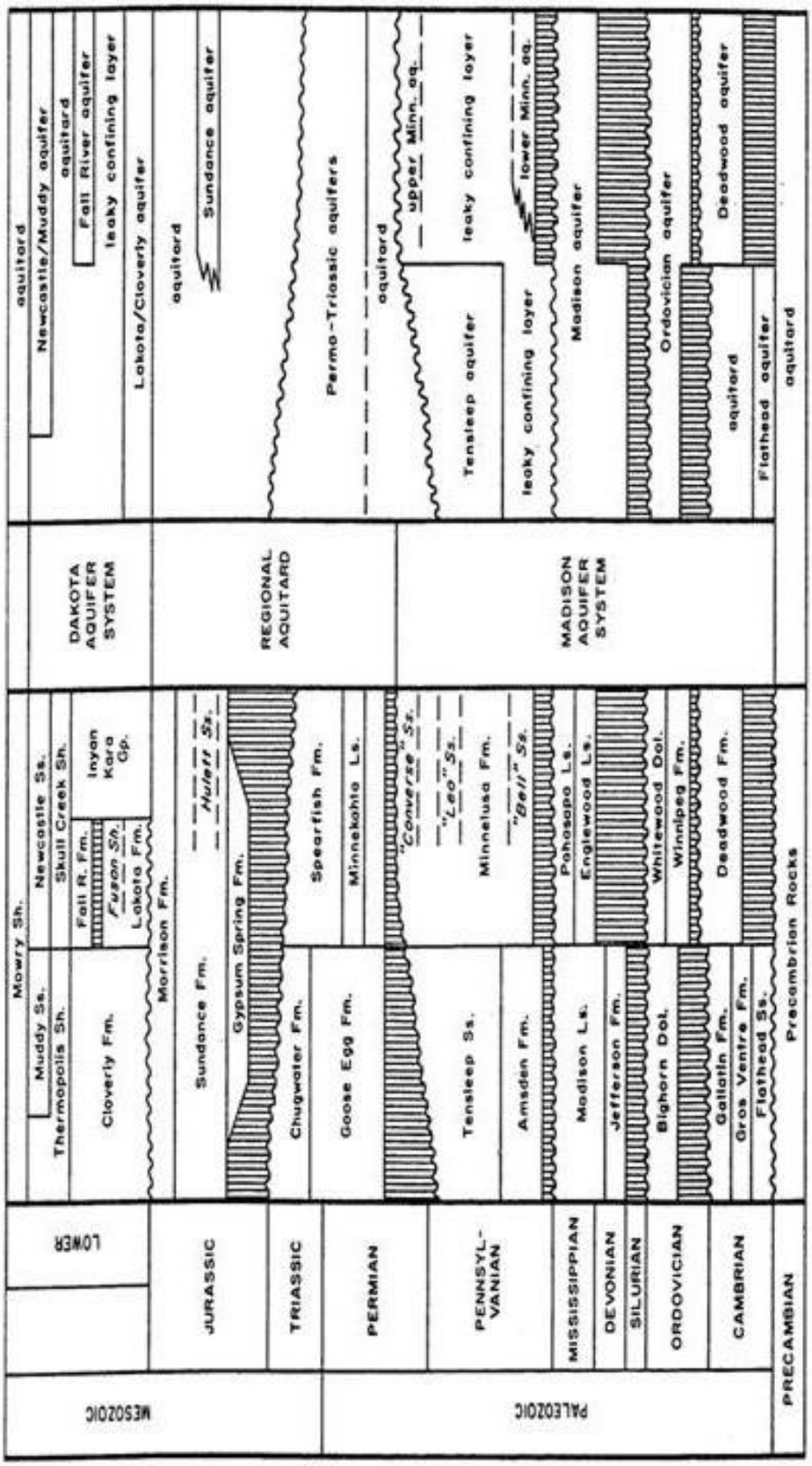

Figure III-25. (continued)

Diagrammatic Hydrostratigraphy of the Powder River Structural Basin within the Powder/Tongue River Basin Plan Area.

Figure Source: Feathers, Libra, Stephenson & Esen, 1981
Occurrence and Characteristics of Groundwater in the Powder River Basin, Wyoming

1984 USGS Report

Information used in the 1984 report did not include all of the data available in USGS files at the time. Constituents were selected by USGS on the basis of their relative abundance and their inclusion in water quality criteria at the time. Water quality data available from the 1984 USGS report included: specific conductance, pH, temperature, dissolved-solids (TDS) concentration and concentrations of the major ions (calcium, magnesium, sodium, potassium, alkalinity (as bicarbonate), sulfate, chloride, fluoride, and nitrate, plus silica, boron, and iron). This data was from 748 ground water sites in the PRSB and adjacent areas.

Information on selected dissolved trace metals were reported for 220 ground water sites in the PRSB and adjacent areas in the 1984 USGS report. Data were reported for nine trace metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, zinc) in the 1982 selection.

Radiochemical data was listed for 65 ground water sites in the PRSB and adjacent areas in the 1984 USGS report. The data included eight radiochemical analyses for each site (gross alpha-dissolved, gross alpha-suspended, gross beta-dissolved, gross beta-suspended, radium 226 dissolved radon method, radium 226 dissolved precipitation method, uranium-dissolved extraction method, uranium-dissolved direct fluorometric method).

2000 USGS Report

The 2000 USGS publication on water co-produced with coalbed methane in the PRSB contained data from 47 ground water sites in the PRSB. Approximately 15 of the sites were located within the planning area. The remaining 32 were located in the Northeast Wyoming River Basins Plan Area.

Water quality data available from the 2000 USGS report included: pH, temperature, dissolved-solids (TDS) concentration and concentrations of the major ions and minor ions (fluoride, chloride, sulfate, bromine, alkalinity, ammonia, calcium, potassium, magnesium, sodium, barium, iron plus silica, strontium, and sodium-adsorption-ratio (SAR)). Data were also reported for seventeen trace elements (silver, aluminum, arsenic, boron, beryllium, bismuth, cadmium, cerium, cobalt, chromium, caesium, copper, mercury, lanthanum, lithium, manganese, nickel).

Water Quality Standards and Suitability for Use

The State of Wyoming has identified the following standards for different classes of ground water:

- Class I ground water is defined as ground water suitable for domestic use.
- Class II ground water is defined as ground water suitable for agricultural use where soil conditions and other factors are adequate.
- Class III ground water is defined as ground water suitable for stock use.
- Class Special (A) ground water is defined as ground water suitable for fish and aquatic life.

- Class IV ground water is defined as ground water suitable for industry.
- Class V ground water is defined as ground water found closely associated with commercial deposits of hydrocarbons, or ground water which is considered a geothermal resource.
- Class VI ground water is defined as ground water that may be unusable or unsuitable for use.

Historically, major ground water uses in the PRSB and the planning area have been for domestic use, agriculture (stock and irrigation), and municipal / public water systems. Ground water has been used for industrial purposes including, coalbed methane production, petroleum production (secondary oil recovery) and coal mining, coal fired steam generation, and uranium mining and processing. Ground water has also been used for fish hatcheries in the eastern part of the PRSB outside the planning area.

The fact that ground water is and has been successfully used for the above uses is a general, practical indicator of ground water quality in the planning area. A general, qualitative evaluation and comparison of ground water produced from the six aquifer systems was performed. The results of the evaluation, including a general characterization of water co-produced with coalbed methane, are summarized in Table III-34 along with the availability and development potential for each aquifer system in the planning area.

Aquifer Sensitivity/Vulnerability

The Wyoming Spatial Data and Visualization Center (SDVC – now known as the Wyoming Geographic Information Science Center or WyGISC) developed a system to assess the sensitivity and vulnerability of ground water to surface water contamination in Wyoming. The SDVC developed aquifer vulnerability maps to define the potential for surface contamination to impact ground water in the uppermost aquifer throughout Wyoming. The highest rated lands generally are located on alluvial deposits adjacent to rivers, streams, and lakes, and are associated with slope wash, colluvium, residium and eolian deposits or are on fractured bedrock areas.

Maps of aquifer vulnerability to contamination for the uppermost or shallowest aquifers were also developed by SDVC. Ground water is vulnerable in areas with high water tables, sandy soils, and areas of presumed pesticide application. The areas with the highest vulnerability are also generally located in the floodplains of the major streams and/or associated with slope wash, colluvium, residium and eolian deposits within the planning area.

The ground water sensitivity and vulnerability maps are provided in the “Available Ground Water Determination” memorandum.

Table III-34
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Quaternary Alluvial Aquifer System	Alluvium and Terrace Deposits	0-100+	Silt, sand and gravel; unconsolidated and interbedded; present along most streams.	Yield of 50 to 300 gpm may be possible, often through induced recharge. Terraces topographically high and often drained. Specific capacity, 0.3-7 gpm/ft; permeability, 380 and 1100 gpd/ft^2 and transmissivity, 9700 and 20300 gpd/ft from two tests in Sheridan County (Lowry and Cummings, 1966). Coarser deposits have better aquifer properties.	TDS content generally range from about 100 to >4000 mg/l. Chemical characteristics of water differ geographically. Chemical type and mineralization of the water can be expected to vary depending on underlying rock types and the nature and degree of interconnection with surface water. Alluvial deposits in the western part of the planning area generally contain water of better quality than alluvial deposits in the eastern part. Suitability for municipal / public, domestic, irrigation and stock is variable and dependent on location and above factors.	Historical source for municipal / public, domestic and stock use. Production has ranged up to 250 gpm with induced infiltration of surface water. Ground water development potential generally better in coarse-grained deposits and poorer in fine-grained materials. Moderate to high yields might be possible to optimally located and properly designed wells if induced infiltration from surface water can be tolerated in the upper reaches of Powder River, Piney, Clear and Crazy Woman Creeks. Moderate supplies may be able to be developed in thicker deposits of coarse material in the alluvuim of Prairie Dog Creek as well as the alluvium of the Tongue River and Dutch Creek. (Lowry and Cummings, 1966), (Whitcomb,	Quaternary alluvial aquifers generally in hydraulic connection with all bedrock aquifers in outcrop areas and also with surface waters. Alluvial aquifers in larger valleys provide hydraulic interconnection between otherwise hydraulically isolated bedrock aquifers (Whitcomb, 1965). Alluvial aquifers also serve as interchange point and storage for ground water in the hydrologic cycle (Davis and Rechard, 1977), (Davis, 1976). Induced recharge from surface waters is probable in areas of extensive development.
Fort Union / Wasatch Aquifer System	Wasatch Formation	500 to 2000±	Fine- to coarse-grained lenticular sandstones interbedded with shale and coal. Yields water from, lenticular sandstone and to a lesser extent from jointed coal and clinker beds (Hodson, Pearl and Druse, 1977). Divided into two conglomeratic members (Kingsbury and Moncrief Members) near the Bighorn Mountains (Lowry and Cummings, 1966).	Yields generally <15 gpm. Specific capacity of Wasatch wells and those completed in the coarse grained facies of the Wasatch Formation in Sheridan County averaged 0.33 and 1.0 gpm/ft respectivley; permeability, 6.5 gpd/ft^2 (one test - coal, Sheridan County); transmissivity, 520 gpd/ft (one test - coal, Sheridan County) and 2200 gpd/ft (one test - sandstone, Sheridan County). (Lowry and Cummings, 1966)	TDS content of waters is variable and ranges from 141 to 6620 mg/l (Larson, 1984). Sulfate and Iron content range from 0.6 - 4080 mg/l and 0 - 25 mg/l respectively and water varies from soft to very hard. Dominant cations generally are Sodium, Calcium and Magnesium, Sodium and Calcium, or Sodium and Magnesium. (Lowry and Cummings, 1966), (Whitcomb, Lowry and McCullough)	Important local source for domestic and stock water supply. Yields from fine grained facies generally small and barely adequate for stock and domestic use and generally can be expected to be < 15 gpm. Wells completed in the Kingsbury Conglomerate and Moncrief Members may have potential for higher production. Water quality generally suitable for domestic supplies although undesireable constituents may make other water sources more attractive if available. Water quality suitability for stock ranges from poor to good. Generally unsuitable for irrigation due to high salinity and sodium content.	Kingsbury Conglomerate and Moncrief Members located at the base of the mountains in Sheridan Counties.

Table III-34
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Fort Union / Wasatch Aquifer System (continued)	Fort Union Formation	1200-3900	Sandstone, fine- to medium-grained, lenticular, interbedded with siltstone, coal and shale. "Clinker" associated with coal outcrops.	Flowing yields of 1-60 gpm reported where confined. Pumped yields up to 250 gpm with several hundred feet of drawdown (eastern Campbell County, east of planning area). Specific capacity for 85 wells in Sheridan County averaged 0.42 gpm/ft; permeability (2.5 and 7.9 gpd/ft^2), transmissivity (10 and 95 gpd/ft), and Storage coefficient (9.0 X 10^{-5} and 3.5 X 10^{-4}) for tests performed on two wells in Sheridan County (Lowry and Cummings, 1966). Coal and clinker generally better aquifer properties than sandstones. Locally clinker transmissivity up to 3,000,000 gpd/ft; Anisotropy and leaky confining layers are common.	TDS content of waters is variable and ranges from 484 - 4630 mg/l (Larson, 1984). Sulfate and Iron content range from 0.3 - 1870 mg/l and 0.06 - 19 mg/l respectively. Water varies from soft to very hard and is generally a Sodium Bicarbonate type. (Lowry and Cummings, 1966), (Whitcomb, Cummings and McCullough, 1966) Water co-produced with coal bed methane is predominantly Sodium Bicarbonate type with TDS content and SAR (15 samples), of 540 - 2010 mg/l (mean of 1309 mg/l) and 7.7 - 32 (mean of 19.82) respectively in planning area. (Rice, Ellis & Bullock, 2000). BLM Wyodak EIS assumed average TDS concentration of 764 mg/l (USDI,BLM, 1999).	Important, extensively used relatively shallow (< 1000 feet depth) local source for domestic and stock supply. Low yields, generally less than 25 gpm can be expected. Four of the 12 municipal / public supply wells in service for the City of Gillette (east of planning area) as of 1994 had been tested at pumping rates ranging from 50 to 130 gpm (Wester -Wetstein and Associates, Inc., 1994).	Total of 6820 Coal Bed Methane wells permitted with WSEO in planning area as of 12/31/00. Maximum, minimum and mean depths and range of actual yields listed on permits were 92 -4100 (mean 637) feet below ground surface (bgs), and 1 - 60 (mean 49) gpm respectively. Range of depths to main water bearing zone listed on WSEO Permits were 58 - 3816 (mean 580) feet bgs. BLM Exxon Pistol Point EA assumed average water production for each CBM well to average between 30 and 45 gpm (USDI,BLM, 1992). BLM Lower Prairie Dog Creek EA assumed average water production for each CBM well to be 15 gpm (USDI,BLM, 1999). BLM Wyodak EIS assumed average expected water production to be 12 gpm over the estimated 12 year life of each CBM well (USDI,BLM, 1999). BLM Wyodak Drainage EA assumed average water production for each CBM well to be 11.1 gpm.
Fox Hills/Lance Aquifer System	Lance Formation	600-1900 (North) 1950-3000 (South)	Sandstone, fine- to medium-grained, lenticular, interbedded with sandy siltstone, claystone and shale.	Generally yields less than 15 gpm with specific capacities, 0.03-.16 gpm/ft in planning area. Limited development due to uneconomical drilling depths. In eastern area of Powder River Structural Basin (PRSB), yields up to 350 gpm but with large drawdowns and long well completion intervals; permeability 34 gpd/ft^2; transmissivity, 76-2100 gpd/ft for wells also completed in Fox Hills Sandstone.	TDS content in waters generally range from <500 - 3060 mg/l. Composition variable, mainly Sodium Sulfate or Calcium Sulfate. Variable iron (0 - 6.03 mg/l) and Sulfate (<100 - 1780 mg/l) content, SAR 1.9 - 39. Generally undesireable for domestic water source due to possible high Iron, Manganese and Sulfate content. Generally fair to poor for stock use. Unsuitable for irrigation due to high salinity and / or high SAR.	Historical source for domestic and stock supply. Generally yields less than 15 gpm in planning area. Development limited due to uneconomical drilling depths. Water quality generally suitable for domestic supplies although undesireable constituents may make other water sources more attractive if available. Water quality suitability for stock ranges from poor to good. Generally unsuitable for irrigation due to high salinity and / or Sodium content.	

Table III-34
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Fox Hills/Lance Aquifer System (continued)	Fox Hills Sandstone	0-700	Sandstone, fine-to medium-grained, interbedded with shale and siltstone.	Generally yields less than 15 gpm with specific capacities, 0.03-.37 gpm/ft in planning area. Transmissivity, 76-1600 gpd/ft for wells also completed in Lance Formation. Limited development due to uneconomical drilling depths.	Similar to Lance Formation. Water suitable for domestic use usually present only near outcrop. Water suitable for stock use generally found at depths of up to 1000 feet, away from outrop. The quality of water may be unsatisfactory for domestic and stock use where the the aquifer is is deeper than 1000 feet. (Crest and Lowry, 1972)	Historical source for municipal / public, domestic and stock supply. Generally yields less than 15 gpm in planning area. No more than 50 gpm can be expected from wells completed in wells in the planning area (Natrona County). Well for Town of Edgerton produced 25 gpm with a specific capacity of 0.037 gpm/ft. (Crist and Lowry, 1972) Development limited due to uneconomical drilling depths. Tested yields of Gillette municipal / public supply wells (east of planning area) have ranged from 85 to 705 gpm (Wester-Wetstein and Associates, Inc.,	High Fluoride content may be of concern in eastern part of planning area. Has been used as municipal / public water supply source for Town of Edgerton. Has been used for oil well water flooding operations in eastern PRSB.
Dakota Aquifer System	Muddy Sandstone (NewCastle Sandstone)	0-40±	Light gray, fine-grained, lenticular sandstone and siltstone often termed a member of Thermopolis shale.	Minor unit of Dakota Aquifer System. Oil field data (PRSB): porosity, 5-20%; permeability, <7 gpd/ft^2 ; transmissivity, <150 gpd/ft.	No data in planning area.	No data in planning area. Ground water possibilities in planning area generally not known. Probably capable of yielding small quantities of no more than 10 gpm water to wells. Deep drilling depths would probably preclude consideration other than at outcrops. Dakota Aquifer System historical source for domestic and stock use in eastern PRSB.	
	Cloverly Formation	140-150	Interbedded dark shale and brown siltstone with 15-45 feet of basal, fine - to coarse-grained well sorted sandstone.	Flowing yields of 1-40 gpm, up to 250 gpm reported for pumped wells (south of planning area); specific capacity, 0.12-.2 gpm/ft. Oil field data: porosity, 15-18%; permeability, 0.4-4 gpd/ft^2; transmissivity, 7-230 gpd/ft.	Water from Cloverly and Morrison Formations in Natrona County predominantly Sodium Bicarbonate type. Other types include Calcium Bicarbonate, Calcium Sulfate, Sodium Sulfate, and Calcium Sulfate. TDS content range between 300 and 3000 mg/l.	Generally deeply buried in planning area except at outcrops. Yields small supplies to springs at outcrops. Well yields of 5 to 20 gpm may be expected. Yields of greater than 100 gpm may be possible from complete section of rocks.	
Madison Aquifer System	Tensleep Sandstone	50-250 (Northwestern Basin) <500 (Southwestern Basin)	Fine- to medium-grained, massive, crossbedded sandstone with occasional thin dolomite beds.	Unit of Madison Aquifer System. Flowing yields up to 400 gpm; Specific capacity, 1 gpm/ft. Oil field data: porosity, 0-24%; permeability, 0-21 gpd/ft^2; transmissivity, 0-1900 gpd/ft.	Water type is variable (Magnesium Carbonate, Calcium Magnesium Sulfate, Sodium Sulfate,Calcium Sodium Sulfate, Calcium Sulfate) and concentration of TDS varies directly to distance from the outcrop and generally ranges from<300 -3240 mg/l. Generally very hard but suitable for domestic, stock and irrigation use at or near outcrop. (Crist and Lowry, 1972), (Whitcomb, Cummings and McCullough, 1966) TDS content 204 - 2930 mg/l in six samples in Natrona County (Larson, 1984).	Sandstone generally well cemented, but primary permeability is sufficient at most locations to permit yields of 50 gpm to wells. There is potential for higher yields where secondary permeability is high. Yield of 600 gpm reported for an irrigation well at the foot of the Bighorn Mountains in Johnson County . Development may be limited economically due to deep drilling depths in Johnson County in outcrop area or in narrow belt generally less than about one mile paralleling the east margin of the outcrop. (Whitcomb, Lowry, and (McCullough 1966), (Crist and Lowry,	

Table III-34
Summary of Ground Water Availability/Development Potential of Major Aquifer Systems, Central and Western Flanks of the Powder River Structural Basin

Major Aquifer System	Geologic Unit	Thickness (Feet)	Lithologic Character	Hydrological Character[A,B]	General Water Quality	Availability / Development Potential[C]	Remarks
Madison Aquifer System (continued)	Amsden Formation	150-300 (Northwestern Basin) 0-200 (Southwestern Basin)	Red and purple shale with some sandstone, cherty dolomite and limestone.	Aquitard unless fractured.		Generally deeply buried in planning area except at outcrops. Ground water possibility generally not known.	
	Madison Limestone	1100± (Northwestern Basin) 200-400 (Southwestern Basin)	Limestone, dolomitic limestone and dolomite, sandy at base.	Principal unit of Madison Aquifer System. Flowing yields over 4000 gpm but highly variable; specific capacity. <1 to 50 but is flow-dependent; transmissivity, 500-90,000 gpd/ft or higher and highly variable.	Waters at Outcrop (TDS < 600mg/l, predominantly Calcium Magnesium Bicarbonate type water). TDS increase basinward to > 3,000 mg/l, Sodium Sufate Chloride predominating. Fluoride enrichment characteristic of Madison System waters throughout the PRSB basin. Concentrations of radionuclides could be of concern in some areas.	Probably most important high yield aquifer in Wyoming. Historical source for municipal / public water supply, industrial, irrigation and stock use in PRSB. Several fish hatcheries use Pahasapa / Madison aquifer as water source in northeastern part of PRSB. Yields variable geographically and dependent on secondary permeability. Drilling depths may inhibit development.	Total estimated recharge to the Madison Limestone in the PRSB in 1973 was about 75,000 acre feet/year. (WSEO, 1976)
	Bighorn Dolomite	400-500 (Northwestern Basin) absent (Southwestern Basin)	Massive dolomite, becoming thin-bedded at top and sandy at base.	Generally deeply buried except in outcrop areas. Ground water possibilities generally not known.		Ground water possibilities generally not known. Probably would yield water to wells depending on secondary permeability.	
	Flathead Sandstone	345± (Northwestern Basin) 90 (Southwestern Basin)	Tan to reddish sandstone, locally conglomeratic, interbedded with green shale and siltstone.	Minor unit of Madison Aquifer System. Not exploited due to deep burial but a few wells yield water near outcrops.		Ground water possibilities generally not known. Probably would yield water to wells depending on secondary permeability. Generally deeply buried except in outcrop areas. Yields small quantities of water to springs from sandstone and conglomerate in the Bighorn Mountains. (McCullough 1966), (Crist and Lowry, 1972)	

[A]Reported yields may reflect development needs rather than aquifer capability; higher yields can sometimes be expected, with corresponding drawdown increases. Reported water well transmissivities or permeabilities may be for wells completed in two aqu
[B]Oilfield (and USGS test) data are variously derived resulting in internal inconsistencies in this compilation. Permeabilities are measured on cores or derived from other data and transmissivities are from drill stem tests or calculated from permeabilit
[C]Actual development potential will require site specific office and field investigations to define aquifer capability and constraints unique to each project and site.

Taken from: Feathers, Libra, Stephenson and Eisen, 1981, *Occurance and Characteristics of Groundwater in the Powder River Basin, Wyoming*

Ground Water Development

Ground water is the major source of water for many uses within the planning area. All five aquifer systems are important water sources in the planning area for all uses. Ground water associated / co-produced with coalbed methane development although not a use, is very important due to withdrawal impacts on ground water levels and existing wells completed in the Fort Union/Wasatch Aquifer System.

Existing Development

Selected existing and historical uses of ground water from the five aquifer systems within the planning area are summarized in Table III-34. The significance of ground water in the planning area is demonstrated by the 16,432 active ground water permits (as of December 31, 2000) within the planning area. Because of the dynamic nature of CBM development, the inventory of permitted CBM wells was updated to reflect data as of December 31, 2001. The number of permits for each use category are summarized below:

- 111 Permitted active agricultural wells with production rates greater than 49 gpm
- 8 Permitted active municipal wells with production rates greater than 49 gpm
- 301 Permitted active industrial and miscellaneous wells with production rates greater than 49 gpm
- 4,646 Active permitted domestic wells
- 4,546 Active permitted stock wells
- 6,820 Permitted coalbed methane wells (9393 by December 31,2001)

The geographic distribution of the permits for the above use categories with respect to surficial and bedrock geology are presented in the "Available Ground Water Determination" memorandum. Two of these maps showing CBM wells and stock wells in relation to the bedrock geology are shown on Figures III-26 and III-27. These maps provide a general indication of the significance of the geologic formations associated with each of the aquifer systems as ground water sources in the planning area.

Ground Water Monitoring Programs

Existing ground water monitoring programs will continue to be important in monitoring the status of ground water in the PRSB and the planning area for all activities. One such program is the Wyoming statewide USGS cooperative program operated by the SEO and other state, county, municipal and federal agencies.

The Gillette Area Groundwater Monitoring Organization (GAGMO) and the recently formed (April 1999) Powder River Basin Area Groundwater Monitoring Organization (PRAGMO) are for coal mining and coalbed methane development. GAGMO is operated by the coal mining industry and PRAGMO by the coalbed methane development operators. These programs provide a common database that satisfy federal and state agency requirements for the respective industries to track and evaluate impacts of their operations on ground water in the PRSB.

Legend

- Additional Wells Permitted as of December 31, 2001
- Wells Permitted as of December 31, 2000

Lake	Tw	Kf	P&m
Qa	Tim	Kgb	P&M
Qt	Thr	Kgbm	PM
Qg	Tfl	Kmr	Pzr
Qls	Tfl	Klt	Mm
Qs	Tft	Kmt	MD
Qu	Tft	Kns	MDe
QTb	Tfu	KJ	MDg
QTg	Kl	KJs	MO
Tmu	Klm	KJg	Ob
Tm	Kfh	Js	O_
Tml	Kfl	Jsg	_r
Tmo	Kfb	@c	Xsv
Twru	Kml	@cd	Xgy
Twr	Kle	@Ps	Xgo
Tid	Kmv	@Pcg	Wg
Tal	Kp	@Pg	Wgn
Twb	Ks	Pmo	Ws
Tle	Kc	Pp	Wmu
Twdr	Kn	MzPz	WVsv
Twmo	Knc	P&c	WVg
Twk	Kcl	P&h	Ugn

Geology from:

Hamerlinck and Arneson, 1998. "Wyoming Ground Water Vulnerability Assessment Handbook." Spatial Data Visualization Center. Laramie, Wyoming.

Miles
9 4.5 0 9 18 27

N W E S

Bedrock Geology with Permitted Coalbed Methane Wells

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Figure III-26

Legend

- Wells
- Lake
- Qa
- Qt
- Qg
- Qls
- Qs
- Qu
- QTb
- QTg
- Tmu
- Tm
- Tml
- Tmo
- Twru
- Twr
- Tid
- Tai
- Twb
- Tie
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- Tim
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- MzPz
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- PM
- Pzr
- Mm
- MD
- MDe
- MDg
- MO
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- O_
- _r
- Xsv
- Xgy
- Xgo
- Wg
- Wgn
- Ws
- Wmu
- WVsv
- WVg
- Ugn

Geology from:

Hamerlinck and Arneson, 1998. "Wyoming Ground Water Vulnerability Assessment Handbook." Spatial Data Visualization Center. Laramie, Wyoming.

8 4 0 8 16 24 Miles

N W E S

Bedrock Geology with Active Stock Wells

HKM Engineering Inc.
Granite Tower Building
222 N. 32nd St., Suite 700
P O Box 31318
Billings, MT 59107-1318
(406) 656-6399, FAX (406) 656-6398

Figure III-27

Other state and federal agencies have their own monitoring programs associated with their management and regulatory responsibilities. State agencies include SEO, Oil and Gas Conservation Commission and the Department of Environmental Quality. Federal agencies include the Bureau of Land Management and the Forest Service.

Agricultural, Municipal, Industrial and Misc., Domestic and Stock Uses and Ground Water

Out of a total of 16,432 active ground water permits inventoried as of December 31, 2000, for the basin plan, 9,612 of the permits were for WWDC categories other than coalbed methane development.

Reported well depths for the 111 active permitted agricultural wells with production rates greater than 49 gpm ranged from 3 to 4,689 feet and averaged 720 feet. Reported depths to the top of the "main water bearing zones" in the permit data ranged from 3 to 4,418 feet and averaged 657 feet. The maximum and average reported "actual yields" of these wells were 2700 gpm and 280 gpm.

There were a total of eight permitted active municipal wells with production rates greater than 49 gpm. Reported well depths ranged from 18 to 4,170 feet and averaged 1,282 feet. Reported depths to the top of the "main water bearing zones" in the permit data ranged from 11 to 2,680 feet and averaged 716 feet. Reported "actual yields" of these wells ranged from 70 to 990 gpm and averaged about 399 gpm.

There were a total of 301 permitted active industrial and miscellaneous wells with production rates greater than 49 gpm. Reported well depths ranged from 9 to 15,400 feet and averaged 1,987 feet. Reported depths to the top of the "main water bearing zones" in the permit data ranged from 4 to 9,722 feet and averaged 1,666 feet. Reported "actual yields" of these wells ranged from 50 to 9,479 gpm and averaged about 375 gpm.

A total of 4,646 permitted domestic wells were reported in the planning area. Reported domestic well depths ranged from 1 to 9,600 feet and averaged 216 feet. Reported depths to the top of the "main water bearing zones" in the permit data ranged from 1 to 4,070 feet and averaged 180 feet. Reported "actual yields" of these wells in the permit data files ranged from 1 to 1,800 gpm and averaged about 13 gpm.

A total of 4,546 permitted stock wells were reported in the data for the planning area. Reported stock well depths ranged from 1 to 9,537 feet and averaged 329 feet. Depths to the top of the "main water bearing zones" ranged from 1 to 6,533 feet and averaged 291 feet. Reported "actual yields" of these wells ranged from 1 to 2,700 gpm and averaged about 14 gpm.

The relative importance of each of the aquifer systems to each use category is summarized in Table III-34. This information together with the maps provided in the Available Ground Water Determination Technical Memorandum can be used to make further inferences at an initial level, as to the relative importance of each of the aquifer systems with respect to the five non-coalbed methane use categories in the planning area.

Impacts on Ground Water and Surface Water Supplies

Impacts to ground water will depend on local geologic and hydrologic conditions in the areas of development. Possible impacts to ground water could include:

- The possible depletion of surface water that is interconnected with aquifer systems. The principal aquifer systems of concern with respect to this impact include the Madison and the Quaternary Alluvial Aquifer Systems. The geographic areas of concern with respect to the Madison Aquifer System, are along the western part of the planning area where streams flow across Madison System outcrops. The areas of concern with respect to the Quaternary Alluvial Aquifer System, are throughout the entire planning area in the alluvium adjacent to surface water systems.

  Ground water development in any of these areas, irrespective of proposed use, will require detailed investigations that also address the possibility and degree of surface and ground water interconnection. Depending on proposed ground water use, the existing SEO permitting process should be able to address the issue. The Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) might also be involved in the permitting process with respect to surface / ground water interconnection under provisions of the USEPA Safe Drinking Water Act (Ground Water Under the Direct Influence of Surface Water).

- Depending on location, geologic source, and water demand requirements, there is the possibility that domestic and stock well densities could create interference problems between wells and / or aquifer depletion problems. This is probably more of a probability in areas experiencing rural development of single family residences and / or multi-family subdivisions where individual or community public water supply wells provide water.

  The SEO permitting process for ground water has historically addressed these issues. New legislation would be required to establish ground water control zones for any ground water use other than agricultural use. The potential problem in conjunction with coalbed methane development has also been recognized (depletion of aquifers and wells), and responsible state and federal agencies are attempting to address related ground water impacts.

- There is the possibility of aquifer systems being impacted due to oil and gas operations. The nature of these impacts would depend on the geographic as well as geologic and stratigraphic location of the activity. A potential impact could involve aquifer depletion if water were used from one of the aquifer systems for secondary recovery operations. Other impacts could be water quality related through drilling and recovery operations and leakage through inadequate and / or failed plugging and abandonment of production wells. The possibility of these impacts and other issues should be able to be addressed by existing regulatory activity and programs of the Wyoming Oil and Gas Conservation Commission, Wyoming Department of Environmental Quality and the SEO.

- The Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) is initiating a Source Water Assessment and Protection Program in 2002 for participating Public Water Systems throughout the state. This program should address issues regarding the safeguarding of aquifers for water quality considerations in areas where public water systems are located.

Coalbed Methane Development and Ground Water

For ease of reference, the main coal seam that is the target of coalbed methane development in the PRSB and within the planning area is referred to as the Wyodak-Anderson coal zone. Methane gas is trapped in micropores and cleat fracture systems within the coal, and is maintained in that state by the natural pressure of ground water. The gas is extracted using wells that are completed in the coal to remove water and lower the water pressure responsible for holding the gas. The gas moves out of the coal as the water pressure is lowered, and is recovered from the well along with the water.

As previously noted, a total of 9,393 coalbed methane wells (December 31, 2001) were identified through the SEO data query for the Basin Plan. Reported coalbed methane well depths ranged from 92 to 15,220 feet and averaged 712 feet. Reported depths to the top of the "main water bearing zones" in the permit data ranged from 58 to 3816 feet and averaged 653 feet. Reported "actual yields" of coalbed methane wells in the permit data files averaged 37 gpm.

The BLM has recently used 12 gpm (USDI, 1999, *Wyodak Coalbed Methane Project Final Environmental Impact Statement*) and 11.1 gpm (USDI, 2000, *Wyodak Drainage Coalbed Methane Environmental Assessment*) for average production rates of coalbed methane wells in the preparation of Environmental Impact statements for coalbed methane development within the planning area. The actual ground water production rate is typically variable throughout the life of each well. As an example, BLM projected the initial ground water production rates of the wells for the Lighthouse Coalbed Methane Project to be 11 gpm, with an interim average of 7 gpm and a final rate of less than 3 gpm per well (USDI, 1995, *Lighthouse Coalbed Methane Project Environmental Assessment*).

The USGS, in cooperation with BLM and coalbed methane production companies, is conducting multidisciplinary studies in the PRSB in an effort to provide a better understanding of coalbed methane resources and associated water. A USGS report for one of the studies in progress provides preliminary compositional data on water from 47 coalbed methane wells sampled between June, 1999 and May, 2000. Water co-produced with coalbed methane is generally a sodium bicarbonate type. Of the 47 wells sampled by USGS, 15 are located within the area of the Powder/Tongue River Basin Plan and 32 are located within the Northeast Wyoming River Basins Plan Area. Total dissolved solids content (TDS) of all 47 samples ranged from 270 to 2010 and averaged 850 mg/l. Values of the sodium adsorption ratio ((SAR), which is a relative measure of the suitability of water for irrigation due to sodium content) for the 47 samples ranged from 5.7 to 32 and averaged 12. For comparison, an SAR of roughly 13 would generally be considered the upper limit for field crops in clayey soils.

TDS and SAR of the 15 samples from coalbed methane wells in the planning area ranged from 540 to 2010 mg/l (mean 1309 mg/l) and 7.7 to 32 (mean 19.82) respectively. TDS and SAR of the 32 samples from coalbed methane wells in the Northeast Wyoming River Basins Plan Area ranged from 270 to 1170 mg/l (mean 653 mg/l) and 5.7 to 12 (mean 7.85) respectively. The results of the USGS samples indicated that TDS and SAR in waters in the Wyodak-Anderson coal zone generally increase in the PRSB from south to north and from east to west.

Concentrations of most of the 17 trace elements analyzed by USGS in samples of water from the 47 coalbed methane wells were below detection limits. All the concentrations of trace elements were below the maximum contaminant levels of the Primary Drinking Water Standards of the USEPA. The USGS reported that there were no noticeable trends in trace element concentrations in the samples from the 47 wells.

Impacts on Ground Water and Surface Water Supplies

Potential impacts to ground and surface water have been identified by BLM in the preparation of environmental assessments (EA) and environmental impact statements (EIS) for numerous coalbed methane projects in the PRSB including the planning area. Impacts to ground water will depend on local geologic and hydrologic conditions in the areas of coalbed methane development. Possible impacts to ground water that have been identified include:

- The dewatering of aquifers and the lowering of water levels and yields in production wells located in the vicinity of coalbed methane development. This includes wells that are completed in the Wyodak-Anderson coal zone and any aquifers that may be in hydraulic connection with the coal. Ground water modeling performed in association with the Wyodak coalbed methane Project EIS, predicted a fairly rapid recovery of water levels within a period of three to four years to within 20 or 30 feet of preoperational conditions at the cessation of coalbed methane operations. This estimate was based on the projected redistribution of the large amount of ground water in storage within the coal west, north, and south of the development. Total recovery was projected to take a very long time as recharge to the coal aquifer would be needed to replace that ground water removed from storage during coalbed methane operations.

- Possible methane seepage into wells and structures in the proximity of coalbed methane development that could pose a health and safety hazard to planning area residents.

- Possible increased infiltration of water from coalbed methane production into shallow alluvial ground water systems in the Gillette area that could aggravate subsurface structure problems.

- Possible increased infiltration of water from coalbed methane production into shallow ground water systems in the planning area that could impact the quality and use of ground water from shallow systems.

- Possible impacts to surface coal mining operations.

- Possible impacts to in-situ leach extraction process of uranium mining in the PRSB southeast of the planning area.

Possible surface water related impacts that have been identified could include:

- Possible change in the drainage characteristics in draws and drainages from ephemeral to perennial. This could result in an increase in the erosion potential and sedimentation problems in receiving drainages. Coalbed methane generated water could result in increased flooding potential in receiving drainages. Higher flows could also impede landowner access to perform normal work associated with their operations.

- A possible alteration of the chemical characteristics of receiving surface waters due to coalbed methane generated water. This could include a change due to increased salinity and sodium content that could impact irrigation practices and the utilization of surface water for irrigation. Concern has also been expressed on the impacts of coalbed methane water on possible toxicity problems and aquatic habitat in receiving waters.

A more comprehensive discussion of all possible impacts including those to both surface and ground water due to coalbed methane development is available in the previously mentioned EA's and EIS's prepared by BLM.

Future Development

The geology, drilling depths, hydrogeologic characteristics and ground water quality of aquifer systems vary throughout the planning area. All of the aquifer systems in the planning area previously discussed probably have some potential for development. Site specific investigations in conjunction with experience and common sense will be required to determine the opportunities available to develop ground water with wells of sufficient capacity for a specific use within the planning area.

Although there have been considerable hydrogeological investigations in the PRSB including the planning area, there have been few regional assessments of the annual recharge, storage and sustained yield capability of the major aquifer systems both in the PRSB and the planning area. General conclusions regarding ground water development potential of four of the five major aquifer systems in the planning area discussed in this report are summarized below:

- The Madison Aquifer System may have the most development potential for high yield wells on a sustained basis in the PRSB and the planning area. Previous investigations have estimated that annual average recharge to this system to be approximately 75,000 acre feet per year within the entire PRSB in northeast Wyoming. Drilling depths and water quality may constrain development at specific locations within the planning area.

- The Fox Hills/Lance Aquifer System may have local potential for development of wells with low to moderate yields. The possible high fluoride content in water from this system might influence the desirability of use for a municipal/public supply without provision for treatment or special management, such as mixing with water from other

sources. Wells completed in the Fox Hills/Lance Aquifer System may offer an alternative source to wells completed in the Fort Union/Wasatch Aquifer System impacted by coalbed methane development.

- The Fort Union/Wasatch Aquifer System is utilized for most uses in the PRSB within the planning area. The Wyodak-Anderson coal and hydraulically interconnected aquifers of the Aquifer System will be heavily impacted by ground water withdrawals in and near coalbed methane development. The water co-produced with coalbed methane may provide an opportunity for utilization, depending on location, quality and nature of potential use. Further consideration of injection of water co-produced with coalbed methane development into the Fox Hills/Lance and Fort Union/Wasatch Aquifer Systems is warranted in the planning area.

- Aquifers in the Alluvial Aquifer (Quaternary Aquifer) System within the planning area may have local development potential if induced infiltration of surface water can be tolerated.

Table III-34 summarizes the development potential of the five aquifer systems within the planning area. Items of interest related to ground water availability/development potential are also summarized in Table III-34. These items include the general lithologic and hydrologic character of the aquifer systems in addition to the general quality of ground water available from the systems.

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IV Demand Projections

For assessing the need for water into the future, this plan has developed estimates of water demand for each major use category out to year 2030. These estimates are discussed in detail in technical memoranda prepared for each topic.

As with all chapters in this final plan report, explicit lists of references are not provided. Instead, all references to reports, documents, maps, and personal communications are maintained in the Technical Memoranda that were prepared during the current planning process. Should the reader desire to review a complete list of references for the information presented in this chapter, the following memoranda should be consulted.

- Irrigation Water Needs and Demand Projections
- Population Projections
- Industrial Water Needs Projections
- Recreational and Environmental Water Requirements

A. Agricultural Demand Projections

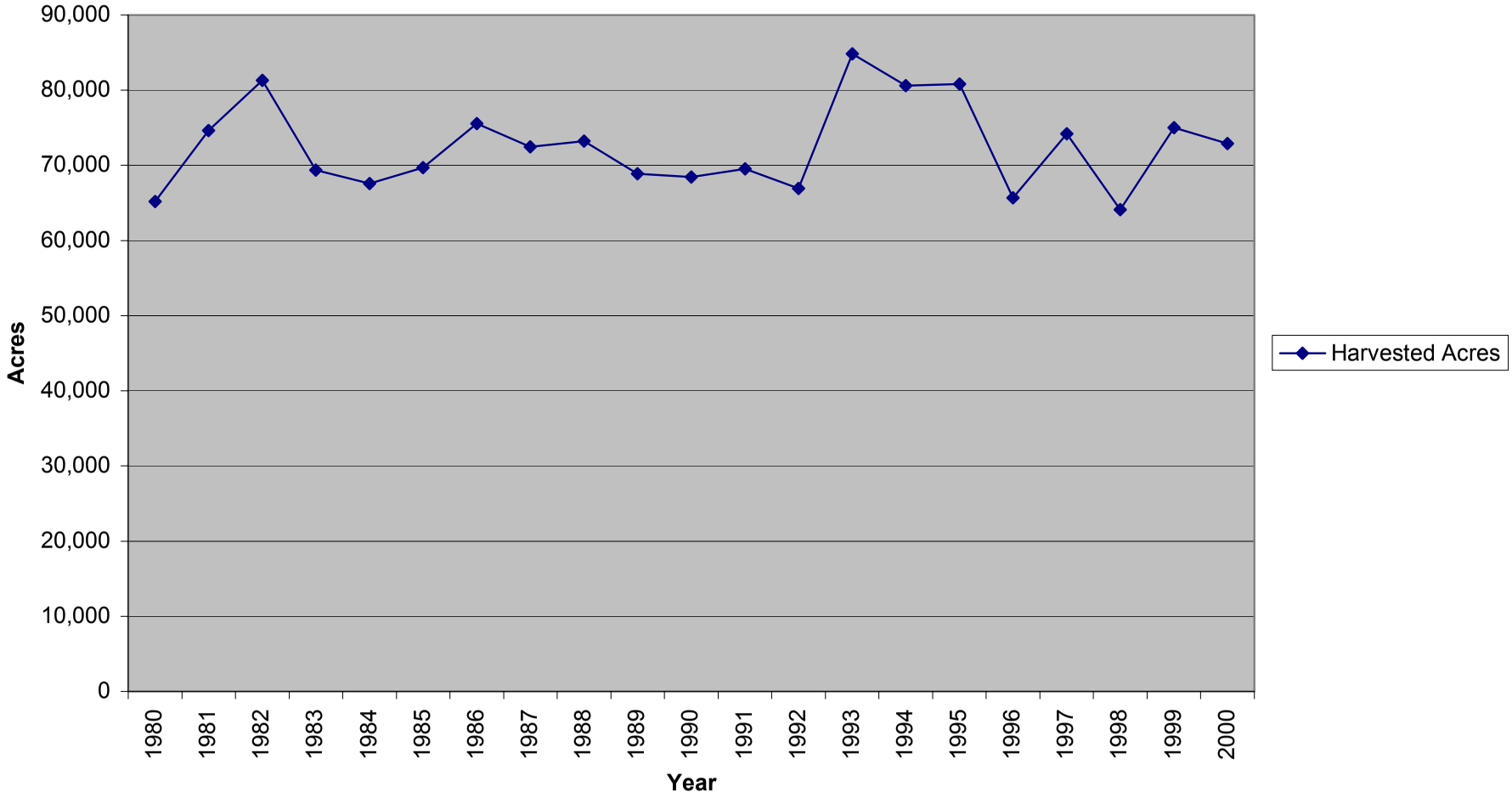
Background

Irrigated agriculture is the largest user of water in the Powder/Tongue River Basin. The irrigated lands analysis conducted for this study indicates that there are about 169,600 acres of irrigated land in the Basin. Of this total, 8,300 are idle, primarily due to water delivery system problems, and another 4,300 acres have been converted or are in the process of conversion to residential use. Of the remaining 157,000 acres that are actively irrigated, about 15,000 are irrigated using spreader dikes or intermittent diversions. Only about 200 acres rely primarily on groundwater as an irrigation water supply. The remaining 156,800 actively irrigated acres are served primarily by surface water diversions. Total surface water depletions in the Basin are estimated to be about 183,800 acre-feet in a normal year, or 1.17 acre-feet per acre for the actively irrigated lands with surface water diversions.

The majority of irrigated land is devoted to the production of forage crops such as alfalfa, grass hay, and irrigated pasture. Figure IV-1 shows estimates of harvested forage acreage in the planning area for the period from 1980 through 2000 as developed by the Wyoming Agricultural Statistics Service (WASS).[1] That figure shows that the number of acres of forage crops harvested each year varied from a low of about 65,000 acres to a high of about 85,000 acres. There appears to be no trend of increasing or decreasing production over time, meaning that the annual variations are likely attributable to variables such as weather, irrigation water availability, and cattle prices.

[1]WASS county level acreage data were adjusted to Basin-wide estimates based upon the estimated proportion of irrigated acreage in each county that lies within the planning area.

Figure IV-1
Harvested Forage Acreage
1980-2000



The distribution of harvested forage acreage by county is depicted in Figure IV-2. That figure shows that Sheridan County is the largest forage producer in the Basin, producing an average of 53 percent of all forage harvested over the period from 1980 through 2000. Johnson County is the second largest producer with 39 percent of the total, followed by Campbell and Natrona Counties, each with four percent of the total.

A number of reservoirs store water for irrigation purposes in the planning area, but the availability of storage water varies among drainages. Eleven significant storage facilities deliver irrigation to irrigators in some parts of the planning area, including the Big Goose Creek and Little Goose Creek drainages in the Tongue River sub basin; Piney Creek and Clear Creek in the Clear Creek sub basin; the North Fork of Crazy Woman Creek and Muddy Creek in the Crazy Woman Creek sub basin: and the North Fork of the Powder River in the Powder River sub basin. A complete description of these storage facilities is presented in a separate technical memorandum.

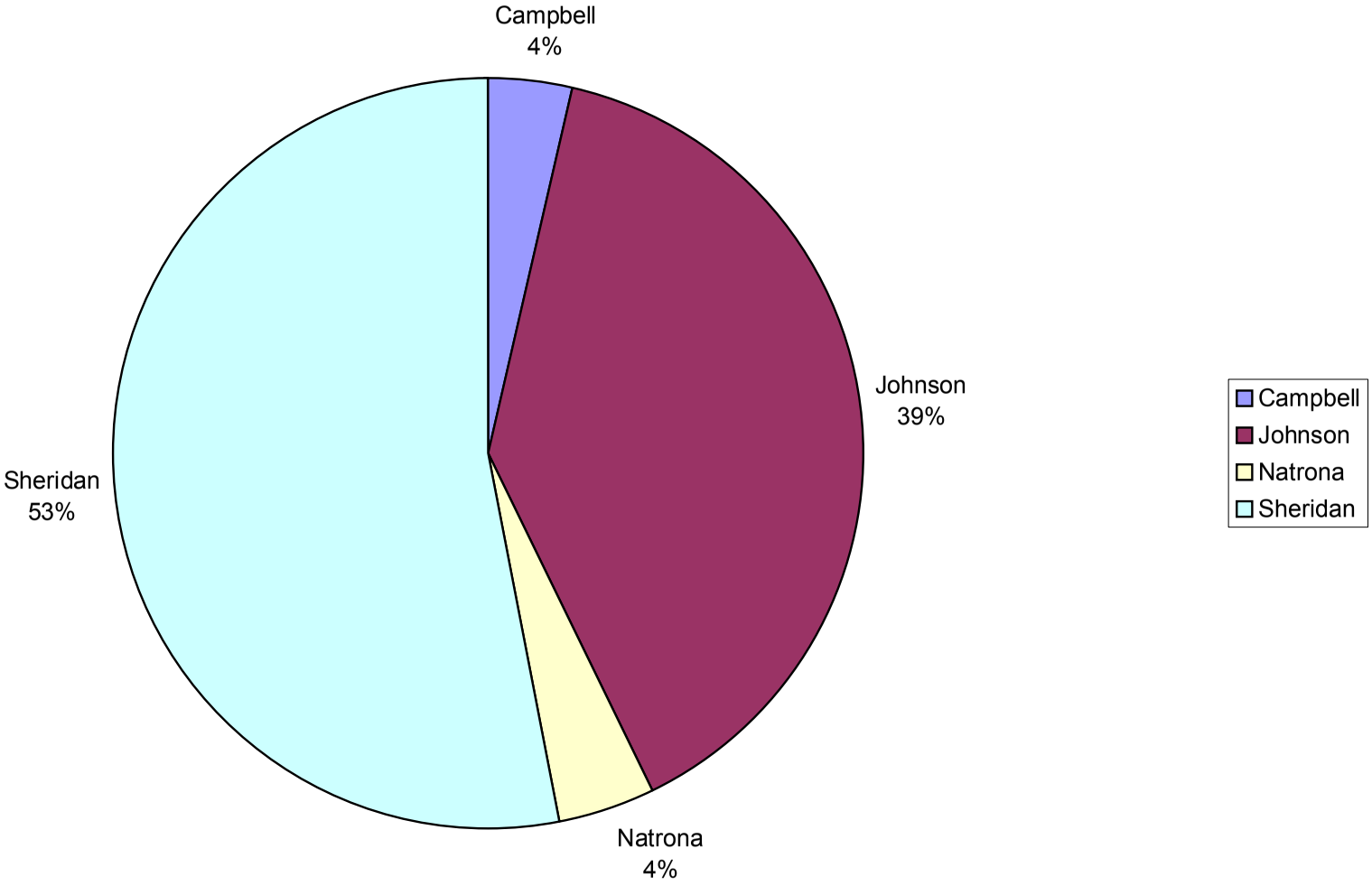
Trends in Livestock Production

Over the past two decades livestock production (cattle and sheep) in the Basin has remained relatively constant. There appear to be several interrelated reasons why this has occurred. One limiting factor with respect to herd size is the availability of summer range on federal lands, which constitute a large proportion of rangeland in the Basin. Both the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) have become more conservative in recent years with respect to the management of federal grazing allotments in an attempt to improve the quality of the range and provide adequate forage for wildlife. There has been little opportunity for producers with federal grazing allotments to increase their production on federal lands in recent years, and in some cases federal grazing rights have been restricted.

In discussing the future of irrigation in the planning area, it is necessary to distinguish between needs and demands for irrigation water. 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 Basin 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. If additional water costs $500 per acre-foot, however, 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 manufacturers 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

Figure IV-2
Distribution of Harvested Forage Acreage by County
(1980-2000 Average)



demands in this planning study. 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.

The hydrologic modeling effort undertaken for this planning study, as well as conversations with irrigators and water professionals, indicate that there are areas of the Powder/Tongue River Basin that could benefit from additional irrigation water, especially in dry years. Areas of particular need appear to be the Little Tongue drainage, some of the irrigated acreage along Clear Creek and its tributaries, the Middle and North Forks of Crazy Woman Creek, and the Powder River and some of its tributaries, especially Buffalo Creek. Additional irrigation water in these areas would stabilize forage production and allow ranchers to operate more profitably. Additional storage would also allow some operators to adjust more readily to potential future changes in the management of federal grazing allotments.

The biggest practical problem associated with fulfilling these needs for additional irrigation water is that the returns to forage production in recent decades have not been sufficient to offset the costs of new water storage projects. Studies of returns to irrigation water in other parts of Wyoming indicate that one acre-foot of irrigation water used for forage production in relatively high altitude areas of the state can be expected to generate a $15 to $25 increase in net farm income. The cost of developing new storage can be significantly higher than that figure even under very favorable circumstances.

Future demands for additional irrigation water in the planning area are thus largely dependent upon factors that might either increase the returns that Basin irrigators receive from irrigation or reduce the cost to them of developing new storage. Possibilities for increasing economic returns to irrigated agriculture in the Basin include diversifying cropping patterns into higher valued crops, the possibility that hay prices may rise to the point that it would be profitable to export hay from the Basin to other domestic markets, and the possibility that cattle prices may rise significantly over the next 30 years.

Although there are some opportunities for diversifying cropping patterns in the Powder/Tongue River Basin, it is doubtful that diversification out of forage production will occur on a wide enough scale over the next 30 years to warrant significant new water development projects. Specialty crops, such as alfalfa seed or seed potatoes, could possibly be grown in some of the lower elevation areas of the Basin. Seed alfalfa production is moving into Wyoming's Bighorn Basin, where acreage has grown from 2,000 to 15,000 acres in recent years. Nevertheless, such crops still require relatively small acreages and tend to be produced in areas that have a competitive advantage with respect to climate and/or soils, which does not appear to be the case in this planning area.

Some trends in the agricultural industry in the western U.S. suggest that certain types of forage production will become more valuable in the future as cash crops. As more agricultural land is taken from production in the future, there will be less hay production because it is among the lower valued crops that can be grown in lower elevation areas.

Wyoming is currently a net exporter of alfalfa and Timothy grass hay. No official statistics are available on the magnitude of hay exports from Wyoming, but some experts put the figure at about 25 percent, and expect that percentage to increase in the future. The largest market for Wyoming hay is now Colorado, but some producers in the Bighorn Basin are shipping hay by rail to dairies as far away as Florida and other east coast states. The types of hay expected to be in high demand in the future are alfalfa for dairies and Timothy hay for horses. Although alfalfa prices have been somewhat depressed in recent years, that trend is now reversing. Timothy hay is already bringing prices as high as $180 per ton in some parts of Wyoming and alfalfa prices in many parts of the state now exceed $100 per ton. If future market prices for these crops stabilize at high levels, it may become practical for some producers to develop additional storage and expand production of these crops for export markets.

Two other events could translate into more demand for irrigation water in the Powder/Tongue River Basin over the next 30 years, a significant and long-term increase in cattle prices and/or an increase in the amount of financial assistance available to producers for reservoir construction from state and federal agencies.

Cattle prices have increased somewhat in recent years as per capita beef consumption in the U.S. has stabilized at around 67 pounds after many years of decline. But according to the Cattleman's Beef Production and Research Board, per-capita consumption is not expected to increase in the future and will most likely decrease from today's levels. The USDA, however, is forecasting a significant increase in exports of U.S. beef over the next 10 years. The basis of this projection is the fact that demand for high quality beef in the Pacific Rim nations is expected to increase significantly in the future as the economies of these countries recover from the 1998 financial crisis that affected the region.

The prospects for increased federal assistance for reservoir construction seem more remote than the projected increase in cattle prices. Federal assistance for agriculture and new reservoir construction has been declining in recent years, and there are no indications that this situation will change over the planning horizon. The WWDC also has tightened its funding criteria for new water project construction in recent years. This tightening has been primarily motivated by budget constraints, however, and the possibility exists that more state funds may be allocated to water development over the next 30 years than are available under current economic conditions.

One potential low cost source of irrigation water for future use is CBM production water. Projections indicate that water production associated with CBM development in the planning area may exceed 150,000 acre-feet annually at some point during the next 10 years. There are several practical problems with utilizing that water for irrigation, however, one of which is the fact that high levels of production are not expected to last more than about 10 years. Given this relatively short duration, it is doubtful that many irrigators would be willing to make the significant changes in their operations that would be required to put this water to beneficial use.

Water Use Projections

For the reasons discussed above, the low, moderate, and high growth scenarios for future irrigation water demand in the planning area are based upon varying assumptions concerning the

financial returns to beef and forage production and the availability of WWDC assistance for new project construction.

Low Growth Scenario

The low growth scenario is based upon the assumptions that irrigation in the Powder/Tongue River Basin will continue to be dominated by forage production for winter livestock feed and that cattle and forage prices will not make sustained increases over the next 30 years relative to reservoir construction costs. This scenario also projects no increase in state funding available for new project construction and no change in WWDC criteria for financial assistance to project sponsors. As a result, irrigators will probably be unwilling to make long-term financial commitments to develop new storage following WWDC funding guidelines.

Numerically, total consumptive use of surface irrigation water is expected to remain relatively constant at 183,800 acre-feet in a normal year.

Moderate Growth Scenario

The moderate growth scenario is based upon the reasonably foreseeable possibility that cattle prices will increase significantly over the next 10 years as forecast by the USDA. Cattle prices are projected to stabilize at these higher prices over the planning horizon. This scenario also assumes that the WWDC will increase its financial commitment to new storage projects.

The combination of higher cattle prices and increased WWDC assistance will allow irrigators to maximize use of existing storage and fund some new storage projects in those parts of the Basin where developable sites are available. Storage in Lake DeSmet that is seldom fully utilized under current economic conditions, and additional water could be made available from Lake DeSmet through agreements with the Joint Powers Board that now owns and operates the reservoir. Furthermore, previous studies have identified several small storage sites that are off the Bighorn National Forest and which could potentially be developed if economic conditions improve for ranchers and the WWDC provides additional financial assistance.

The moderate growth scenario assumes that a combination of increased usage of Lake DeSmet storage plus one or two small storage projects would increase stored irrigation water use by an average of 15,000 acre-feet in a normal year. The equivalent increase in consumptive irrigation water use would be approximately 6,000 ace-feet annually. This scenario also assumes that Basin-wide irrigation efficiency would increase by one percent as a result of financial incentives, adding another 4,600 acre-feet to consumptive irrigation water use in a normal year. As a result, total surface irrigation water use would increase from 183,800 acre-feet under current conditions to 194,400 acre-feet in a normal year.

High Growth Scenario

The high growth scenario is based not only upon the reasonably foreseeable possibility that cattle prices will increase over the planning horizon, but that reductions in forage production in high

growth areas of the west will drive forage prices high enough to encourage Basin irrigators to produce more alfalfa and Timothy hay.

If forage prices stabilize at higher levels and WWDC funding is increased in the future, additional storage could be developed in the Basin to support increased forage production. The amount of additional storage that would be developed and the amount of additional water that would be consumptively used under this scenario are difficult to estimate because the outcome depends not only upon future financial returns to forage and beef production, but also upon the cost of developing additional storage in those areas where unappropriated water is available.

The water use projection developed for this scenario is that the increase in surface irrigation water under high growth conditions will be double the amount of the increase projected for the moderate growth scenario. That means that the amount of irrigation water consumptively used in a normal year will increase by 21,200 acre-feet annually relative to the low growth scenario. That increase would bring average annual consumptive use by Basin irrigators to 205,000 acre-feet annually. Projected future irrigation water use for all scenarios is depicted in Figure IV-3.

B. Municipal and Domestic Demand Projections

Municipal and domestic use projections were created by combining current use rates with population projections for the Tongue/Powder River Basin. Current municipal and domestic consumption is described in Chapter II.

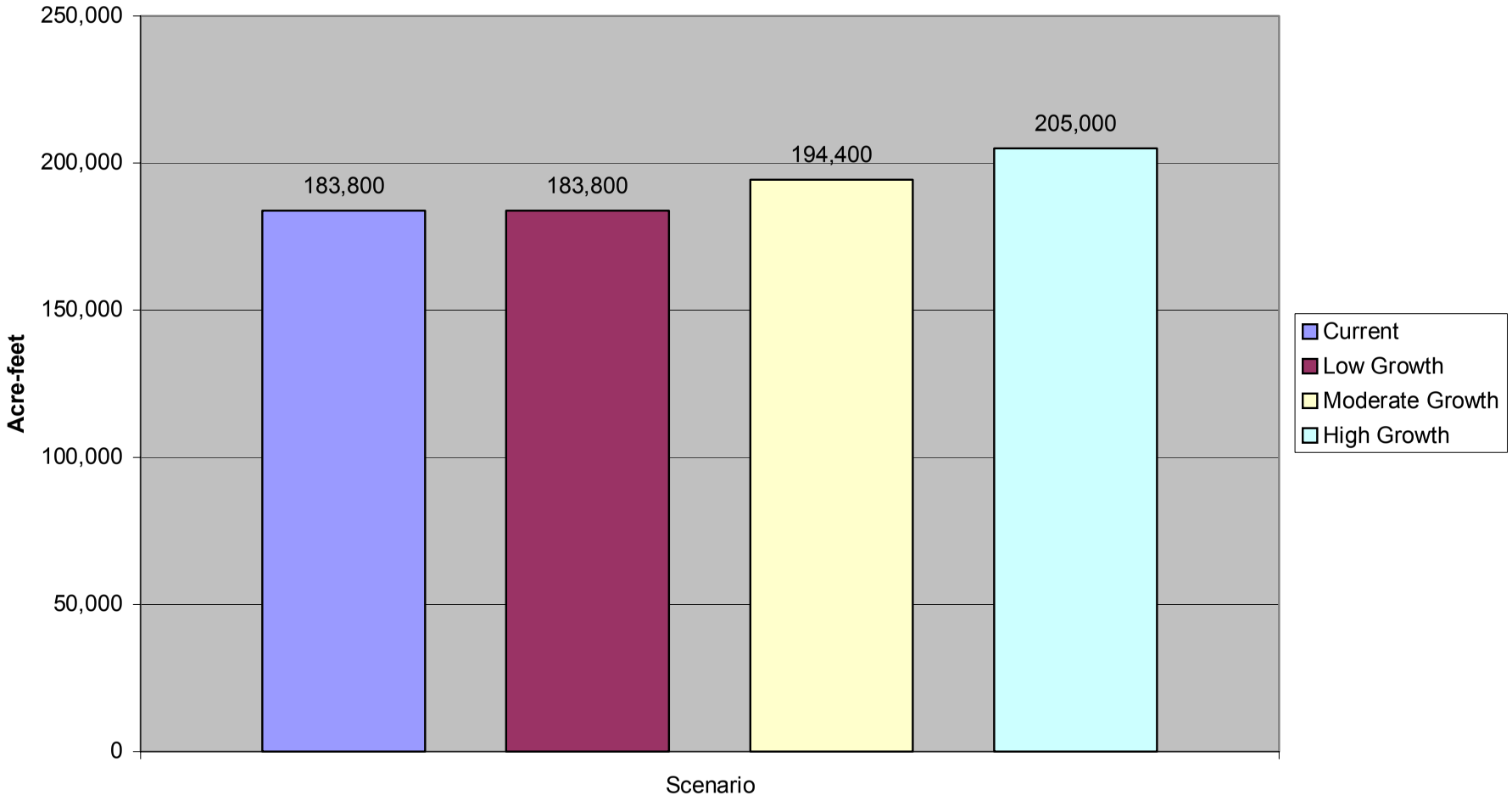
Population Projections

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 Population Estimates

The first step in developing population projections for the planning area was to estimate its current population. Population estimates for cities and towns were taken from the results of the 2000 Census. Because the geographical boundaries of the planning area do not adhere to county lines, it was necessary to adjust the county population estimates

Figure IV-3
Summary of Consumptive Irrigation Water Use Projections
2000-2030



from the 2000 Census to reflect only the proportion of each county that lies within the planning area boundaries. After this adjustment, the total current population of the Powder/Tongue River Basin is estimated to be approximately 38,400 persons.

The geographical distribution of the Basin's current population by county is depicted in Figure IV-4. That figure shows that almost 70 percent of the Basin's population resides in Sheridan County. Johnson County accounts for about 18 percent of the Basin's population, while Campbell and Natrona Counties each account for about six percent of the total.

WDAI Population Projections

The Division of Economic Analysis of the Wyoming Department of Administration and Information (WDAI) produces population forecasts for Wyoming counties, cities, and towns. The county population forecasts are based upon time series data from which growth rates are derived from variables such as population, sales tax collections, and school enrollments. These growth rates are used to forecast individual county population totals, and these county totals are adjusted to make them, consistent with state-level population forecasts that incorporate elements of the cohort survival and employment-drive approaches.

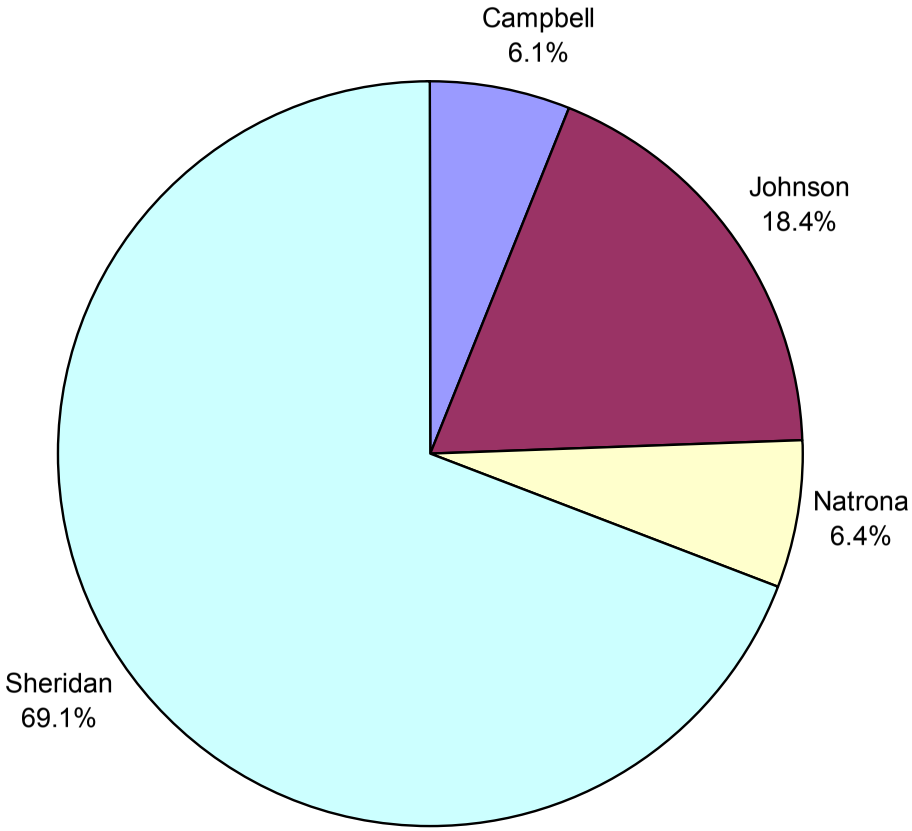
The Division of Economic Analysis forecasts population only 10 or fewer years into the future because of the uncertainties associated with such projections. Its most recent projections are through the year 2008 and are relatively conservative, a reflection of the relatively slow economic growth that many parts of the state have witnessed in recent years. A reasonable set of low growth rate population projections can be derived by computing the WDAI's average annual population growth rates for the planning area for the period from 1990 through 2008 and extending those growth rates through the year 2030.

U.S. Census Bureau (USCB) Projections

The USCB periodically produces population forecasts for each of the 50 states using a cohort survival approach. The most recent forecasts for the State of Wyoming are two sets of population projections through the year 2025, 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 effects of this migration pattern are apparent in parts of the Powder/Tongue River Basin. The USCB projections are based upon the assumption that this moderate rate of net in-migration will continue into the future.

Figure IV-4
Distribution of Current Population



Historical Growth Projections

A third set of population projections was developed from an analysis of historical population growth. The planning area experienced more rapid population growth during the 1990s than it experienced during the preceding 30-year period from 1960 through 1990. A reasonable set of high growth population projections can be developed by assuming that the absolute population growth that occurred during the 1990s will occur in each of the three following decades through the year 2030. Projecting this level of population growth into the future for each community and rural area in the Basin is the equivalent of assuming that the stimuli that lead to population grow in the 1990s, namely CBM development and lifestyle related in-migration, will continue to have the same population growth effects for the foreseeable future.

Results

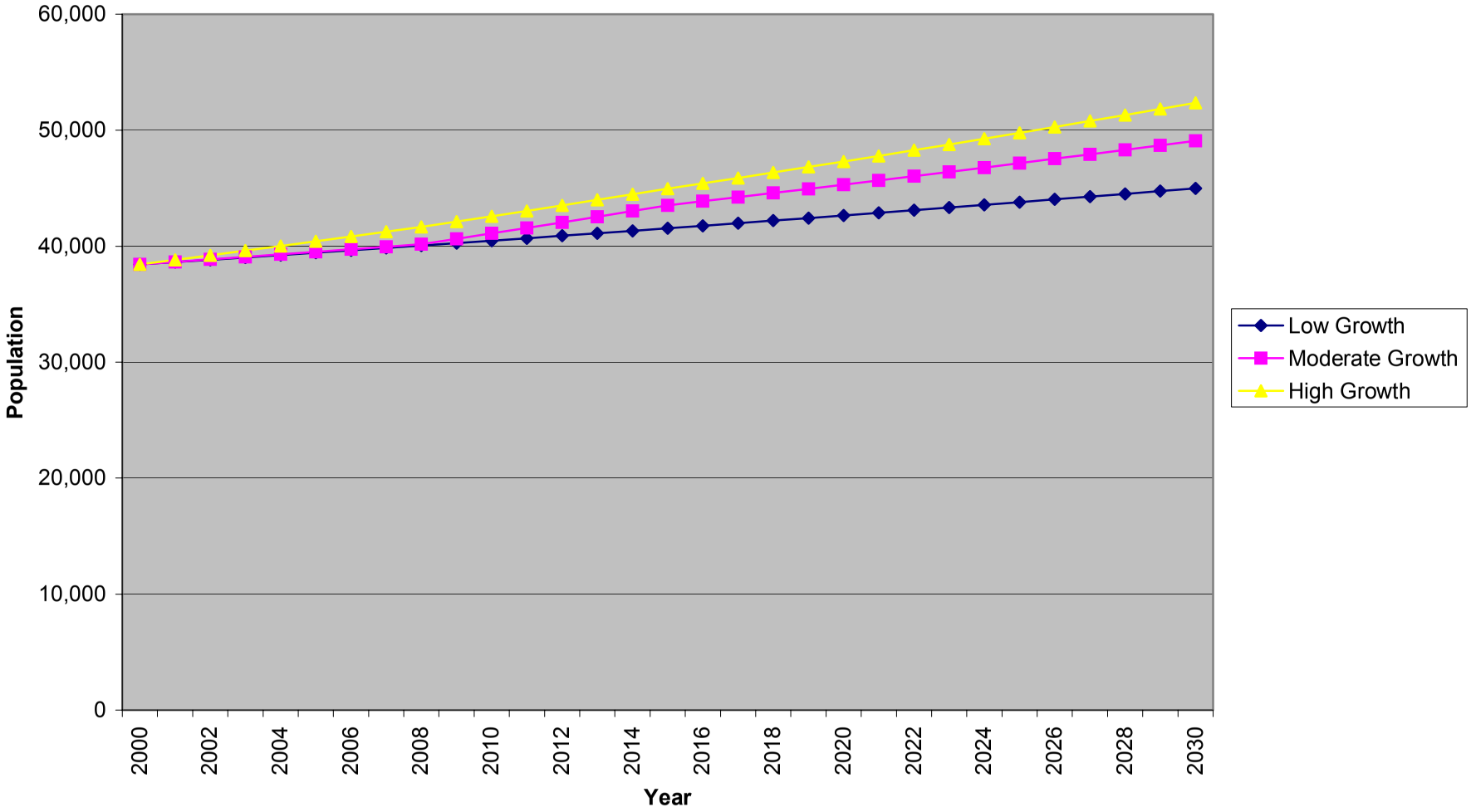
The three methods described above were used to generate population forecasts through the year 2030 for each community and rural areas. Generally speaking, the WDAI extended forecasts resulted in the smallest population projections, followed by the U.S. Census Bureau projections and the historical growth projections in that order. There were some exceptions to this generality, however, primarily because some communities have experienced population declines that were projected to continue over the next 30 years in the historical growth scenario. In some cases, these communities were projected to have higher growth rates (or less severe population declines) in one of the other two scenarios.

To adjust for such anomalies, the high growth scenario for each community and rural area was defined as the largest population forecast for 2030 generated by any of the three methods. Similarly, the low growth scenario was defined as the lowest population forecast, and the moderate growth scenario was defined as the middle 2030 population forecast. The results of the low, moderate, and high growth projections for the entire planning area are presented graphically in Figure IV-5.

Municipal Use Projections

Current per capita use rates for municipal water consumption are presented in Chapter II. These rates were applied to population projections for incorporated cities and towns in the planning area to estimate future municipal use. It should be noted that Chapter II describes municipal systems for some small-unincorporated areas for which population projections are not available. For purposes of projecting future use, these unincorporated areas are included in the domestic demand projections presented in the next section.

Figure IV-5
Low, Moderate, and High Growth Population Projections



Projections of future municipal use are presented in Table IV-1. That table shows that the four communities utilizing surface water supplies; Buffalo, Dayton, Ranchester, and Sheridan are projected to need between 8,600 and 10,000 acre-feet of water annually by the year 2030. The two communities relying on groundwater supplies, Clearmont and Kaycee, are projected to need between about 65 and 90 acre-feet annually by the year 2030. Two other communities, Edgerton and Midwest, are not included in the projections because they obtain their water supplies from a regional water system in Casper, and thus do not place demands upon water resources in the Powder/Tongue River Basin. The projections of municipal use for surface water users in Table IV-1 are diversion requirements, not consumptive use estimates. Consumptive use for the four communities using surface water is defined as the difference between diversions and returns to the stream from water treatment plants. As noted in Chapter II, total surface water depletions by municipalities in the Basin are estimated to be about 2,700 acre-feet annually. Projections of annual depletions for the low, moderate, and high growth scenarios are 3,200, 3,500, and 3,800.

In some cases there is a small difference between the populations shown for municipalities in the Population Projections technical memorandum and the population figures presented in Table IV-1. This difference is due to the fact that the population figures in Table IV-1 represent "service area" populations, whereas the population estimates in the technical memorandum adhere strictly to municipal boundaries.

An assessment was made of whether municipal systems for the communities listed in Table IV-1 have the capacity to supply their projected future water needs. This assessment involved comparing the peak demands associated with the projections with capacity of existing systems to meet those peak demands. The results indicate that all of the municipal systems listed in Tables IV-1 except Kaycee's have the capacity to meet all future projected needs. Kaycee's system capacity would be exceeded only under the high growth population projection scenario. It should be noted that this finding applies only to system capacity, not water availability. Some communities using surface water supplies, such as Sheridan, may need to acquire additional water rights to meet projected future needs.

Domestic Use Projections

Domestic use projections were developed by first calculating the number of persons in the planning area that are not served by the municipal systems listed in Table IV-1 and projecting that population figure into the future. (This calculation excluded the populations of Edgerton and Midwest, which are served by an out-of-basin water source.) Per capita domestic water consumption rates were then applied to the population projections to estimate future water use. The results are presented in Table IV-2 for two different daily per capita water consumption rates and three growth scenarios. The results show that current domestic use is estimated to be between 2,400 and 4,800 acre-feet per year. Future use projections range from a low of 2,800 acre-feet to a high of 6,400 acre-feet annually, depending upon the scenario. This water is expected to come from ground water sources.

Table IV-1
Municipal Use Projections

City/Town	Current	Current	2030 Population Projections			2030 Use (gpd)			2030 Use (acre-feet/yr)		
Surface Water Users	Population	Use(gpcpd)	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Buffalo	3,900	325	4,808	5,086	5,763	1,562,600	1,652,855	1,872,912	1,750	1,851	2,098
Dayton	678	234	792	868	936	185,328	203,175	218,979	208	228	245
Ranchester	701	300	776	800	891	232,800	239,906	267,200	261	269	299
Sheridan	18,500	260	21,809	23,762	25,158	5,670,407	6,178,068	6,541,162	6,352	6,920	7,327
Total	23,779		28,185	30,515	32,748	7,651,135	8,274,003	8,900,253	8,570	9,268	9,970
Groundwater Users											
Clearmont	125	220	112	139	158	24,630	30,609	34,674	28	34	39
Kaycee	300	210	275	333	377	57,687	69,831	79,193	65	78	89
Total	425		387	472	535	82,317	100,440	113,867	92	113	128
Grand Total	24,204		28,572	30,987	33,282	7,733,452	8,374,443	9,014,120	8,663	9,381	10,097

Table IV-2
Domestic Use Projections

Description	Current	Low Growth	Moderate Growth	High Growth
Basin Population	38,436	44,994	49,096	52,379
Municipal Population	24,204	28,629	31,008	33,353
Rural Population	14,232	16,365	18,088	19,026
Domestic Use (150 GPCD-in af/yr)	2,391	2,750	3,039	3,197
Domestic Use (300 GPCD-in af/yr)	4,783	5,499	6,078	6,394

C. Industrial Demand Projections

Current industrial water uses in the Powder/Tongue River Basin are described in Chapter II. This section presents projections of industrial water needs in the Basin for the period from 2000 through 2030. These projections provide a basis for gauging the adequacy of current water supplies in the Basin to meet potential future needs. Projections were developed for low, moderate, and high growth scenarios.

Coal-fired Electric Power Production

Currently there are no coal-fired electric generating facilities in the Powder/Tongue River Basin. The Basin has coal and water resources to support such a facility, however, and the area has been studied in the past as a possible site for power generation. The Lake DeSmet Energy Company is actively pursuing a developer to use its coal reserves and water rights for power production, but no firm proposals have been submitted to date. The company has vast coal reserves in the vicinity of Lake DeSmet, and has storage rights for 62,000 acre-feet in Lake DeSmet and 5,140 acre-feet of storage in Healy Reservoir that could be used for power production.

There could be an air quality constraint involved in locating a generating facility in the planning area due to its proximity to wilderness areas in the Bighorn National Forest. Whether this constraint would be a fatal flaw depends upon a number of factors that are matters of speculation at this time, including the plant's design and location and the results of air quality modeling that would have to be undertaken for permitting purposes. The area does have the advantage of existing storage rights in Lake DeSmet that could be used to support wet cooling technology for power production, which is in use at other facilities in the state, including the Laramie River Station in Platte County and the Jim Bridger Power Plant in Sweetwater County. Wet-cooled plants are usually more efficient and less costly to run than dry-cooled plants such as the Wyodak facilities near Gillette, but their water requirements are much larger.

Another potential source of water for power production is low-cost groundwater from coal-bed methane (CBM) production. The process of extracting methane gas from coal seams produces large quantities of water that must be disposed of in some fashion, and use of that water for wet cooling in electric power production would be a logical way to make use of water that would otherwise be re-injected into aquifers, stored in small reservoirs, or discharged into streams.

There are problems with implementing such a proposal, however. One problem is the fact that although the production life of coal-bed methane resources in the Basin is not known with certainty, resources may be depleted in a shorter time frame than the 50-plus year life expectancy of a coal-fired generating facility. Also, that water production from coal seams tends to peak when the seam is first tapped, and then drop off dramatically as methane production increases, meaning that there is a great variation in the amount of water produced at one location over time.

Projections of future water needs for electric power generation are described below for low, moderate, and high growth scenarios. These projections are based upon the assumptions of wet cooling technology and surface water utilization.

Low Growth Scenario

The low growth scenario assumes that no electric power generating facilities will be built in the planning area over the next 30 years. This scenario is equivalent to assuming that (1) the competitive advantage that other areas have held in power production in the past will continue in the future, or (2) air quality constraints will be too restrictive to site a facility in a desirable location.

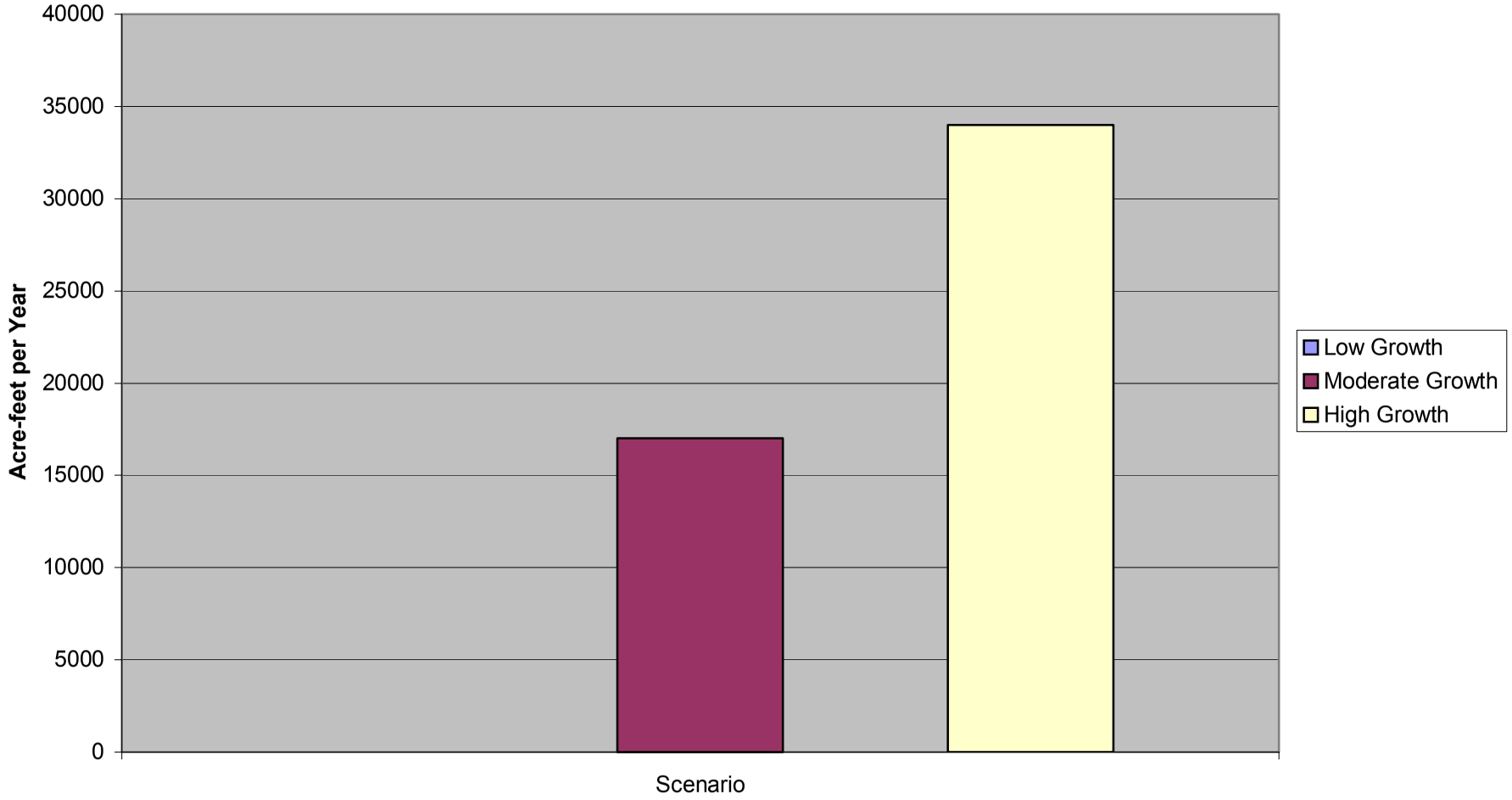
Moderate Growth Scenario

The moderate growth scenario for electric power production assumes that air quality constraints on power generation can be overcome and that the availability of coal and the water resources needed for wet cooling technology will be attractive enough for a power generator to build a 1000 megawatt (MW) facility in the PTRB sometime during the nest three decades. The industrial water requirements for this scenario are 17,000 acre-feet annually.

High Growth Scenario

The storage rights available in Lake DeSmet should be large enough to support 2000MW of coal-fired electric power generation using wet cooling technology. The high growth scenario for electric power production thus assumes the relatively low cost water available for power production in Lake DeSmet will be used to generate 2000MW of power sometime during the next 30 years. The industrial water requirements for this scenario are 34,000 acre-feet annually. Future electric power generation water use projections for all three growth scenarios are presented graphically in Figure IV-6.

Figure IV-6
Electric Power Water Demand Projections
2030



Coal Mining

Most of the active coal mines in northeastern Wyoming are located in the Belle Fourche and Cheyenne River Basins to the west of the Powder River. The one large active surface coal mine in the planning area is the Spring Creek Mine Operated by Kennecott Energy in northern Sheridan County. This mine produces approximately 11.3 million tons of coal annually, or about three percent of the 338 million tons of coal that were mined in Wyoming in 2000.

Surface coal mines use water primarily for dust abatement and reclamation, with lesser amounts used for equipment wash-down and domestic 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.

Future water use by the coal industry in the Powder/Tongue River Basin is expected to increase slightly for two reasons. First, the Spring Creek Mine may expand production in the future if coal prices remain firm at current levels or increase. Second, some additional mines may be opened in the future to supply coal for electric generating facilities either in or out of the Basin. Nevertheless, most mines will continue to meet their relatively small operational water needs from groundwater sources on site. These activities are not expected to affect either surface water resources or other groundwater users in the Basin. Thus, water requirements for the mining industry have not been projected into the future.

Oil and Natural Gas Production

Traditional oil and gas production in the Powder/Tongue River Basin has been declining in recent years. According to the Bureau of Land Management, the number of wells plugged is expected to exceed the number of wells drilled each year for the foreseeable future. This trend will be offset by an increase in CBM production as discussed in the following section.

Very little water is consumptively used by the oil and gas industry in the planning area; only small amounts are consumed for domestic purposes and to create drilling mud. Pumping operations generally produce water as a by-product of oil and gas production. This process water can be re-injected or discharged (with appropriate permits) depending upon circumstances. Water flooding operations are sometimes carried out on mature fields to increase production. In such cases, water wells can be drilled to provide flooding water. There are about 240 such wells in the Powder/Tongue and Northeast Wyoming River Basins combined.

In summary, water use by the oil and gas industry is generally non-consumptive, is spread over a large geographic area, and typically does not impact either surface water

resources or other groundwater users in the planning area. For these reasons, future requirements for this industry have not been quantified.

Coal-bed Methane Production

Coal-bed methane production has become widespread in Powder/Tongue River Basin over the past few years, and is expected to increase dramatically 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 presents both problems and opportunities in the formulation of a water plan for the Basin.

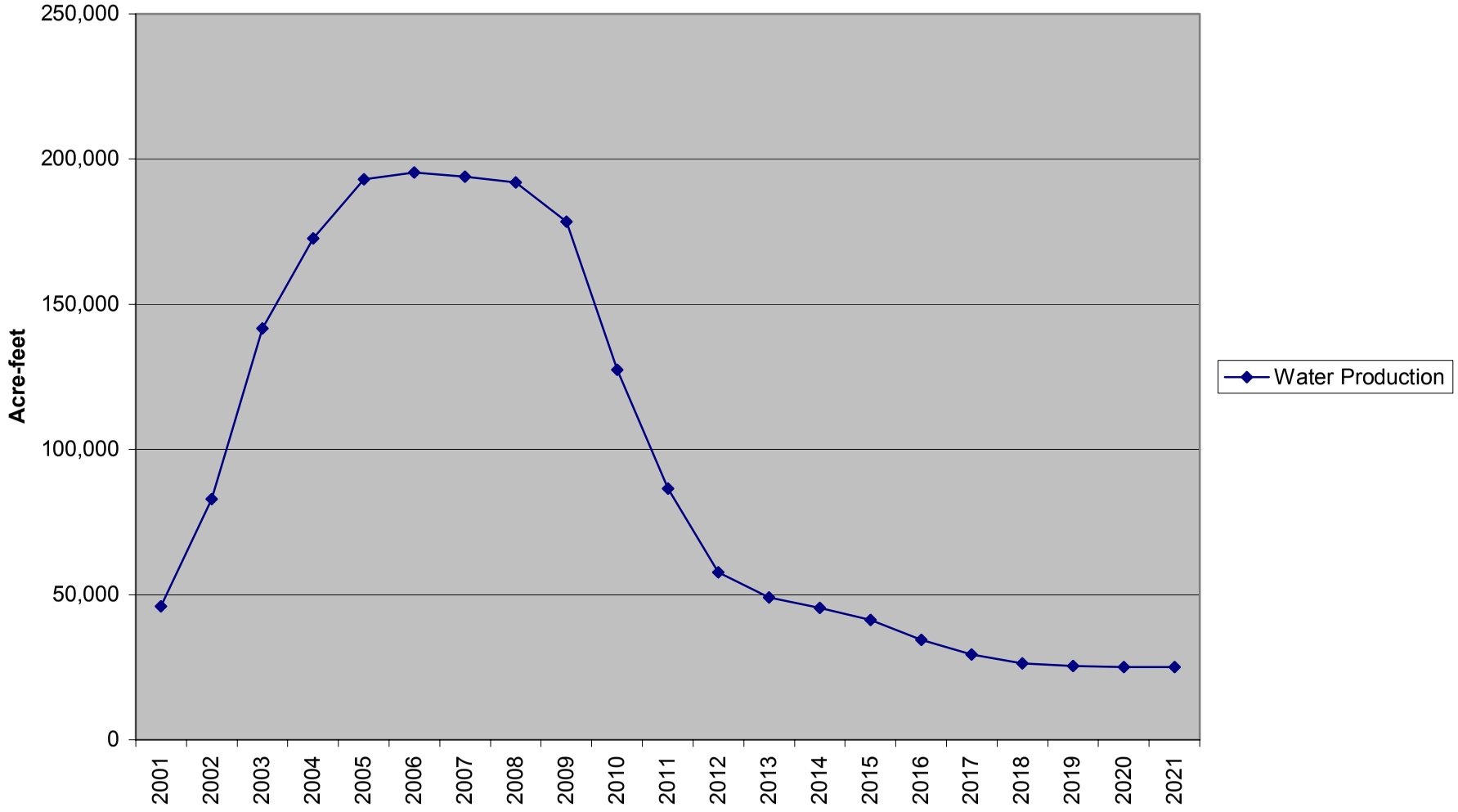
Projected water production for Powder/Tongue River Basin CBM wells is depicted in Figure IV-7 for the period from 2001 through 2020. That figure shows that produced water is expected to reach a peak of about 190,000 acre-feet annually by the year 2005. Production is expected to remain at that level for about five years, and then drop off to less than 25,000 acre-feet annually by the year 2019. The projected dramatic drop off in CBM production water after the year 2010 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 will be available for only a relatively short period.

Coal Conversion Facilities

Several companies have studied the possibility of building coal conversion facilities in the 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 mean 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.

If coal conversion facilities were constructed in Wyoming during the next 30 years, they would more likely be sited in the Belle Fourche River Basin than in the Powder/Tongue River Basin because there are more active coalmines in the Belle Fourche Basin. Nevertheless, it is not improbable that some type of coal conversion facility might be sited in the Powder/Tongue River Basin over the planning horizon of this study. One reason is that as energy related industrial activity increases in the Belle Fourche River Basin, some activity may be forced to other locations for air quality considerations. For that reason, the high growth scenario for industrial water use assumes that one coal conversion facility designed to produce solid boiler fuel from coal will be constructed in the planning area by the year 2030. The water requirements for such a facility would be approximately 1,000 acre-feet annually.

Figure IV-7
Projected Annual CBM Water Production



Other Potential Future Uses

The industrial water use projections described above focus on existing industrial uses or those that have been proposed but not implemented in the past. The potential for other water-intensive industries, not discussed above, to relocate to the Powder/Tongue River Basin over the next 30 years also warrants discussion.

According to the U.S. Department of Commerce, four industry groups in the United States account for over 95 percent of all industrial water use. Those industries are (1) electric power producers, (2) chemical and allied products manufacturers, (3) primary metals producers, and (4) paper and allied products manufacturers. Electric power producers alone account for over 80 percent of all industrial water use in this country each year. The other three industrial groups account for roughly 14 percent of all industrial water use.

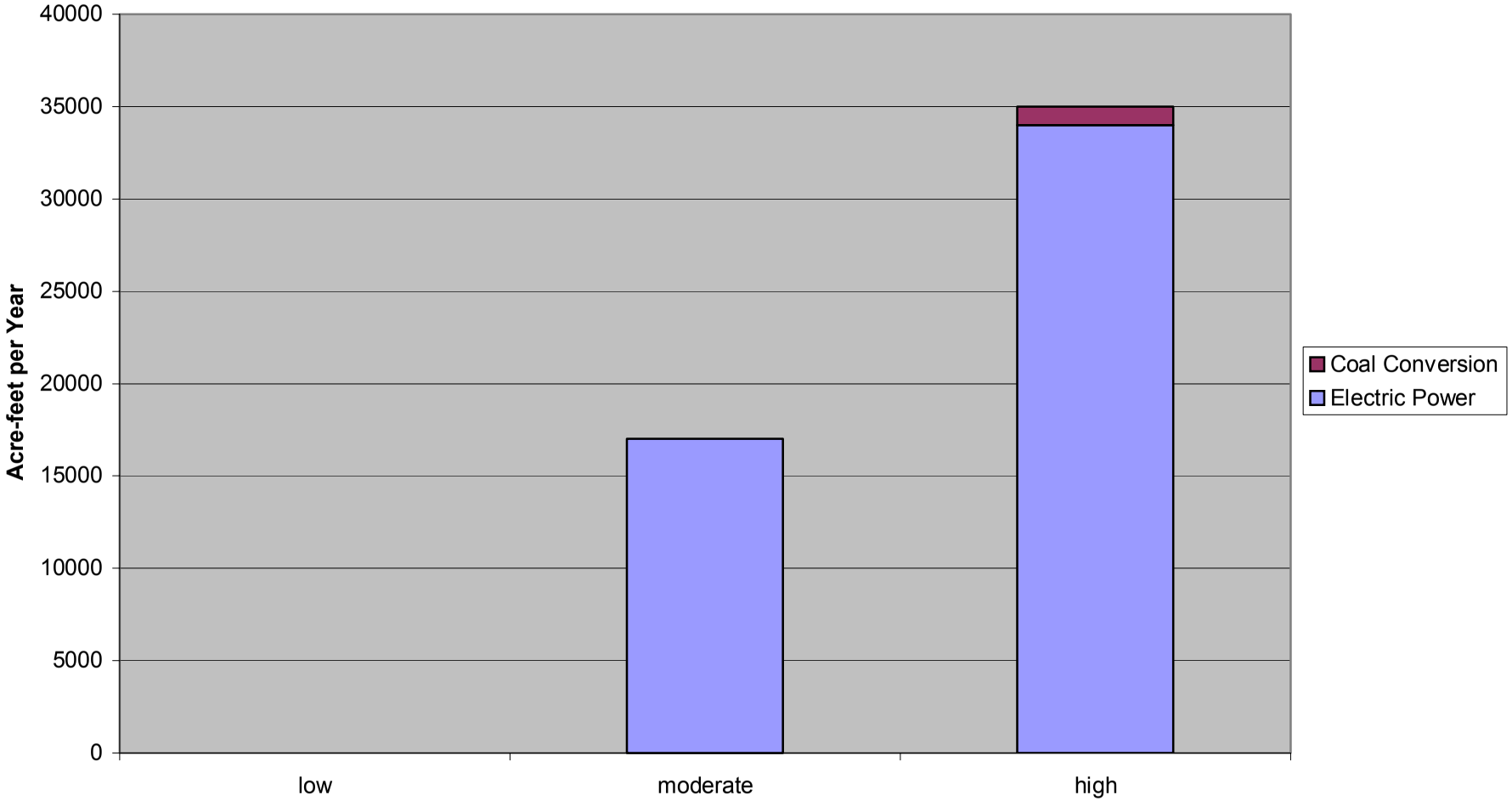
Projections of future water requirements for electric power generators are discussed above. The other three water intensive industries, chemicals, primary metals, and paper, tend to locate in areas close to their primary inputs. The fact that none have located in the Powder/Tongue River Basin in the past is an indication that commercially viable resources needed for their manufacturing operations are not present on a competitive basis compared to other regions of the country. Although this situation could change in the future as resources are exhausted elsewhere, such developments are not foreseeable at this time.

Summary of Findings

The largest demand for industrial water in the Powder/Tongue River Basin over the next 30 years is expected to be associated with the construction of new coal-fired electric generating facilities. A smaller amount of water will be needed for facilities that convert coal to alternative fuels. The most likely source of water for such facilities is storage in Lake DeSmet. That storage is owned by the Lake DeSmet Energy Company and by the joint powers board that is now operating the reservoir on behalf of Campbell, Johnson, and Sheridan Counties.

Projections of total future industrial water use in the planning area are given in Figure IV-8. That figure shows that for the low growth scenario, no additional industrial water use is projected beyond the small (unquantified) amounts employed in coal mining and oil and gas activity. For the moderate growth scenario, a projected 17,000 acre-feet would be utilized annually for wet cooling of a 1000MW coal-fired electric generating facility. For the high growth scenario, 34,000 acre-feet annually would be used for power generation and an additional 1,000 acre-feet would be utilized in a coal conversion facility, bringing total water requirements to 35,000 acre-feet annually.

Figure IV-8
Total Industrial Water Demand Projections
2030



D. Recreation Demand Projections

Current Recreation Activity

The most popular water-based recreational activity in the Powder/Tongue River Basin is fishing. Figure IV-9 shows that about 53 percent of Basin residents participate in fishing. The second most popular water-based recreational activity among residents is waterfowl hunting, followed by power boating, rafting and canoeing, and sailing.

The WGFD provided estimates of the number of annual activity days of angling and waterfowl hunting in the Powder/Tongue River Basin. Stillwater fishing on lakes and reservoirs in the Basin accounts for 132,000 activity days annually. About one-third of this activity occurs on Lake DeSmet. Much of the remaining stillwater fishing activity occurs on alpine lakes and reservoirs, which are concentrated on national forest lands.

Stream fishing in the Basin accounts for about 140,000 activity days annually. The upper reaches of many of the streams in the Basin provide very good trout fishing opportunities. The most popular areas for stream fishing in the Basin include the Tongue River, Clear Creek, the Powder River, and Crazy Women Creek.

Waterfowl hunters spend about 2,000 days annually in the pursuit of ducks and geese that inhabit or pass through the Basin. Activity day estimates are not available for other water-based recreational pursuits, including boating, water skiing, rafting, canoeing, sailing, and wind surfing.

Demand Projections

Future demands for recreational water resources in the planning area 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 horizon. This assumption means that projected recreational demands are proportional to growth in population and tourism in the Basin. The potential effects of congestion on future recreational water uses are discussed in the following section.

Projections of population growth in the Powder/Tongue River Basin are described earlier in this chapter. Those projections are summarized in Table IV-3 in terms of average annual growth rates for the low, moderate, and high growth planning scenarios. Table IV-3 also gives projections of tourism growth over the planning horizon for low, moderate, and high growth scenarios.

Figure IV-9
Resident Participation in Water-based Recreational Activities

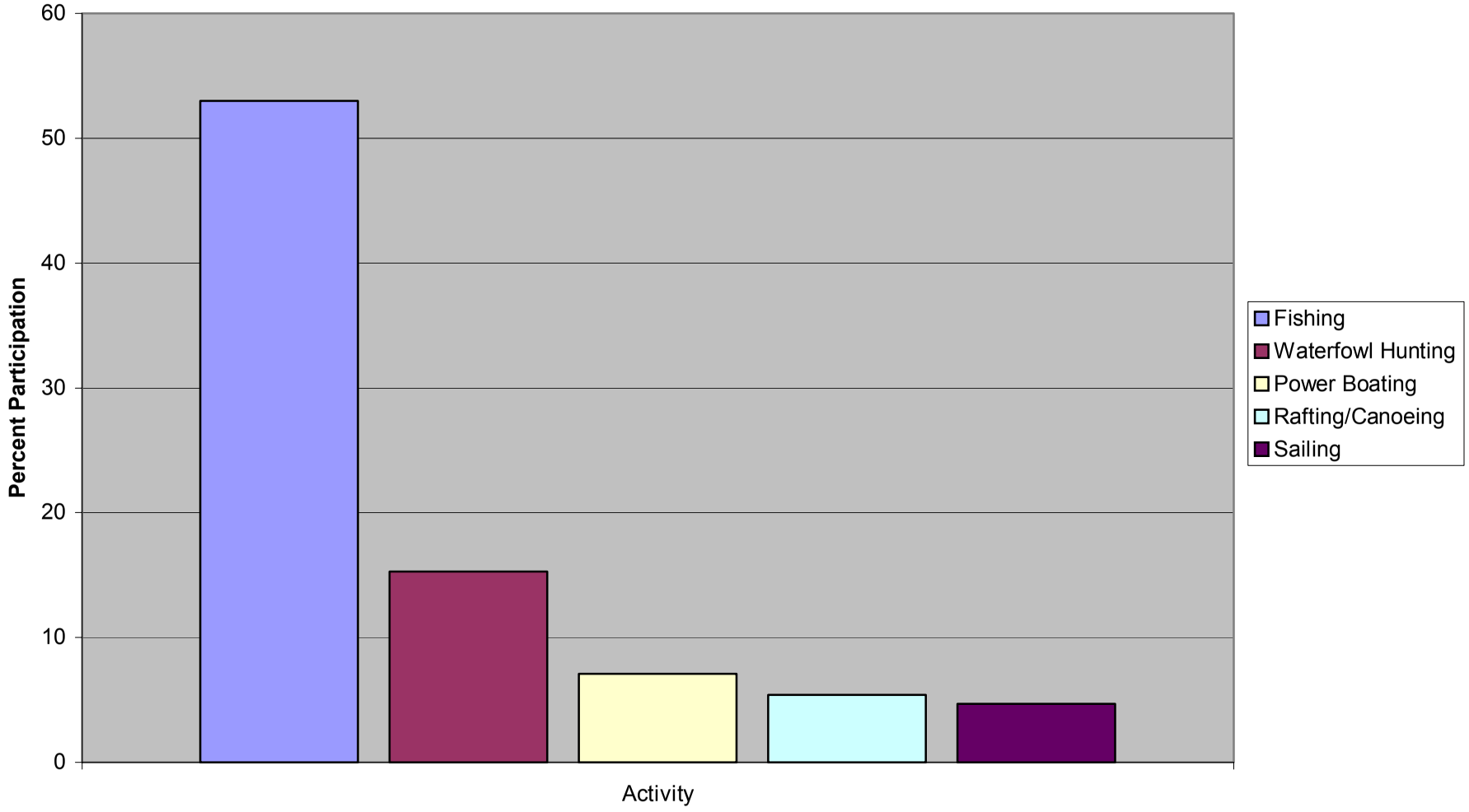


Table IV-3
Projected Annual Growth Rates: Population and Tourism (2000-2030)

Scenario	Average Annual Growth Rate	
	Population	Tourism
Low growth	0.53	1.00
Moderate growth	0.82	2.00
High growth	1.04	3.00

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 non-residents.

This information was used to project future recreational activity days over the 30-year planning horizon from 2000 to 2030. Those projections are given in Table IV-4. The demand for stillwater fishing in the planning area 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 over the planning horizon, but at a lesser growth rate than for fishing.

Table IV-4
Current and Projected Water-based Recreational Activity Days

Activity	Activity Days by Scenario			
	Current	Low Growth	Moderate Growth	High Growth
Stillwater fishing	132,000	159,000	183,000	208,000
Stream fishing	140,000	169,000	194,000	221,000
Waterfowl Hunting	2,000	2,300	2,500	2,700
Totals	274,000	330,300	379,500	431,700

Adequacy of Existing Resources to Meet Projected Demands

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 that the Department believed at that time (1988) 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 the Powder/Tongue River Basin, but for an area including the Powder/Tongue, Little Missouri, Belle Fourche, Cheyenne, and Niobrara 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 angling opportunities. Individual water may experience overcrowding at times, however, because they are easily accessible.

The projections of future demands for fishing opportunities described above range from 328,000 to 429,000 activity days annually by the year 2030, depending upon the growth scenario used. These demand scenarios indicate that fishing pressure demands may approach the supply of resources available in the Powder Tongue River Basin 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 Basin 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.

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 through 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 ride from a current level of 2,000 activity days to between 2,300 and 2,700 activity days by the year 2030. The WGFD has not estimated the supply of waterfowl hunting opportunities in the Basin, 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.

E. Future Environmental Water Requirements

Current environmental uses of water in the Powder/Tongue River Basin are described in Chapter II. Those uses include:

- instream flows and reservoir bypasses;
- minimum reservoir pools; and
- maintenance of wetlands, riparian habitat, and other wildlife habitat.

Unlike recreational water requirements, 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 in the Powder/Tongue River Basin 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.

Examples of such legislation include Wyoming Statutes S41-3-1001 to 1014, which stipulate that instream flows are a beneficial use of Wyoming's water and specify procedures for establishing such flows using unappropriated water. This legislation authorizes the WGFD to specify stream segments and flow requirements for an instream flow filing. The WWDC is authorized to file an instream flow application with the State Engineer and perform hydrologic analyses on filings recommended by the WGFD. The State Engineer can then issue a permit for an instream flow water right following a public hearing.

Future water requirements for instream flows in the Powder/Tongue River Basin (and other river basins throughout the state) depend largely upon how Wyoming's instream flow legislation is implemented over the 30-year planning horizon. Projecting the outcome of this process quantitatively would be difficult, and is perhaps unnecessary because instream flows and other environmental water uses are largely non-consumptive. Instream flow designations can conflict with potential new out-of-stream uses at specific locations, however, a topic that is discussed below.

Instream Flows and Reservoir Bypasses

Wyoming's instream flow statutes recognize the obvious economic fact that Powder/Tongue River Basin water resources have value in non-consumptive uses such as instream flows. Such flows not only contribute to aesthetic character and biological diversity of the Powder/Tongue River Basin, they also support recreational fisheries that are important to Basin residents and to the Basin's economy.

The WGFD has a goal of maintaining and enhancing existing fisheries in the Powder/Tongue River Basin through the statutory designation of instream flow segments and other management strategies. To date, a total of three applications involving six stream segments in the Little Bighorn, Tongue, and Powder River Drainages have been filed with the State Engineer. The extent to which current filings and future instream flow requests may conflict with potential storage developments for supplemental irrigation water in the Basin 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 of water to the state in instream versus out-of stream uses.

Another tool for maintaining fisheries habitat in the planning area is the provision of minimum flow bypasses at reservoir sites. Currently, only three reservoirs in the Basin have minimum flow bypasses included as requirements in their permitting documents; Park, Tie Hack, and Twin Lake Reservoirs. 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.

Minimum Reservoir Pools

Another environmental water use is the provision of minimum reservoir pools for fish and wildlife purposes. Six reservoirs in the Basin have minimum pools listed in their permitting documents; Park, Dull Knife, Willow Park, Kearney, Cloud Peak, and Tie Hack. Given the current federal regulatory environment and public desires to maintain and enhance recreational fisheries in the 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.

Wildlife Habitat

Another important environmental use of water in the Powder/Tongue River Basin is the provision of habitat for wildlife. Wildlife habitat exists in wetland and riparian areas on public and private lands through out the Basin, 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 area 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 a separate technical memorandum.

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 program 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 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.

Direct Wildlife Consumption

There are no current estimates of consumptive water use by wildlife for the Powder/Tongue River Basin. 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. A similar figure would be roughly correct for the Powder/Tongue River Basin. This level of consumptive use is relatively small and is not expected to change significantly over the planning horizon.

F. Summary of Projected Surface Water Demands

Table IV-5 summarizes current surface water uses in the planning area and projected demands for surface water resources through the year 2030 for the three growth scenarios.

Table IV-5
Summary of Current and Projected Surface Water Uses

Use	Current	Projected Use by Growth Scenario (Acre-feet/Yr.)		
		Low	Moderate	High
Municipal	2,700	3,200	3,500	3,800
Industrial	(included in municipal)	(included in municipal)	17,000	35,000
Irrigation	184,000	184,000	194,000	205,000
Evaporation	11,300	11,300	11,300	11,300
Recreational	(non-consumptive)			
Environmental	(not estimated)			
Total	**198,000**	**198,500**	**225,800**	**255,100**

G. Future Uses as Related to Compact Allocation

A comparison of projected surface water demands with water available under the Yellowstone River Compact is presented in Table IV-6. The comparison is broken down into the Tongue and Powder River sub-Basins because different compact limitations apply in each sub-basin. The Little Bighorn sub-Basin is not included in the projections because the compact does not cover it.

Table IV-6
Projected Use of Compact Allocation (Normal Year)

Surface Water	Projections by Growth Scenario (Acre-feet/Yr.)		
	Low	Moderate	High
Estimated Tongue River Depletions	78,200	81,800	87,400
Wyoming's Remaining Compact Allocation of Tongue River Flows [1]	40,000 to 67,000	40,000 to 67,000	40,000 to 67,000
Estimated Powder River Depletions	112,200	136,800	160,400
Wyoming's Remaining Compact Allocation of Powder River Flows[2]	74,300	49,700	26,100

Notes:

1: These values are based on the limiting dry year conditions and include an assumed demand for 18,702 acre-feet of water for the State of Wyoming to supplement the supply of pre-1950 water rights. The total projected increase in depletions (87,400-78,200) is within the limits of this assumption. The remaining allocation is therefore not reduced under the moderate and high growth scenarios assuming the expanded depletions occur under pre-1950 water rights.

2. These values are based on the limiting dry year conditions.

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V Future Water Use Opportunities

A. Introduction

Previous chapters of this report quantify water resources available for development and use and identify present and future water needs in the Powder/Tongue River Basin. This chapter identifies future water use opportunities that can be implemented to satisfy the water demands in the Little Big Horn River, Tongue River, and Powder River Basins in Wyoming. The list of opportunities presented in this report is intended to be used by individuals and organizations that need to develop a water supply to satisfy their specific needs.

To further assist the users of this list to identify potential opportunities to satisfy their demands, a methodology is presented that can be employed to evaluate a specific opportunity on the list relative to similar and related opportunities. The suggested methodology evaluates opportunities according to the likelihood they are desirable, functional, and capable of receiving the support required for development. By using the list of future water use opportunities and employing the evaluation methodology, individuals and organizations will have "a place to start" in their investigation to develop a water supply to satisfy their specific needs.

The procedure used to complete this task consists of the following four steps which are described in this section of the report:

1. Develop screening criteria to evaluate future water use opportunities;
2. Develop a long-list of future water use opportunities;
3. Develop a short-list of opportunities; and,
4. Evaluate the opportunities on the short-list.

Following the discussion of future water use opportunities, legal and institutional constraints that need to be addressed in water management and development are described. The final section of this chapter discusses water quality issues in the planning area.

B. Screening Criteria

A significant component of the river basin planning process is the development of screening criteria and methods for evaluating future water use opportunities identified for the study basins. For the Powder/Tongue River Basin, the screening criteria and evaluation method developed for the Green River Basin Plan were presented to the Basin Advisory Group (BAG) for consideration, modification, and adoption. The criteria adopted by the BAG, and a description of each criterion, is presented below:

Criterion 1: Water Availability

> This criterion reflects the general ability of a project to function, given likely bypasses for environmental uses and prior rights. It is not a reflection of the relative size of the project.

Criterion 2: 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 vs. cultivation of alfalfa or row crops). The intent of this criterion is to indicate the likely ability to afford the project or meet Wyoming Water Development Commission (or other) funding source criteria. A low number represents a project with suspect ability to be repaid, whereas a high number represents a project that should more easily meet funding and repayment requirements.

Criterion 3: 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.

Criterion 4: Number of sponsors/beneficiaries/participants

This criterion reflects the desirability, all other things being equal, that a project serving a larger segment of the population should be evaluated higher (higher number) than one serving only a few (lower number).

Criterion 5: 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.

Criterion 6: Environmental/Recreation 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.

C. Long-List of Future Water Use Opportunities

Compiling the long-list of future water use opportunities began with a review of 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 BAG contributed to the development of the final version of the long-list. The long-list is presented in Table V-1 and on Figure V-1. Additional information on the opportunities is available in the technical memorandum prepared for this topic.

Specific groundwater development projects were not identified and included on the long-list. However, groundwater development was included on the short-list as a generic future water use opportunity for each of the sub-basins and was considered along with the surface water opportunities. Similarly, water conservation was not included on the long-list but was included in the short-list evaluations. Water conservation, resulting from improvements to irrigation practices, provides additional water to satisfy present and projected demands by decreasing the current level of irrigation depletions. This decrease in irrigation depletions can be achieved without reducing the number of acres irrigated by changing the irrigation method from flood to sprinkler and by lining ditches experiencing significant seepage losses.

Groundwater produced in the development of coal bed methane was not included on the long-list of future water use opportunities. Although this resource has the potential to supply small, localized demands over the short-term, the feasibility of developing a significant water supply from this activity is considered to be limited because of the wide geographic dispersion of the wells and the projected short time of operation.

Water right permit applications have been submitted to the State Engineer for many of the projects included on the long-list. Some of the applications have been approved and the State Engineer has granted permits authorizing project development. The majority of the projects, however, have not been elevated to permit status and the applications remain in the pending status.

Water right information was not compiled for the projects nor was water right status considered in the subsequent evaluations of the projects. Each of the projects on the long-list were evaluated under the assumption a water right for the project could be perfected and conflicts with competing water rights could be resolved. Consideration was given to simply compiling the water right status for information only and not for the purpose of evaluation. However, this task proved to be beyond the scope of this river basin planning study and, more important, the information derived from this effort promised to be more confusing than useful.

Another future water use opportunity in the Powder/Tongue River Basin is the establishment of instream flow water rights. These water rights are developed through a specified procedure that begins when the Wyoming Game and Fish Department proposes a stream segment for an instream flow water right. The segment is then studied by the Water Development Commission, and the water right is granted or rejected by the State Engineer. This opportunity is not, however, included on the long-list since the segments that have been proposed are either under investigation, have been granted, or have been rejected. As new segments are nominated they will be advanced through the process.

Table V-1
Long-list of Future Water Use Opportunities

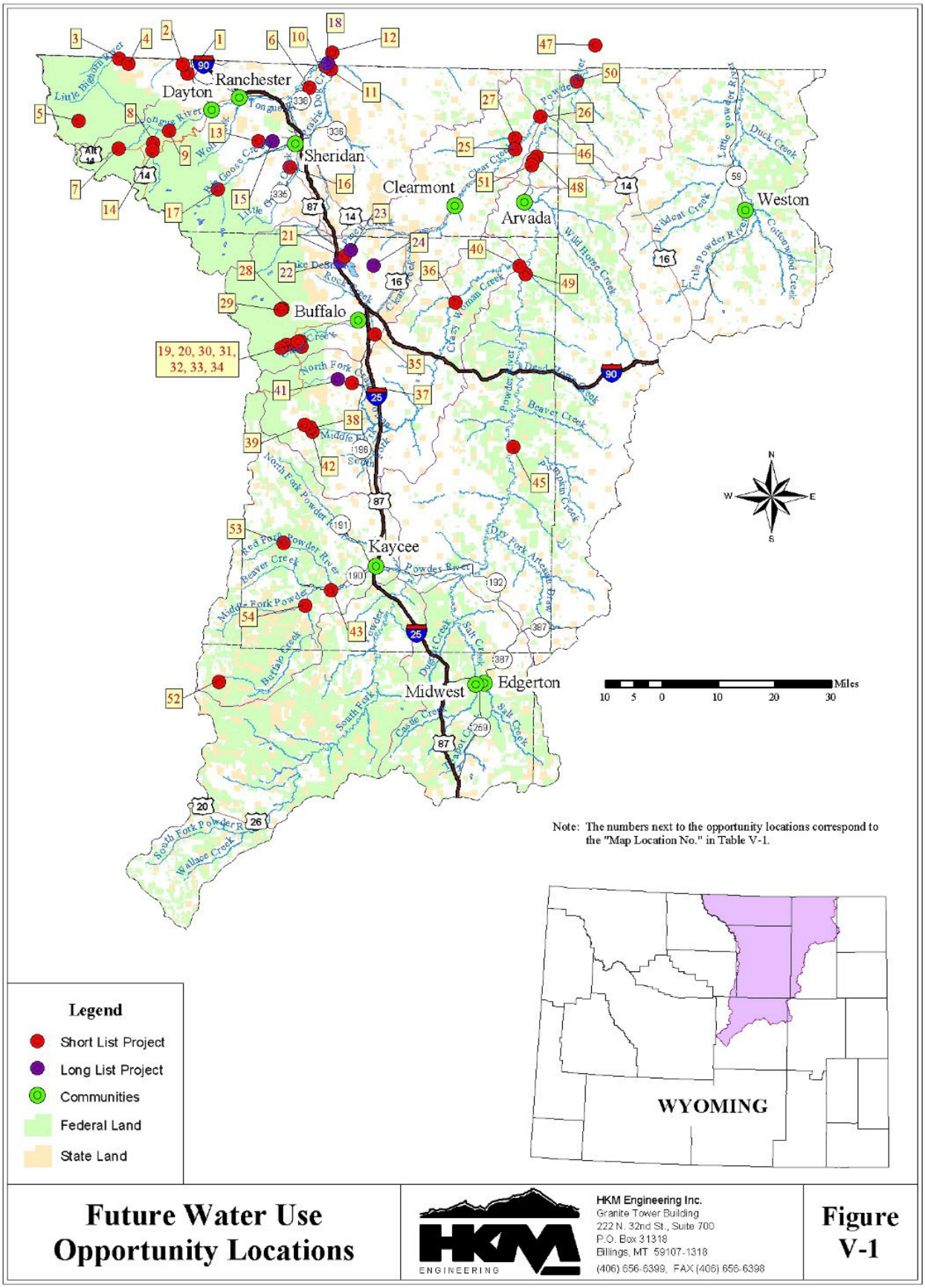
Title	Map Location Number
Little Big Horn River Basin	
Little Big Horn River Export System	1,6
BEPC Sunrise Project	2
Twin Creek Reservoir	2
Fuller No. 1 Reservoir	3
Fuller No. 2 Reservoir	4
Half Ounce Reservoir	5
Tongue River Basin	
North Fork Reservoir	7
South Fork Reservoir	8
Rockwood Reservoir	9
Upper State Line Reservoir	10
Prairie Dog Reservoir	11
Lower State Line Reservoir	12
Sheridan Canal System	13
Shutts Flats Reservoir	14
Alliance Lateral Ditch Rehabilitation *	15
Jones Draw Reservoir	16
West Fork Reservoir	17
WTM Reservoir *	18
Clear Creek Basin	
Little Sour Dough Reservoir	19
Camp Comfort Reservoir	20
Lake DeSmet and Enlargements	21
Reynolds Shell Creek Reservoir *	22
Reynolds Piney Creek Reservoir *	23
Boxelder Reservoir *	24
B.C.L Reservoir	25
Lower Clear Creek Reservoir	26
Tex Ellis Reservoir	27
South Rock Creek Reservoir	28
Triangle Park Reservoir	29
Canyon Reservoir	30
South Clear Creek Reservoir	31
Lynx Park Reservoir	32
Sour Dough Creek Reservoir	33
Tie Hack Reservoir Enlargement	34

* denotes opportunities not included on the short-list

Table V-1 (concluded)
Long-list of Future Water Use Opportunities

Title	Map Location Number
Crazy Woman Creek Basin	
Enlargement of Negro Creek Reservoir	35
Crazy Woman Reservoir	36
North Fork Crazy Woman Reservoir	37
Hazelton Watershed Site "A" SCS	38
Hazelton Watershed Site "B" SCS	39
Lower Crazy Woman Creek Reservoir	40
Crazy Woman Watershed Improvement District *	41
Doyle Creek Reservoir	42
Powder River Basin	
Middle Fork Powder River Reservoir	43
Pumpkin Reservoir	45
Bass Industrial Reservoir	46
Moorhead Reservoir	47
Arvada Reservoir	48
Fortification Creek Reservoir	49
Fence Creek Reservoir	50
Gibbs Reservoir	51
Morgareidge No. 7 Reservoir	52
Red Fork Powder River Reservoir	53
Buffalo Creek Reservoir	54
Clarks Fork Exchange	Not in study area
Little Powder River Basin	
Coal Mine Reclamation Reservoirs	Not specified

* denotes opportunities not included on the short-list


Ranchester
Dayton
Sheridan
Clearmont
Arvada
Weston
Buffalo
Kaycee
Midwest
Edgerton
19, 20, 30, 31, 32, 33, 34
Miles
10 5 0 10 20 30
N
W
E
S
Note: The numbers next to the opportunity locations correspond to the "Map Location No." in Table V-1.
Legend
Short List Project
Long List Project
Communities
Federal Land
State Land
WYOMING
Future Water Use Opportunity Locations
HKM Engineering Inc.
Granite Tower Building
222 N. 32nd St., Suite 700
P.O. Box 31318
Billings, MT 59107-1318
(406) 656-6399, FAX (406) 656-6398
Figure V-1

D. Short-List of Future Water Use Opportunities

Projects and opportunities on the long-list were reviewed to determine if they should be included on the short-list. Reasons considered to eliminate projects include: 1) the project has already been constructed; 2) the location of project facilities, i.e. within a National Forest or wilderness area, presents major legal, institutional, and permitting constraints; and, 3) the original demand for the project no longer exists and is not expected to appear within the planning period.

As previously noted, water conservation was not included on the long-list but was included in the short-list evaluations. The only water conservation measure considered in this short-list evaluation was ditch lining. The process involved compiling a list of ditches having high seepage losses, estimated to be greater than 30%, and including these ditches in the short-lists as "Misc. canal rehab. (Conservation)". The list was compiled from the Diversion Operation Technical Memorandum prepared for the Powder/Tongue River Basin Plan and the State of Wyoming 2001 Irrigation System Survey Report. The list was then reviewed and modified by the State Board of Control Superintendent of Water Division Number Two. The resulting list included the following nine ditches: Alliance, PK, Burn-Cleuch, Colorado Colony, East Side, Gerdel, Peralta, Interstate (Pennoyer), and South Side. All of these ditches are in the Tongue River Basin.

Comments and suggestions received from BAG members and contributed to the development of the final short-list. Future water use opportunities included on the long-list that were not carried forward to the short-list are identified in Table V-1 and on Figure V-1. Specific reasons for not including the projects on the short-list are provided in Appendix A to the technical memorandum prepared for this topic.

E. Short-List Evaluation Methodology

The methodology described in this section is intended to assist the user of the short-list of future water use opportunities. The process described can be employed to establish "a place to start" in the quest to match specific water demands to future water use opportunities.

The process begins after the short-list of future water use opportunities has been prepared. The result of the process is an evaluation of opportunities according to their relative likelihood they are desirable, functional, and capable of receiving enough public support to be implemented. In general, the results present an overall picture of the favorability of a future water use opportunity or project.

The first step in the process is to categorize the future water use opportunities into one of the four types described below:

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.

By categorizing the short-list projects into one of these four types, projects are evaluated only relative to similar type projects. Furthermore, the projects are grouped by basin to allow planning evaluations by geographic locale.

After the short-list projects have been assigned to a type category, the six evaluation criteria were used to evaluate the projects under each of the types.

The evaluation process entails assigning a weight value to each of the criteria. These values range from a weight of 10 for criteria judged to be very important, to a weight of 1 if the criterion is not considered significant. Different criterion weight values are assigned for each of the four type categories. For example, Criterion 1: Water Availability is not significant for Type 1 projects, since these projects already have an established water supply, and will be assigned a low weight value. Conversely, this criterion is very important for projects categorized under Types 2, 3, and 4, and will be assigned higher weight values.

Each project is then assigned an evaluation score for each of the six criteria. These scores range from a high of 10 if the project is very favorable for that criterion, to a low score of 0 if the project is very unfavorable. Scoring a project under each criterion is accomplished relative to the other projects in the same type category. For example, consider Project X and Project Y that are categorized as Type 2 projects and the evaluation of these two projects concludes Project X will result in more environmental and recreational benefits (Criterion 6). Therefore, Project X will receive a higher score than Project Y under Criterion 6 with the difference in scores reflecting the degree to which Project X provides more environmental and recreational benefits than Project Y.

The total evaluation score for a project is then computed as the sum of the products of the weight value and the evaluation score. Projects achieving a higher total score are considered to be more desirable, more functional, and have a higher capability of receiving enough public support to be implemented, relative to the other projects in the same type category.

As previously stated, the level of information and data available for the projects on the list of future water use opportunities varies significantly from very sketchy to completed conceptual designs. Therefore, the exercise of assigning weights to criterion and evaluation scores to projects is totally subjective and the results of the evaluation process can only be interpreted to reflect the knowledge and judgement of the individual assigning the weights and scores. In order to make the process more objective and less subjective, detailed engineering, legal, and environmental investigations would need to be completed to advance all projects to the same level of information and data.

The suggested evaluation process described above was applied to the short-lists of future water use opportunities to provide an example of the thought process followed in its application. The results of the application of the process are presented in the six tables presented on the following pages for each of the six basins of the planning area.

Table V-2
Evaluated Short-List for the Little Big Horn River Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
Type 1 (None)									
Type 2 (None)									
Type 3			***6***	***5***	***6***	***5***	***8***	***6***	
BEPC Sunrise Project	2	82,110 c	6	7	7	5	5	6	214
Little Bighorn River Export System	1	29,600 y	8	7	6	7	3	5	208
Groundwater Development		unk	5	6	8	4	7	4	208
Half Ounce Reservoir	5	10,000 y	8	6	4	5	5	3	185
Twin Creek Reservoir	6	38,588 c	8	6	4	4	4	4	178
Fuller No. 1 Reservoir	3	22,829 c	4	3	5	4	5	5	159
Fuller No. 2 Reservoir	4	1,549 c	4	3	5	4	5	4	153
Type 4 (None)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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 V-3
Evaluated Short-List for the Tongue River Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
Type 1									
Misc. Canal Rehab (Conservation)		unk	Not ranked, only one project of this type						
Type 2									
Sheridan Canal System	13	68,500 y	Not ranked, only one project of this type						
Type 3			***6***	***8***	***6***	***7***	***6***	***6***	
Upper State Line Reservoir	10	75,000 y	8	6	7	7	6	7	265
Lower State Line Reservoir	12	88,000 y	8	6	7	7	6	7	265
Jones Draw Reservoir	16	2,500 y	5	5	8	8	7	4	240
West Fork Reservoir	17	2,500 y	5	5	8	8	7	4	240
Prairie Dog Reservoir	11	20,000 y	6	4	7	4	6	6	210
Rockwood Reservoir	9	93,000 y	7	7	4	5	3	5	205
Groundwater Development		unk	4	4	9	4	6	4	198
North Fork Reservoir	7	21,600 y	7	5	5	4	3	5	188
South Fork Reservoir	8	13,200 y	7	5	5	4	3	5	188
Shutts Flats Reservoir	14	7,600 y	7	4	5	4	3	5	180
Type 4 (None)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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 V-4
Evaluated Short-List for the Clear Creek Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
Type 1 (None)									
Type 2 (None)									
Type 3			***6***	***8***	***6***	***7***	***6***	***6***	
Lake DeSmet Enlargements	21	239,243 c	8	9	7	5	7	4	263
Lower Clear Creek Reservoir	26	30,300 y	8	5	6	6	6	7	244
B.C.L. Company Reservoir	25	29,300 c	7	5	6	6	6	7	238
Tex Ellis Reservoir	27	17,100 y	7	4	7	6	7	6	236
Tie Hack Reservoir Enlargement	34	7,500 c	4	5	7	8	4	7	228
Groundwater Development		unk	4	3	7	3	6	5	177
Little Sour Dough Reservoir	19	1,642 c	4	3	4	3	3	4	135
Camp Comfort Reservoir	20	11,640 c	4	3	4	3	3	4	135
South Rock Creek Reservoir	28	13,300 c	4	3	4	3	3	4	135
Triangle Park Reservoir	29	3,000 c	4	3	4	3	3	4	135
Canyon Reservoir	30	5,000 c	4	3	4	3	3	4	135
South Clear Creek Reservoir	31	5,000 c	4	3	4	3	3	4	135
Lynx Park Reservoir	32	10,700 c	4	3	4	3	3	4	135
Sour Dough Creek Reservoir	33	4,500 c	4	3	4	3	3	4	135
Type 4 (None)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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 V-5
Evaluated Short-List for the Crazy Woman Creek Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
Type 1 (None)									
Type 2			***6***	***7***	***5***	***6***	***4***	***3***	
Hazelton Watershed Site "B"	39	3,000 acres	5	7	5	7	4	4	174
Doyle Creek Reservoir	42	3,000 acres	5	7	5	7	4	4	174
Hazelton Watershed Site "A"	38	1,580 acres	7	5	6	5	3	3	158
Type 3			***6***	***8***	***5***	***6***	***5***	***6***	
Crazy Woman Reservoir	36	10,500 y	7	6	6	6	5	5	211
Lower Crazy Woman Reservoir	40	67,200 y	7	4	6	7	4	6	202
North Fork Crazy Woman Reservoir	37	2,759 c	6	5	5	4	6	4	179
Enl. Negro Creek Reservoir	35	13,900 c	7	5	5	5	3	4	176
Groundwater Development		unk	4	3	7	3	6	5	161
Type 4 (None)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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 V-6
Evaluated Short-List for the Powder River Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
Type 1 (None)									
Type 2			***6***	***7***	***5***	***6***	***4***	***3***	
Morgareidge No. 7 Reservoir	52	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	47	35,000 y	8	7	7	6	5	6	236
Buffalo Creek Reservoir	54	unk	8	3	7	6	7	6	214
Pumpkin Reservoir	45	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	46	123,380 c	6	6	6	5	5	5	199
Arvada Reservoir	48	35,000 y	6	6	6	5	5	5	199
Middle Fork Powder River Reservoir	43	27,000 y	5	5	5	6	7	5	196
Fence Creek Reservoir	50	106,700 c	7	4	7	5	6	4	193
Fortification Creek Reservoir	49	63,300 y	5	4	7	6	6	4	187
Gibbs Reservoir	51	10,800 y	6	5	6	4	5	5	185
Groundwater Development		unk	3	3	7	3	6	5	155
Type 4 (None)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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 V-7
Evaluated Short-List for the Little Powder River Basin

Project Type (see below) Project Title	Map Location Number	Est. Yield(y), Cap(c) or Depl(d) (AF)	Project Evaluation Criteria: Water Availability	Financial Feasibility	Public Acceptance	No. of Sponsors/ Beneficiaries	Legal/ Institutional Constraints	Environmental/ Recreation Benefits	Total Score
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)									

Notes:
1. Each criteria has a different weighting for each type of project; 10 is most important, 1 is least important
2. Under each project, the criteria are individually scored; 10 means largely favorable, 0 is unfavorable
3. Total scores are the additive result of multiplying each project criteria weighting by the associated project type criteria score

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

It must be emphasized the six evaluated short-list tables reflect the knowledge and judgement of the individual that performed the exercise. When another individual having different opinions and a different level of knowledge of the projects being evaluated completes the exercise, different total scores will likely result. Variable results will be achieved because different weights will be assigned to the evaluation criteria and different scores will be assigned to the projects.

Given this intrinsic characteristic of the evaluation methodology, it is difficult if not impossible to use the resulting evaluated short-lists for anything other than to establish "a place to start" the required investigations leading to the selection of a future water use opportunity compatible with the specific water demands of the reviewer. The evaluated short-lists simply aren't appropriate to be used by the Wyoming Water Development Commission or any other funding entity to prioritize funding awards.

F. Legal and Institutional Constraints

Individuals and organizations involved in water resource management and development need to be aware of the federal and state laws, rules, regulations and policies that affect these activities. This section of the report discusses the legal and institutional constraints effecting water resources in the Powder/Tongue River Basin.

Federal Environmental Laws

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 – enacted to protect threatened and endangered plant and animal species.

- National Environmental Policy Act – requires a comprehensive analysis of the impacts predicted to result from a proposed action, and the consideration of alternative actions.

- Clean Water Act – designed to protect and enhance water quality by controlling the discharge of pollutants into streams.

Federal Lands

A significant portion of the Powder/Tongue River Basin is federal lands administered by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS). Federal agencies managing these lands must assure that the requirements of the above laws are met before they can issue a special use permit authorizing a proposed action, such as construction of a water project.

Wyoming Environmental Laws

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 the 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 U.S. Army Corps of Engineers.

Wyoming Water Law

The Wyoming constitution establishes water in the state to be the property of the state, and use of water requires a permit from the State Engineer. Consequently, before a proposed water project can proceed to development the project sponsor must obtain a permit from the State Engineer.

The use of water is administered by the State Engineer and the State Board of Control that consists of the State Engineer and the Superintendent of each of the four water divisions of the state. Water is administered under the prior appropriations doctrine that dictates the water right with a senior or earlier priority date is entitled to receive its full amount before water rights with later, or junior, priority dates receive any of their allocation. The priority date of a water right is established as the date the water right application is filed with the State Engineer. Before water is available for use by a new project all water rights with priority dates senior to the priority of the proposed project need to be satisfied.

River Basin Compacts

The development and use of water from the Tongue River, Powder River, and Little Powder River are subject to the terms of the Yellowstone River Compact of 1950. This compact recognizes existing uses as of the date of the compact, January 1, 1950, then divides the water of the tributaries of the Yellowstone River between the States of Wyoming and Montana as follows:

- Tongue River: 60% to Wyoming, 40% to Montana
- Powder River and Little Powder River: 42% to Wyoming, 58% to Montana

Article X of the Compact stipulates that no water shall be diverted from the Yellowstone River Basin without the unanimous consent of the three signatory states, Wyoming, Montana, and North Dakota.

Wyoming Water Development Program

In 1975, the Wyoming Legislature authorized the Wyoming Water Development Program and defined the program in W.S. 41-2-112(a), which states:

> *The Wyoming water development program is established to foster, promote, and encourage the optimal development of the state's human, industrial, mineral, agricultural, water and recreation resources. The program shall provide through the commission, procedures and policies 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 program shall encourage development of water facilities for irrigation, for reduction of flood damage, for abatement of pollution, for preservation and development of fish and wildlife resources [and] for protection and improvement of public lands and shall help make available the water of this state for all beneficial uses, including but not limited to municipal, domestic, agricultural, industrial, instream flows, hydroelectric power and recreational purposes, conservation of land resources and protection of the health, safety and general welfare of the people of the state of Wyoming.*

The Wyoming Water Development Commission (WWDC), which was authorized by the legislation, is responsible for setting priorities under the all-encompassing definition provided in the legislation. The WWDC is made up of ten Wyoming citizens who are appointed by the Governor. The Wyoming Water Development Program is administered by the director and staff of the Wyoming Water Development Office.

The WWDC can invest in water projects as state investments or can provide loans and grants to public entities such as municipalities, irrigation districts and special districts, for the construction of projects specific to their water needs. The WWDC has adopted operating criteria to serve as a general framework for the development of program or project recommendations and generation of information.

G. Water Quality Issues

Introduction

The success of a water development project is dependent on the ability of the source to meet the water quality needs of the proposed uses. In addition, the project itself must protect existing and potential uses of waters of the state.

The quality of water refers to its physical, chemical, radiological, biological and bacteriological properties. The concentration levels of various constituents within the water dictate the potential uses of a water source. Quality of a water source can be impacted by natural processes or by human actions. The technical memorandum prepared for this topic provides a comprehensive description of the water quality character of the Powder/Tongue River Basin.

As a result of the Environmental Quality Act, the Water Quality Division of the Department of Environmental Quality (WQD/DEQ) developed and implemented surface water quality standards. These standards are detailed in Chapter 1, Wyoming Water Quality Rules and Regulations. Chapter 1 contains numerical and narrative standards to establish effluent limitations for point source discharges, and best management practices (BMPs) for nonpoint sources.

Ongoing Water Quality Programs

Several programs have been initiated to protect and enhance the quality of surface water in the planning area. These programs, listed below, are described in the water quality technical memorandum.

- DEQ Total Maximum Daily Load (TMDL) – establishes the amount of pollutant which a stream can accept and still meet its designated uses, and develops programs to improve the quality of impaired streams.

- Wyoming Water Development Commission Three Horses Study – reviews coal bed methane impacts on the drainages of Dead Horse Creek, Spotted Horse Creek, and Wild Horse Creek.

- Wyoming State Geological Survey Interactive Geologic, Geohydrologic, and Geochemical Database and Model – associates water quality with aquifers in the northern portion of the Powder/Tongue River Basin.

- Wyoming Association of Conservation Districts Watershed Planning – provides local control and planning relative to the imposition of TMDLs.

- Sheridan County Conservation Districts Tongue River Watershed Assessment – encompassed data from a number of entities to conclude the water quality of the assessed segment of the Tongue River is good to excellent with few exceptions.

- U. S. Geologic Survey Monitoring Program and Interest-Specific Studies – includes operation of 66 surface water quality monitoring stations in the planning area, the National Water-Quality Assessment (NAWQA), the Pathogen Indicator Synoptic Study, and the Pesticide Monitoring Program.

- U. S. Environmental Protection Agency CBM Water Disposal Study – updates the Best Available Technology (Economically Achievable) listing to include entries on coal bed methane produced water.

Current Water Quality Issues

Primary issues related to the quality of water in the planning area are detailed in industrial, agricultural, and municipal categories.

- Industrial – quality and quantity of discharges associated with coal bed methane production, but other industrial activities also impact water quality.

- Agricultural – livestock activities in riparian areas, pesticide use, and animal feeding operations.

- Municipal – controlling storm water discharges may become a significant issue in the future.