7 Water Availability

Water availability is the amount of water that is physically and legally available for new water uses in the Basin. Water availability was determined for surface water uses using a spreadsheet model. Groundwater availability was determined by the Wyoming State Geological Survey in a separate report, and has not been included herein. In addition to water availability, this chapter describes current conservation practices within the Basin, and provides a general summary of water use and availability within the Basin. Additional information on the spreadsheet models used to develop water availability and detailed results of the analysis can be found in Technical Memorandums 4B and 4C.

7.1 Surface Water

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

7.1.1 Methodology

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

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

The spreadsheet models were developed to be consistent with the Guidelines for Development of Basin Plans (States West 2001). The guidelines recommend that for the purposes of the river basin plans, the hydrologic analysis be conducted for three 12-month periods using average dry-year conditions, average average-year conditions and average wet-year conditions. Therefore, each hydrologic region in the model has one model with three associated datasets representing those three hydrologic conditions. The gaged flows used in the spreadsheet model were developed by averaging recorded monthly streamflows for groups of years falling into those three hydrologic categories during a consistent period-of-record.

Once the study period is selected, the monthly data are further reduced into average data for dry, average and wet hydrologic year classifications. To determine which years within the period-of-record fall into which hydrologic year classifications, the previous Basin Plan selected index gages within each of the hydrologic units based upon their period-of-record and their lack of influence by diversion and return flows. Then, the hydrologic classification for the index gage was applied to the remaining gages within its influence area. This same method was used for the Basin Plan Update. The hydrologic classification methods for the Wind-Bighorn Basin Plan Update are consistent with the hydrologic classifications for the other river basin plans and with the guidelines. As determined by streamflow at key gages, the driest 20 percent of years are considered dry years, the wettest 20 percent of years are considered wet years, and the middle 60 percent of years are considered average years.

A summary of the hydrologic year classification for each of the index gages is presented in Table 52. The table shows three distinct hydrologic periods that are common throughout the study area. The first is from 1973 through 1994, which shows a consistent mix of dry, average and wet years. The next period is from 1995 through 1999, which shows a wet period throughout the Basin. Finally, the drought that has occurred throughout the study area is shown as starting in 2001 and continuing through 2007. The final year in the study period, 2008, shows average to wet conditions in all basins.

This information was incorporated into the modeling described below through the reduction of historical streamflow data into dry, average and wet-year hydrologic data. Gage records were reduced from monthly data throughout the study period to the hydrologic classifications shown by averaging the data for the years within each hydrologic classification, based upon the classification at the index gage. Because several of the last seven years added to the study period are classified as dry to average years, the additional years changed the distribution of dry, average and wet years. Therefore, the effect of adding the dry to average years, in many cases, raised the dry year average flows, but lowered average and wet year average flows. A similar approach was used to reduce historical diversion data for use in the historical/calibration model scenario.

Table 52. Summary of Hydrologic Classifications for Study Area

		1970							1980										1990										2000								
Gage No.	Gage Name	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8
06037500	Madison River Near West Yellowstone MT	Average	Wet	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average	Wet	Average	Dry	Average	Dry	Average	Dry	Average	Average	Wet	Wet	Wet	Wet	Wet	Wet	Average	Dry	Dry	Dry	Dry	Average	Dry	Average
06191500	Yellowstone River At Corwin Springs MT	Average	Wet	Average	Wet	Dry	Average	Average	Dry	Average	Wet	Average	Average	Average	Wet	Dry	Dry	Average	Average	Average	Average	Average	Dry	Average	Wet	Wet	Average	Wet	Average	Dry	Average	Average	Dry	Average	Average	Dry	Wet
06205500	Clarks Fk Yellowstone R Ab Squaw C Nr Painter,WY	Average	Wet	Wet	Wet	Dry	Wet	Average	Average	Average	Wet	Average	Average	Dry	Average	Dry	Dry	Average	Average	Average	Average	Average	Dry	Average	Wet	Wet	Average	Average	Average	Dry	Average	Average	Dry	Average	Average	Dry	Wet
06222700	Crow C Nr Tipperary WY	Dry	Average	Average	Average	Dry	Wet	Average	Average	Dry	Wet	Wet	Average	Dry	Wet	Average	Dry	Average	Average	Wet	Average	Average	Dry	Wet	Average	Wet	Average	Wet	Average	Dry	Dry	Average	Average	Average	Average	Average	Average
06224000	Bull Lake Creek Above Bull Lake, WY	Average	Average	Average	Average	Dry	Average	Average	Average	Average	Wet	Wet	Average	Dry	Wet	Average	Dry	Average	Average	Wet	Dry	Average	Dry	Wet	Average	Wet	Wet	Wet	Average	Dry	Dry	Average	Average	Average	Average	Dry	Average
06228350	Sf L Wind R Ab Washakie Re Nr Ft Washakie WY	Average	Average	Average	Average	Dry	Wet	Average	Average	Average	Average	Wet	Average	Average	Wet	Average	Dry	Average	Average	Wet	Dry	Average	Dry	Wet	Average	Wet	Wet	Wet	Average	Dry	Dry	Dry	Average	Average	Dry	Average	Average
06233000	Little Popo Agie River Near Lander, WY	Average	Wet	Average	Average	Dry	Average	Average	Wet	Average	Average	Wet	Wet	Average	Wet	Average	Average	Dry	Average	Average	Dry	Average	Average	Wet	Average	Wet	Average	Wet	Average	Dry	Dry	Dry	Average	Average	Dry	Dry	Average
06260000	South Fork Owl Creek Near Anchor, WY	Average	Average	Average	Average	Dry	Average	Average	Average	Average	Average	Average	Average	Dry	Wet	Average	Average	Average	Average	Wet	Wet	Average	Dry	Wet	Wet	Wet	Wet	Wet	Average	Dry	Dry	Average	Dry	Average	Dry	Dry	Average
06270000	Nowood River Near Tensleep, WY	Wet	Average	Wet	Average	Average	Wet	Average	Dry	Dry	Dry	Wet	Wet	Dry	Average	Average	Average	Dry	Average	Average	Dry	Wet	Average	Wet	Average	Average	Wet	Average	Average	Dry	Dry	Average	Average	Average	Average	Average	Average
06275000	Wood River At Sunshine, WY	Wet	Wet	Average	Average	Dry	Average	Average	Average	Average	Dry	Wet	Average	Dry	Average	Average	Dry	Dry	Dry	Average	Average	Average	Average	Wet	Wet	Wet	Wet	Wet	Average	Dry	Dry	Average	Average	Average	Average	Average	Average
06278500	Shell Creek Near Shell, WY	Average	Average	Wet	Wet	Average	Wet	Wet	Average	Average	Average	Average	Average	Dry	Wet	Average	Average	Dry	Average	Average	Average	Average	Dry	Wet	Average	Average	Average	Wet	Average	Dry	Dry	Dry	Dry	Average	Dry	Average	Wet
06280300	South Fork Shoshone River Near Valley, WY	Average	Wet	Average	Wet	Dry	Wet	Average	Average	Average	Wet	Average	Average	Average	Wet	Dry	Dry	Average	Average	Average	Dry	Average	Dry	Average	Wet	Wet	Average	Average	Average	Dry	Average	Average	Dry	Average	Average	Dry	Wet

Notes:

(1) Hydrologic Year Classification

- Dry Year (Driest 20 percent of years in study period)
- Average Year (Middle 60 percent of years in study period)
- Wet Year (Wettest 20 percent of years in study period)

7.1.2 Surface Water Model

The following provides a general overview of the surface water model data input, use and enhancements made as part of the Basin Plan Update. Additional information can be found in Technical Memorandum 4B.

Model Overview

In the previous Basin Plan, three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. As part of the Basin Plan Update, each of the models was combined into a single model with an option to simulate each of the hydrologic conditions. This eliminates the need to make construction updates to three separate models. The model simulates one calendar year of flows, on a monthly time step.

Model Structure and Components

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

The basin planning area was divided into the 13 sub-basin models shown Table 53.

Table 53. Wind-Bighorn Sub-basin Models

Basin	Sub-basin Model
Yellowstone	Madison/Gallatin
	Yellowstone
Clarks Fork	Clarks Fork
Wind	Upper Wind
	Little Wind
	Popo Agie
	Lower Wind
Bighorn	Upper Bighorn
	Owl Creek
	Nowood
	Lower Bighorn
	Greybull
	Shoshone

Stream Gage Data

Monthly stream gage data were obtained from the Wyoming Water Resources Data System (WRDS) and the USGS for each of the stream gages used in the model. Linear regression techniques were used to estimate missing values for the many gages that had incomplete records. Once the gages were filled in for the study period, monthly values for dry, normal, and wet conditions were averaged from the dry, normal, or wet years of the study period. The dry, normal, and wet years were determined on a sub-basin level from index gages in each sub-basin (index gages were previously shown in Table 52).

In order for the model to accurately simulate streamflow and diversions for the entire Basin, an estimation of streamflow above all diversions is required. However, in many parts of the Basin, there are no streamflow gaging stations above the most upstream diversion on the stream. Therefore, streamflow upstream of the diversion must be estimated. Two methods are available to make these estimations:

(1) estimate streamflow based on regional equations which are a function of basin characteristics such as location, elevation and orientation;
(2) estimate streamflow by adding diversions and subtracting inflows from the closest downstream gage.

For most locations, the regional equation methodology was used to estimate streamflow for ungaged headwaters sites. However, in areas where this methodology yielded implausible results (such as the streamflow being less than the actual measured diversion or the streamflow being greater than the next downstream gage adjusted for inflows and diversions), the estimated headwaters flows were adjusted based on the available data.

<u>Diversion Data</u>

Surface water diversions are primarily for agricultural use. If actual diversion data existed for a modeled stream, that information was used in the modeling effort for historical/calibration simulation runs. However, because actual diversion records were unavailable in many locations, estimates of diversions were made for historical/calibration runs. For full supply model runs, estimated full supply diversion requirements were used. Diversion estimates were previously discussed in Section 5.1. Monthly values for dry, normal, and wet conditions were averaged from the dry, normal, or wet years of the study period using the same index gages as those used for streamflow.

<u>Reach Gain/Loss</u>

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

Wind-Bighorn Hydrologic Database

As part of the Basin Plan Update, a hydrologic database entitled "WindBig_Hydro.mdb" was developed using the Microsoft Access database platform to house all of the hydrologic datasets required by the spreadsheet models. Macros coded in Visual Basic for Applications (VBA) were developed within the database program to process raw data into full monthly datasets, and to develop the dry-average-wet year hydrologic datasets used by the spreadsheet models. The remainder of the calculations required to process datasets use standard Microsoft Access query techniques.

The database contains the following general datasets required by the model:

- Streamflow Data – Includes daily USGS gage data, monthly SEO gage data, daily USBR Hydromet data and regression equation information used to fill missing streamflow data (see Technical Memorandum 4A – Surface Water Hydrology for description of specific data)

- Natural Flow Data – Natural flow data nodes and site data (imported from GIS layers) and equations used for natural flow calculations (see Technical Memorandum 4A – Surface Water Hydrology for description of specific data)

- Historical Diversion Data – SEO Division III daily spot data and monthly continuous flow data (see Technical Memorandum 3A – Agricultural Water Use for description of specific data)

- Crop Irrigation Requirements (CIR) and Diversion Requirements (DR) – Input data and calculations for CIR and DR, including irrigated acres polygons (imported from GIS layers), cropping pattern information (imported from USDA database) and efficiencies

- Reservoir Data – Historical reservoir data, including end-of-month storage contents, evaporation and estimated releases.

- Spreadsheet Model Data – Model nodes and descriptions

Basin Plan Update Model Enhancements

As previously stated, the spreadsheet model construction remains mostly the same in the Basin Plan Update as the previously developed spreadsheet models. However, some changes were made as part of the Basin Plan Update. These changes include the incorporation of dynamic hydrologic database queries directly into the spreadsheet models, the development of a single spreadsheet model file rather than separate spreadsheet files for each hydrologic condition, and the development of new model interface spreadsheet file that allows running all models at the same time rather than running each model individually. Each of these improvements is inter-related, and entirely dependent upon the new database connection.

Model Limitations

In reviewing the model results, the limitations of the model should be noted. A brief summary of these limitations follows. More information regarding the model and its limitations is presented in Technical Memorandum 4B.

- The model does not explicitly account for water rights, appropriations or compact allocations and is not operated on these legal principals. For instance, the model cannot forego a diversion to an upstream junior water right to satisfy a downstream senior water right. Compact allocations are considered in available flow determinations. See later sections of this chapter for a discussion.

- The model does not “operate” storage reservoirs to meet downstream demands, nor can the model differentiate between different owners of storage accounts. The model only uses historical reservoir releases and satisfies the diversions in order of their physical location on the stream. However, as with water rights, the historical operations and diversion of stored water is normally reflected in the historical records.

- Because the model does not contain time-series hydrology, it does not perform a detailed analysis of reservoir carryover storage. This is important in multi-year drought conditions.

As the model is constructed, it only shows the starting reservoir level as the average during all dry years, which does not necessarily simulate a drought (although this specific scenario could be at least partially analyzed in the model by varying starting storage contents). However, the importance of filling and emptying large reservoirs over a number of years is not explicitly analyzed in the model.

It should be noted that throughout this report, available flow, shortage and streamflow values are reported to the nearest acre-foot. However, this should not be interpreted as an indication that the spreadsheet models are accurate to the nearest acre-foot. Model accuracy has not been specifically determined. Model accuracy is dependent upon the input data, model construction, model assumptions, calibration and general model operations. Use and interpretation of the data contained herein should consider the inherent accuracy of the model given these factors.

Simulated Scenarios

The Wind-Bighorn sub-basin models can simulate four different scenarios as described below. The three full supply scenarios roughly correspond to the low, mid and high future water use scenarios developed in the economic analysis. The model scenarios do not match the future water use scenarios exactly because the spreadsheet models were not designed to simulate several of the water use changes that are documented in the economic analysis, including additional irrigated lands in the high water use scenario, because the location and other details of these additional water uses are mostly unknown.

- Calibration (Historical) – Simulates actual historical diversions. This mode is primarily used for model calibration.

- Full Supply for Existing Irrigated Lands – Simulates full supply, based on computed diversion requirements, for existing irrigated lands with water rights mapped as part of the planning process. This roughly corresponds to existing conditions.

- Full Supply for Existing Irrigated Lands and Riverton East Futures Project - Simulates full supply, based on computed diversion requirements, for irrigated lands with water rights mapped as part of the planning process and the Riverton East Tribal Futures project. This roughly corresponds to the mid future water use scenario.

- Full Supply for Existing Irrigated Lands and All Futures Projects - Simulates full supply, based on computed diversion requirements, for irrigated lands with water rights mapped as part of the planning process and all Tribal Futures project. This roughly corresponds to the high future water use scenario.

The calibration, or historical, scenario is primarily used for calibration of the model. It utilizes historical diversion data and return flows with historical gage flows to calculate ungaged gains and losses. It does not recognize whether historical diversions were reduced due to water supply constraints nor does it model full supply to irrigated lands with water rights. Per the definition of the calibration scenario, the model does not show any shortages at diversions. Therefore, no results from this run are presented in this report. The results in this report are for the Fully Supply for Existing Irrigated Lands and the two Full Supply for Existing Irrigated Lands and Futures Projects modes.

7.1.3 Current Available Supply Estimates

The available surface water for each basin is defined as the amount of water available for water development within a reach in the model after meeting simulated downstream demands. These demands include:

1. Existing irrigation, municipal or industrial demands
2. Compact requirements
3. Instream flow requirements

Methods for calculating available flow within each reach have varied between different WWDC basin plans. The method for calculating available flow in this Basin Plan Update is consistent with that used in the original Wind-Bighorn Basin Plan. In some river basin planning models, the available flow within each reach was calculated as the outflow from the reach (HKM 2002). However, it was found that in the Wind-Bighorn sub-basin models, some of the reach outflows (i.e. flow at the end of the reach) were greater than the flow at other locations within the reach. Thus, the defining flow availability is the minimum flow within the reach, taking into account compact requirements for the Basin and instream flow requirements within the reach. Therefore, for the Wind-Bighorn available flows, the available flow within each reach was taken as the minimum flow at all nodes within the reach. The minimum flow for the individual reach was then calculated as the minimum flow within the reach and of all downstream reaches, including instream flow and compact requirements. Descriptions of compact and instream flow requirements are contained in later sub-sections.

It should be noted that performing these calculations on an annual basis could give different results than performing the calculations on a monthly basis. The monthly basis is considered more accurate because of the shorter calculation time period. The annual value of available flow is the sum of the 12 months' available flow.

This section presents a summary of annual available flows for selected mainstem and major tributary reaches. However, available flow was calculated for all reaches in the models on a monthly basis, and are available in Technical Memorandum 4C. It should be noted that available flow estimates are not additive. In other words, if a portion of the available flow in an upstream reach were diverted, this flow would not be available for diversion in all downstream reaches. Therefore, the sum of all available flow estimates in a particular sub-basin or basin cannot be added to determine available flow for the sub-basin or basin.

Annual available flows for selected reaches under the Full Supply scenario for the Clarks Fork, Yellowstone and Madison/Gallatin Basins are shown in Table 54. Available flow was calculated for reaches in Yellowstone National Park. However, it is unlikely that this flow could be developed for agricultural, industrial or municipal and industrial (M&I) consumptive uses, and thus there is actually no available flow. Flow is available for development within the Clarks Fork Basin. Both the mainstem of the Clarks Fork and several major tributaries have flow available for development during all hydrologic conditions.

Table 54. Clarks Fork, Yellowstone and Madison/Gallatin Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft) Dry	Average	Wet
Madison/Gallatin	Reach 600: Madison River	327,292	362,240	428,664
	Reach 620: Gibbon River	85,140	102,820	131,451
	Reach 640: Firehole River	242,151	259,420	297,213
	Reach 800: Gallatin River	484,920	606,325	697,306
Yellowstone	Reach 400: Yellowstone River above Lamar River Confluence	859,775	1,087,063	1,333,160
	Reach 500: Yellowstone River below Lamar River Confluence	1,610,549	2,064,723	2,524,621
	Reach 580: Gardner River	68,952	106,749	146,675
Clarks Fork	Reach 100: Clarks Fork River above Sunlight Creek Confluence	268,983	350,497	430,247
	Reach 190: Sunlight Creek	48,401	67,306	82,983
	Reach 200: Clarks Fork River from Sunlight Creek to Bennett Creek	268,983	350,497	430,247
	Reach 300: Clarks Fork River below Bennett Creek Confluence (1)	338,022	420,270	498,294

Annual available flow for major reaches in the Wind River Basin is shown in Table 55. Upper portions of the Wind River Basin are affected by instream flows in the Wind River upstream of the East Fork. It should be noted that the East Fork Wind River is downstream of this instream flow segment. However, due to model construction, its impacts are imposed on the East Fork. Available flows in tributaries are fairly limited, although most tributaries have flow available during winter and spring months.

Table 55. Wind River Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft) Dry	Average	Wet
Upper Wind	Reach 100: Wind River Headwaters to DuNoir Creek	2,375	40,538	62,375
	Reach 200: Wind River from DuNoir Creek to East Fork	2,375	54,359	80,768
	Reach 300: Wind River from East Fork to Bull Lake Creek	86,324	279,268	488,431
	Reach 290: East Fork Wind River	8,074	31,985	53,418
	Reach 320: Dinwoody Creek	12,567	38,674	56,009
	Reach 390: Bull Lake Creek	16,414	120,412	164,332
	Reach 400: Wind River from Bull Lake Creek to Little Wind	135,045	336,128	551,084
Little Wind	Reach 500: Little Wind River	37,660	78,797	126,763
	Reach 510: South Fork Little Wind	7,907	15,362	31,930
	Reach 520: North Fork Little Wind	21,360	57,191	88,039
	Reach 530: Trout Creek	3,348	5,347	7,775
Popo Agie	Reach 1.1: North Popo Agie River: From Gage 06232000 to Gage 06232500	33,134	65,581	97,752
	Reach 2.1: Middle Popo Agie River - Upstream of Gage USGS 06231600	69,014	93,841	119,592
	Reach 3.3: Little Popo Agie River: - Confluence Twin Creek to Mouth at Hudson	44,391	73,727	103,606
	Reach 580: Popo Agie River	126,384	229,330	326,104
Lower Wind	Reach 600: Wind River from Little Wind Confluence to Boysen Reservoir	385,710	733,752	994,136
	Reach 700: Muddy Creek	3,408	3,836	4,434
	Reach 800: Badwater Creek	13,938	20,059	25,180

Annual available flow for major reaches in the Bighorn River Basin is shown in Table 56. Significant amounts of water are available in the mainstem of the Bighorn and Shoshone River Basins during all hydrologic conditions and during most months of the year. Availability in tributaries varies. The Owl Creek Basin has a relatively low amount of available flow when compared with existing diversions and shortages. The remaining larger tributaries have flow available during all hydrologic conditions at least during portions of the year. Smaller tributaries generally have lower amounts of available flow, and are limited by both hydrologic conditions and time of year. Smaller tributaries in the Greybull Basin have limitations in available flow due to permitted instream flows.

Table 56. Bighorn River Basin Available Flow - Full Supply Scenario

Basin	Location	Available Flow (ac-ft) Dry	Average	Wet
Upper Bighorn	Reach 100: Bighorn River to Owl Creek	650,525	947,250	1,369,806
	Reach 400: Bighorn River from Owl Creek to Gooseberry Creek	659,028	958,939	1,397,158
	Reach 460: Cottonwood Creek	5,060	12,278	24,393
	Reach 480: Gooseberry Creek	7,856	13,716	20,179
	Reach 500: Bighorn River from Gooseberry Creek to Nowood River	771,835	1,138,561	1,663,246
	Reach 900: Bighorn River from Nowood River to USGS Gage	802,761	1,172,511	1,700,980
Owl Creek	Reach 200: Owl Creek from N. & S. Fork Conf. To Mud Creek Conf.	4,779	8,055	13,974
	Reach 220: South Fork Owl Creek	849	3,125	8,352
	Reach 250: N. Fork Owl Creek	1,191	3,226	7,299
	Reach 300: Owl Creek from Mud Creek Conf. To Bighorn River	7,508	12,825	28,210
Nowood	Reach 600: Nowood River above Ten Sleep Creek	5,874	9,760	16,207
	Reach 690: Ten Sleep Creek	1,831	5,972	14,541
	Reach 700: Nowood River from Ten Sleep Ck. To Paint Rock Ck.	157,247	188,298	214,570
	Reach 790: Paint Rock Creek	69,055	90,108	101,699
	Reach 800: Nowood River from Paint Rock Ck. To Bighorn Riv.	248,963	316,886	374,819
Lower Bighorn	Reach 1000: Bighorn River at Greybull River	839,498	1,222,566	1,763,394
	Reach 1500: Bighorn River at Shell Creek	857,582	1,241,414	1,784,027
	Reach 1600: Shell Creek	29,382	47,364	54,770
	Reach 1700: Bighorn River at Yellowtail	902,512	1,331,142	1,886,436
	Reach 1740: Crystal Creek	1,053	2,837	6,542
Greybull	Reach 1100: Greybull River Headwaters	17,192	28,659	85,562
	Reach 1200: Wood River	46,436	66,811	82,381
	Reach 1300: Greybull River below Wood River	19,709	38,593	95,533
	Reach 1350: Meeteetse Creek	1,560	2,688	7,846
	Reach 1400: Greybull River Below Roach Gulch	31,251	49,011	103,211
Shoshone	Reach 1800: South Fork Shoshone River Headwaters	7,760	11,724	17,536
	Reach 1900: South Fork Shoshone River below Bob Cat Creek	179,299	292,339	406,277
	Reach 2000: North Fork Shoshone River Headwaters	30,858	55,475	93,112
	Reach 2100: North Fork Shoshone River below Wapati	324,952	476,366	571,620
	Reach 2200: Buffalo Bill Reservoir	438,624	601,936	737,047
	Reach 2300: Shoshone River below Buffalo Bill Reservoir	468,879	642,526	746,855
	Reach 2390: Sage Creek	188	334	596
	Reach 2400: Shoshone River below Sage Creek	468,301	653,740	749,983
	Reach 2500: Shoshone River below Bitter Creek	569,919	855,715	1,023,558

7.1.4 Future Available Supply Estimates

As previously discussed, two Futures water supply availability scenarios were simulated, including a Full Supply with Riverton East scenario and a Full Supply with all Futures Projects scenario. Futures Projects diversions were simulated in the model which are approximately 209,300 acre-feet within the Wind, Little Wind and Popo Agie Basins. Of this, approximately 17,500 acre-feet is for the Riverton East Futures Project.

Available flows for the Full Supply with Riverton East Futures Project scenario for the Wind River Basin are shown in Table 57 while available flows for the Full Supply with All Futures Projects scenario are shown in Table 58. A comparison of available flow for all scenarios is presented in Figure 41. Development of the Riverton East Futures Project would reduce water availability in the Lower Wind by approximately 17,300 acre-feet per year in dry years and 9,800 acre-feet per year in average and wet years. For development of all Futures Projects, water availability is reduced substantially. In the Upper Wind, water availability is reduced by 15,400 acre-feet per year to 140,700 acre-feet per year, while in the Lower Wind, water availability is reduced by 65,200 acre-feet per year to 100,800 acre-feet per year. In addition, as previously mentioned, storage in Boysen Reservoir would be reduced beyond historical conditions for the full Futures development scenario, and some of the available flow would be required to refill Boysen Reservoir.

Table 57. Wind River Basin Available Flow - Full Supply with Riverton East

		Available Flow (ac-ft)		
Basin	**Location**	**Dry**	**Average**	**Wet**
Upper Wind	Reach 100: Wind River Headwaters to DuNoir Creek	2,375	40,538	62,375
	Reach 200: Wind River from DuNoir Creek to East Fork	2,375	54,359	80,768
	Reach 300: Wind River from East Fork to Bull Lake Creek	86,324	279,268	488,431
	Reach 290: East Fork Wind River	8,074	31,985	53,418
	Reach 320: Dinwoody Creek	12,567	38,674	56,009
	Reach 390: Bull Lake Creek	16,414	120,412	164,332
	Reach 400: Wind River from Bull Lake Creek to Little Wind	135,045	336,128	551,084
Little Wind	Reach 500: Little Wind River	37,660	78,797	126,763
	Reach 510: South Fork Little Wind	7,907	15,362	31,930
	Reach 520: North Fork Little Wind	21,360	57,191	88,039
	Reach 530: Trout Creek	3,348	5,347	7,775
Popo Agie	Reach 1.1: North Popo Agie River: From Gage 06232000 to Gage 06232500	33,134	65,581	97,752
	Reach 2.1: Middle Popo Agie River - Upstream of Gage USGS 06231600	69,014	93,841	119,592
	Reach 3.3: Little Popo Agie River: - Confluence Twin Creek to Mouth at Hudson	44,391	73,727	103,606
	Reach 580: Popo Agie River	126,384	229,330	326,104
Lower Wind	Reach 600: Wind River from Little Wind Confluence to Boysen Reservoir	368,451	723,990	984,337
	Reach 700: Muddy Creek	3,408	3,836	4,434
	Reach 800: Badwater Creek	13,938	20,059	25,180

Table 58. Wind River Basin Available Flow - Full Supply with All Futures Projects

Basin	Location	Available Flow (ac-ft) Dry	Average	Wet
Upper Wind	Reach 100: Wind River Headwaters to DuNoir Creek	0	26,392	51,528
	Reach 200: Wind River from DuNoir Creek to East Fork	0	36,382	69,921
	Reach 300: Wind River from East Fork to Bull Lake Creek	74,760	143,284	357,697
	Reach 290: East Fork Wind River	2,612	23,030	42,566
	Reach 320: Dinwoody Creek	4,977	35,609	56,009
	Reach 390: Bull Lake Creek	8,628	68,516	124,454
	Reach 400: Wind River from Bull Lake Creek to Little Wind	119,672	202,118	410,376
Little Wind	Reach 500: Little Wind River	37,660	78,797	126,763
	Reach 510: South Fork Little Wind	7,907	15,362	31,930
	Reach 520: North Fork Little Wind	21,360	57,191	88,039
	Reach 530: Trout Creek	3,348	5,347	7,775
Popo Agie	Reach 1.1: North Popo Agie River: From Gage 06232000 to Gage 06232500	27,310	57,264	89,095
	Reach 2.1: Middle Popo Agie River - Upstream of Gage USGS 06231600	66,685	92,235	117,723
	Reach 3.3: Little Popo Agie River: - Confluence Twin Creek to Mouth at Hudson	44,391	73,727	103,606
	Reach 580: Popo Agie River	120,518	223,965	318,537
Lower Wind	Reach 600: Wind River from Little Wind Confluence to Boysen Reservoir	320,558	626,369	893,326
	Reach 700: Muddy Creek	3,408	3,836	4,434
	Reach 800: Badwater Creek	13,938	20,059	25,180

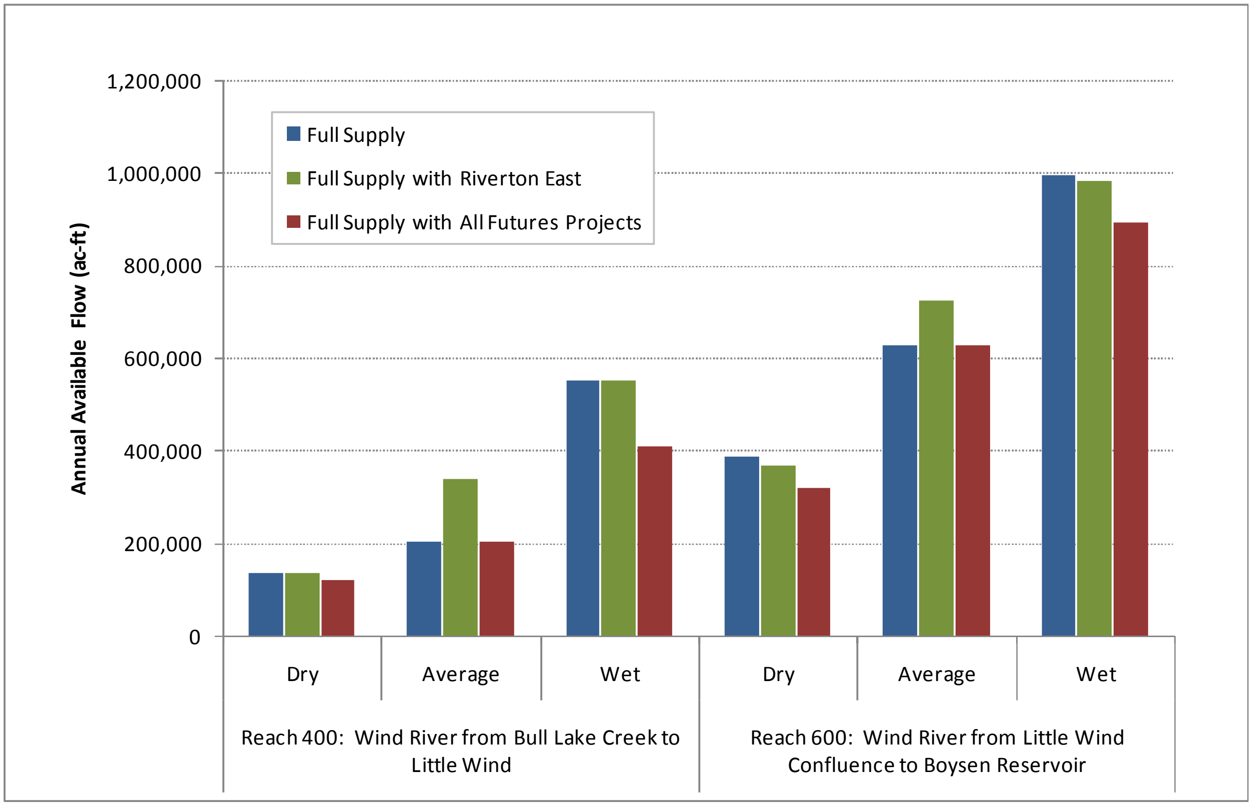

Figure 41. Comparison of Available Flow for Full Supply and Futures Scenarios

Downstream of Boysen Reservoir, the model does not show any impacts to diversions for all scenarios. This is because Boysen Reservoir acts as a "buffer" between the Wind and Bighorn Basins. More storage within the reservoir can be used to meet downstream demands. For the Full Supply with Riverton East scenario, model results could potentially be interpreted as showing if multiple years of average or below average hydrologic conditions were to occur back-to-back, there may be more difficulty in filling Boysen Reservoir. A graph depicting average monthly storage in Boysen Reservoir for the three scenarios during the average year is shown in Figure 42. The graph shows that historically and for all simulated conditions except the scenario with all Futures Projects developed, the reservoir contents at the end of the year are equal to or greater than at the beginning of the year. Therefore, during average years in these scenarios, the reservoir is at equilibrium (i.e. inflows exceed outflows). However, for the Full Supply with All Futures Projects developed scenario, end-of-year contents are nearly 100,000 acre-feet less than beginning-of-year contents. Therefore, storage contents are depleted during an average year if outflows remain the same. However, this information cannot be used to conclude that shortages would occur downstream of Boysen Reservoir during average years. The Bighorn River shows available flow in all conditions, so Boysen Reservoir outflows could potentially be adjusted to keep the reservoir at an equilibrium condition during average years. A more detailed carry-over storage analysis is required to analyze the full effects of Futures Projects on storage in Boysen Reservoir.

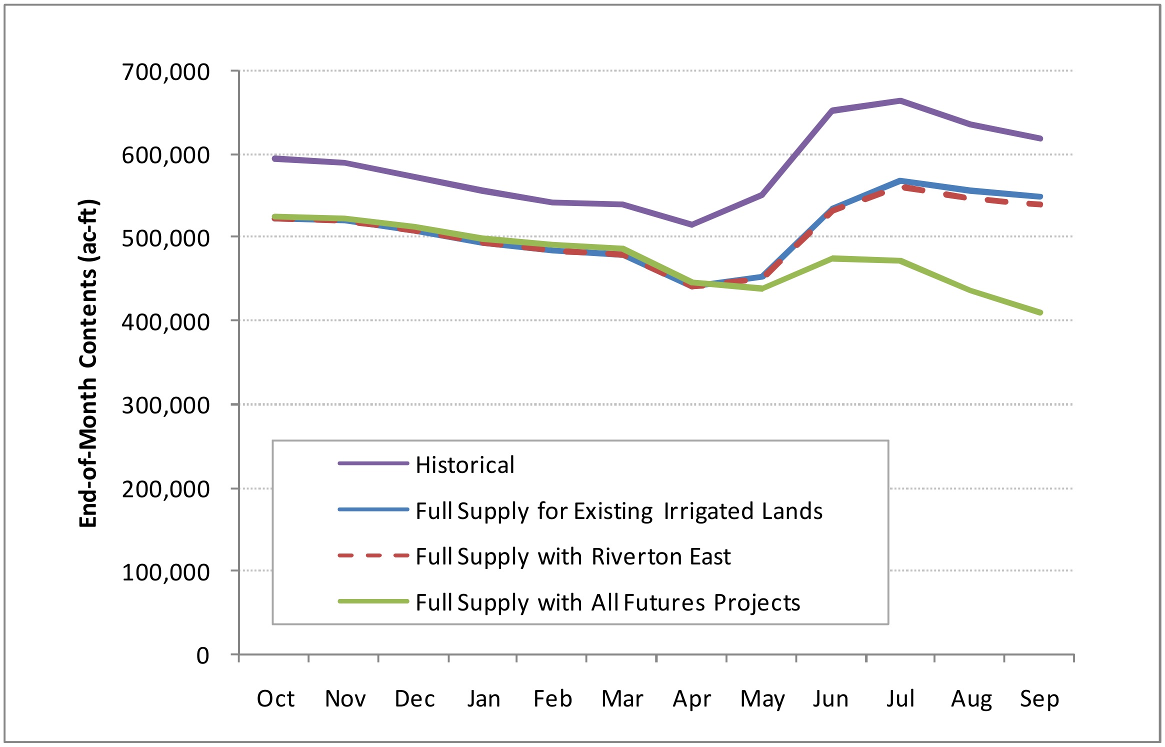

Figure 42. Simulated End-of-Month Contents for Boysen Reservoir – Average Year

In interpreting available flow estimates, model limitations should be recognized. The model does not contain a water rights accounting system. In addition, the model does not "operate" storage to meet downstream demands. It simply releases the historical volumes. For instance, in the Futures Projects scenarios, additional releases could be made from Bull Lake to meet some Wind River shortages, or additional water could be stored in Boysen Reservoir during peak runoff, which would impact flows downstream of the reservoir during those months.

7.1.5 Compact Availability

All projections of available water use consider the constraints of the Yellowstone River Compact (Compact). The following quantifies the amount of water historically available in the Clarks Fork and Bighorn Basins under the Compact.

Clarks Fork

Based upon the gage flows available from the USGS, the unallocated flow calculation methodology and the Compact percentages, Wyoming's portion of the unallocated flow of the Clarks Fork was estimated for the dry, average and wet year hydrologic conditions. These results are presented in Table 59. These values have been included in the available flow calculations for the Clarks Fork River. To simplify model accounting, the calculations were performed on an annual basis, then pro-rated over the year according the flow pattern at the Clarks Fork near Belfry gage (06207500).

Table 59. Calculation of Wyoming Portion of Unallocated Flow for the Clarks Fork River

Calculation	Period-of-Record Average (1922-2008)	Model Study Period (1973-2008) Overall Average	Dry Year	Average Year	Wet Year
Gaged Flow (ac-ft)	727,846	693,412	563,671	693,804	823,811
Adjusted Flow (ac-ft)	734,531	700,097	570,456	700,450	830,491
Wyoming Portion of Unallocated Flow (ac-ft)	440,718	420,058	342,273	420,270	498,294

White Horse Canal average diversion (6,685 ac-ft/year) used for years without data

Bighorn River

Based upon the gage flows available from the USGS, the unallocated flow calculation methodology and the Compact percentages, Wyoming's portion of the unallocated flow of the Bighorn River was estimated for the dry, average and wet year hydrologic conditions. These results are presented in Table 60. These values have been included in the available flow calculations for the Bighorn River. To simplify model accounting, the calculations were performed on an annual basis, then pro-rated over the year according to a weighted monthly flow pattern at the Bighorn River at Kane gage (06279500) and the Shoshone River at Kane gage (06286200). In reality, Yellowtail Reservoir serves to balance out Compact requirements over the year, so there could be some deviation allowed from the monthly requirements.

Table 60. Calculation of Wyoming Portion of Unallocated flow for the Bighorn River

Calculation	Period-of-Record Average (1954-2008)	Model Study Period (1973-2008) Overall Average	Dry Year	Average Year	Wet Year
Gaged Flow (ac-ft)	2,587,194	2,517,350	1,556,476	2,621,939	3,216,753
Adjusted Flow (ac-ft)	2,398,089	2,324,313	1,347,055	2,446,913	2,995,072
Wyoming Portion of Unallocated Flow (ac-ft)	1,918,472	1,859,450	1,077,644	1,957,530	2,396,058

7.2 Groundwater

The WSGS is currently completing the Wind-Bighorn River Basin Plan Update Groundwater Level I Study. Tasks in this study related to groundwater availability include identification of the quantity of water available, and safe yield of aquifers within the Basin. Future groundwater use opportunities are based on results of the technical analyses. All work will be presented in the Wind-Bighorn Groundwater Basin Planning Report.

7.3 Water Conservation

Water management in the arid climate of the Basin is challenging because of the timing of water availability compared to water demand. Because of this, storage and water conservation are two critical components in water management. This section discusses current conservation studies, programs, and specific practices within the Basin. Additional information on conservation is presented in Technical Memorandum 6C.

In 1998, the WWDC and the WSEO, in partnership with the USBR, initiated a water conservation program for the state. The water conservation program has a multi-faceted approach to water management and conservation with the following targets: addressing water conservation practices, investigating strategies, evaluating methodology, analyzing implementation ramifications, evaluating impacts and identifying sources of assistance. The program created a conservation component to the state water plan and provides public outreach and education (WWDC 2009). Wyoming has also been involved with the Bridging-the-Headgate partnership. This program brings together federal, state and local agencies, nonprofit conservation organizations and private industries to expand technical resources for conservation activities and assistance programs. One goal of the partnership is to increase awareness and understanding among all partners of each individual group's mission and goals and to increase collaboration of on-farm conservation assistance programs (Headgate 2009). In Wyoming, the project produced a statewide database of water related activities including recent, current, and on-going water quantity and water quality projects which are available on the WWDC website.

7.3.1 Agricultural Water Conservation

Most crop production in the Basin requires irrigation. Agricultural water users can conserve water through improved irrigation efficiency. Sub-surface drip irrigation is the most efficient in water usage (95 percent to 98 percent efficiency), followed by micro-sprinklers (85 percent to 95 percent), pivot sprinkler systems (75 percent to 85 percent), and then furrow and flood irrigation (60 percent to 75 percent; Doll 2009). Flood irrigation and gated pipes are the most commonly used irrigation methods in the Basin. However, center pivot irrigation is being increasingly used as a way to conserve water and maximize production. Data shows that sprinkler use (primarily center pivot) in the Midvale Irrigation District has increased from 10 percent in 1992 to 25 percent in 2007 (SCS 1992; ACE 2007a). While not many such systems are in use in the Basin, micro-irrigation and drip systems with pressure-flow regulation are promising in some situations.

Improving the efficiency of existing sprinkler systems includes improving the system's ability to uniformly distribute water across all plants in the field. This may involve replacing nozzles, ensuring the irrigation pump is in good working condition and not irrigating in high winds. Irrigation scheduling (when and how much to irrigate) can also help achieve maximum water use efficiency. Monitoring the soil moisture in the field is an important part of determining proper irrigation timing. One method used for monitoring soil moisture is the burial of gypsum blocks in the field. Measurement of water in gypsum blocks reflects the amount of water in the soil. Another method is commercially available soil moisture sensors. The Natural Resource Conservation Service (NRCS) also has several computer models and tools available for download online to help with irrigation scheduling (NRCS 2009).

Canal lining and other conveyance system conservation measures can decrease water loss to seepage. The WWDC performs Irrigation System Survey Reports (WWDC 2008b). The entities within the Basin that provided information in the 2008 survey reported the estimated losses, issues and whether or not they have a conservation measure or habitat benefit associated with the system. Not all issues listed can be addressed through conservation measures, but many are related to seepage and maintenance. As shown, conveyance losses can be very high and seepage issues are a common problem listed. However, as previously mentioned, reducing conveyance losses in irrigation canals and improving irrigation application efficiencies can impact aquifers, wildlife habitat and other environmental resources. Often another use is dependent on the return flows produced from such inefficiencies. Consideration of the impact of agricultural conservation measures is important for water managers.

7.3.2 Municipal Water Conservation

The WWDC conducts water system surveys for quantifying municipal water use. Listed in the survey are any conservation measures the municipalities and water districts employ. These include any programs supported by the entity to reduce water consumption and increase public awareness about water conservation, such as a tiered rate structure, subsidies for efficiency and municipal wasting ordinances. In both the 2007 and 2009 surveys, 46 entities within the Basin were listed. In 2007, six entities reported a tiered rate structure, and three reported a wasting ordinance (two of which also reported a tiered rate structure). There were seven entities that reported some other form of conservation measures. In 2009, five entities reported a tiered rate structure. The wasting ordinance and other categories were the same as in 2007. Education and “encouragement” to conserve were included in the “other” category.

Most municipal water conservation studies have found that changes in the national plumbing code that require use of certain maximum capacity toilets, appliances and fixtures create reductions in per capita water use as existing appliances and fixtures are replaced and as new buildings make up a larger percent of the building stock. Potential water conservation strategies that could be implemented within the Basin include rebates for water saving devices, leak detection and rehabilitation programs, and water use audits (TWDB 2009). Generally high water rates and accurately metered usage is perhaps the best conservation measure currently used by water providers in Wyoming. Measures that address outdoor water use for landscape irrigation can be particularly effective at reducing peak use rates.

7.3.3 Industrial Water Conservation

Among the biggest industries in Wyoming is the oil and gas industry. To promote conservation, there is a Wyoming Oil & Gas Conservation Commission (WOGCC 2008). The commission regulates underground injection class II wells on behalf of the EPA. This agency encourages the beneficial and environmentally responsible development of the state’s oil and gas resources. It strives to generate revenue for the general fund which supports other agencies and the benefits they provide to Wyoming. The commission has two major goals:

- to protect human health and the environment by avoiding contamination of the soils and underground and surface water at drilling and producing locations, and
- to ensure those locations are properly reclaimed at the end of production activities so that the land can be returned to beneficial use.

The Commission is charged with preventing waste of hydrocarbons beneath the state’s lands and protecting correlative rights as well as maximizing the state’s resources (WOGCC 2008).

Unlike municipal and agricultural conservation, there is no survey report conducted by WWDC to solicit information on industrial water use conservation. In general, industrial water users in the Basin are actively seeking ways to conserve water. However, the types and amount of conservation generally is not available to the general public. There are various ways industries can conserve water. For example, treated waste water from industrial processes can be used for landscape watering, cooling systems can utilize recycling equipment and evaporative cooling systems can recirculate water. Natural gas producers in southeastern New Mexico have reported in the Sustainable Global Performance report to have utilized innovative water treatment technologies to remove the hydrogen sulfide gas that is entrained in the produced water (API 2006). This water can then be used in the company's drilling operations, thereby reducing the amount of fresh groundwater that has to be used. Produced water from CBNG operations, if treated to meet water quality standards, can also be managed for beneficial uses. For example, it can be utilized for aquifer recharge, constructed wetlands, irrigation water or to augment instream flow targets (Kuipers et al. 2004; ALL 2003).

7.4 Basin Level Water Availability and Use

This section presents a basin-level discussion of existing water uses investigated in the Task 3 technical memoranda, modeling of available flow and shortages developed in Task 4 technical memoranda, and the future water uses discussed in the Task 5 technical memorandum. Information is presented in this section in order to define water needs and frame development of future water use opportunities that are discussed in Chapter 8 of this document. Full information on each of these analyses is presented in the specific memoranda developed for each subject.

Because the Full Supply with the Riverton East Futures Project is the "most likely" future water supply scenario, unless otherwise noted, all of the graphs within this section show flows resulting from this scenario. For all basins but the Wind River Basin, flows and shortages for the Full Supply with Riverton East scenario are the same as those for the Full Supply with Existing Irrigated Lands scenario and the Full Supply for All Futures Projects scenario. Summaries of study area simulated shortages for dry, average and wet years for the Full Supply with River East scenario are presented in Table 61.

The Full Supply with All Futures Project scenario is the highest water use scenario simulated. A summary of shortages for this scenario is presented in Table 62. For this scenario, shortages in the Wind River Basin would increase compared to the Full Supply scenario by approximately 197,600 acre-feet in dry years, 28,500 acre-feet in average years and 17,200 acre-feet in wet years. The dry year value is nearly the full diversion requirement for Futures Projects. Impacts of full Futures Projects development can be problematic to other large diversions in the Upper Wind Basin because return flows for the North Crowheart Project, the largest of the Futures Projects, accrue to the river at locations where they cannot be rediverted by downstream entities as is the current practice.

A map-based summary of available flow, shortages, industrial wells and permitted industrial discharge points is presented in Figure 43, Figure 44, Figure 45, and Figure 46. Shortages shown in these maps are for dry-year hydrologic conditions in the Full Supply with Riverton East scenario, which is a "worst-case" condition for shortages in this scenario. Available flows are shown for dry, average and wet year hydrologic conditions. In addition, permitted industrial water uses and permitted discharges are also shown in the figures.

It should be noted that most available flows are shown on mainstem streams. In many basins, most shortages are on tributaries, meaning some of the available flow may be inaccessible to the diversion structures that need it without significant additional infrastructure (such as new canals, pump stations and/or pipelines). In addition, in some cases, shortages and available flow are reported for the same reach or stream segment. This occurs when there are shortages during low-flow times of the year (typically early spring, late summer and early fall) and available flow during high-flow times of the year (during late spring and early summer). Presentation of available flows by month for all reaches in the model is contained in Technical Memorandum 4C.

Table 61. Summary of Modeled Diversion Shortages – Full Supply with Riverton East

Basin	Full Supply Diversion [(1)] (ac-ft)	Reach Shortages (ac-ft)			Reach Shortages (percent)		
		Dry	Normal	Wet	Dry	Normal	Wet
Madison/Gallatin	0	0	0	0	0%	0%	0%
Yellowstone	0	0	0	0	0%	0%	0%
Clarks Fork	76,404	19,658	11,883	7,647	26%	16%	10%
Sub-Total	76,404	19,658	11,883	7,647	26%	16%	10%
Upper Wind	816,008	64,729	29,011	25,384	8%	4%	3%
Little Wind	345,803	74,358	38,393	27,657	22%	11%	8%
Popo Agie	143,343	8,214	3,263	1,854	6%	2%	1%
Lower Wind	75,736	14,347	10,757	7,043	19%	14%	9%
Sub-Total	1,380,890	161,649	81,425	61,938	12%	6%	4%
Upper Bighorn	393,076	20,009	11,971	7,520	5%	3%	2%
Owl Creek	140,220	64,794	41,266	28,662	46%	29%	20%
Nowood	124,656	10,679	6,905	5,270	9%	6%	4%
Lower Bighorn	146,652	27,485	15,504	9,355	19%	11%	6%
Greybull	457,243	67,566	21,661	6,791	15%	5%	1%
Shoshone	646,384	31,671	20,635	9,922	5%	3%	2%
Sub-Total	1,908,232	222,203	117,942	67,520	12%	6%	4%
Total	3,365,526	403,510	211,250	137,105	12%	6%	4%

Notes:
(1) Full supply diversions include "carrier diversions" that are diversions of water from one location to another with no associated consumptive use (such as a diversion from a river for storage in a reservoir).

Table 62. Summary of Modeled Diversion Shortages – Full Supply with All Futures Projects

Basin	Full Supply Diversion [(1)] (ac-ft)	Reach Shortages (ac-ft)			Reach Shortages (percent)		
		Dry	Normal	Wet	Dry	Normal	Wet
Madison/Gallatin	0	0	0	0	0%	0%	0%
Yellowstone	0	0	0	0	0%	0%	0%
Clarks Fork	76,404	19,658	11,883	7,647	26%	16%	10%
Sub-Total	76,404	19,658	11,883	7,647	26%	16%	10%
Upper Wind	988,450	255,455	57,150	42,604	26%	6%	4%
Little Wind	348,437	74,358	38,393	27,657	21%	11%	8%
Popo Agie	150,587	10,746	3,586	1,854	7%	2%	1%
Lower Wind	75,736	18,706	10,757	7,043	25%	14%	9%
Sub-Total	1,563,210	359,266	109,887	79,159	23%	7%	5%
Upper Bighorn	393,076	20,009	11,971	7,520	5%	3%	2%
Owl Creek	140,220	64,794	41,266	28,662	46%	29%	20%
Nowood	124,656	10,679	6,905	5,270	9%	6%	4%
Lower Bighorn	146,652	27,485	15,504	9,355	19%	11%	6%
Greybull	457,243	67,566	21,661	6,791	15%	5%	1%
Shoshone	646,384	31,671	20,635	9,922	5%	3%	2%
Sub-Total	1,908,232	222,203	117,942	67,520	12%	6%	4%
Total	3,547,846	601,127	239,711	154,325	17%	7%	4%

Notes:
(1) Full supply diversions include carrier diversions.

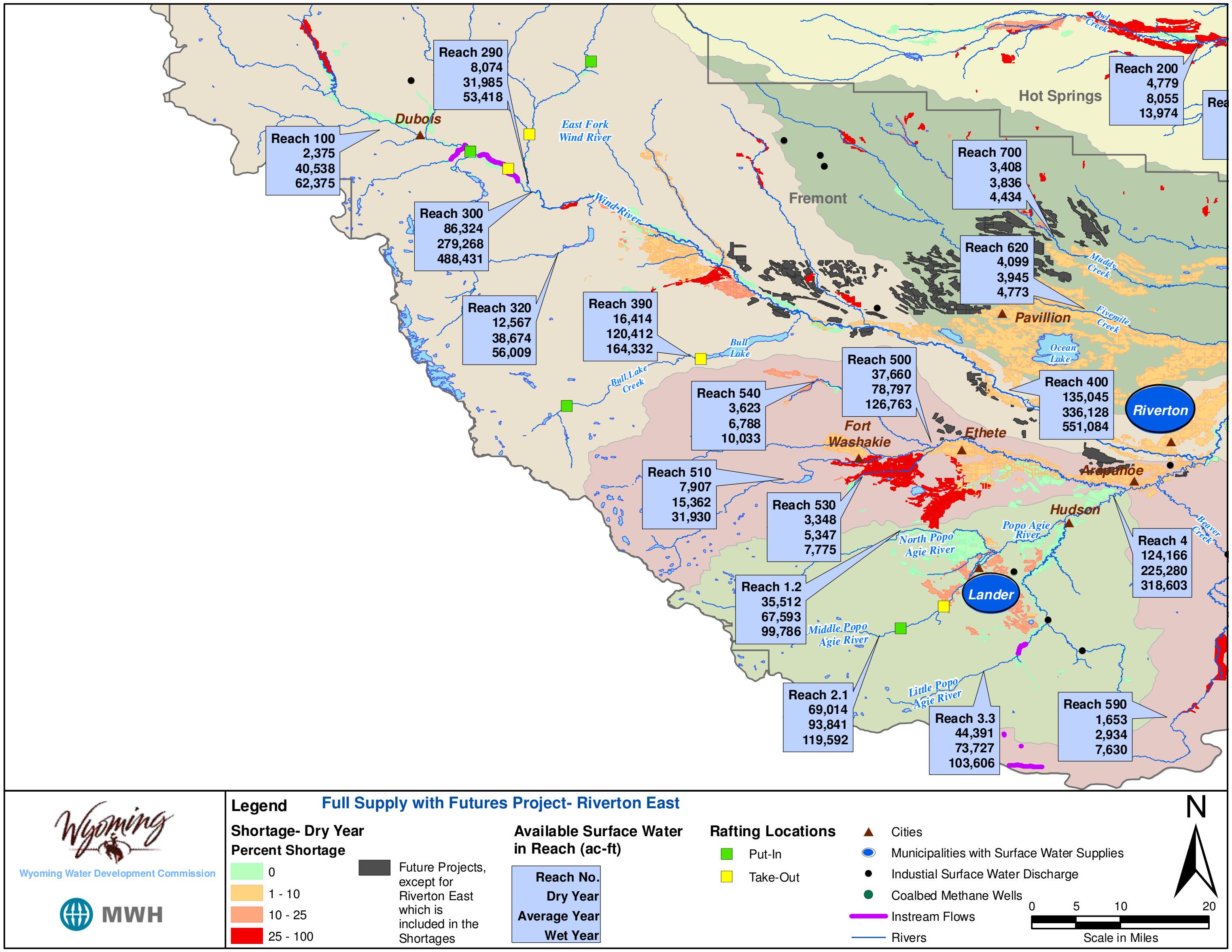

Figure 43. Wind River Basin West - Shortage and Available Flow Map

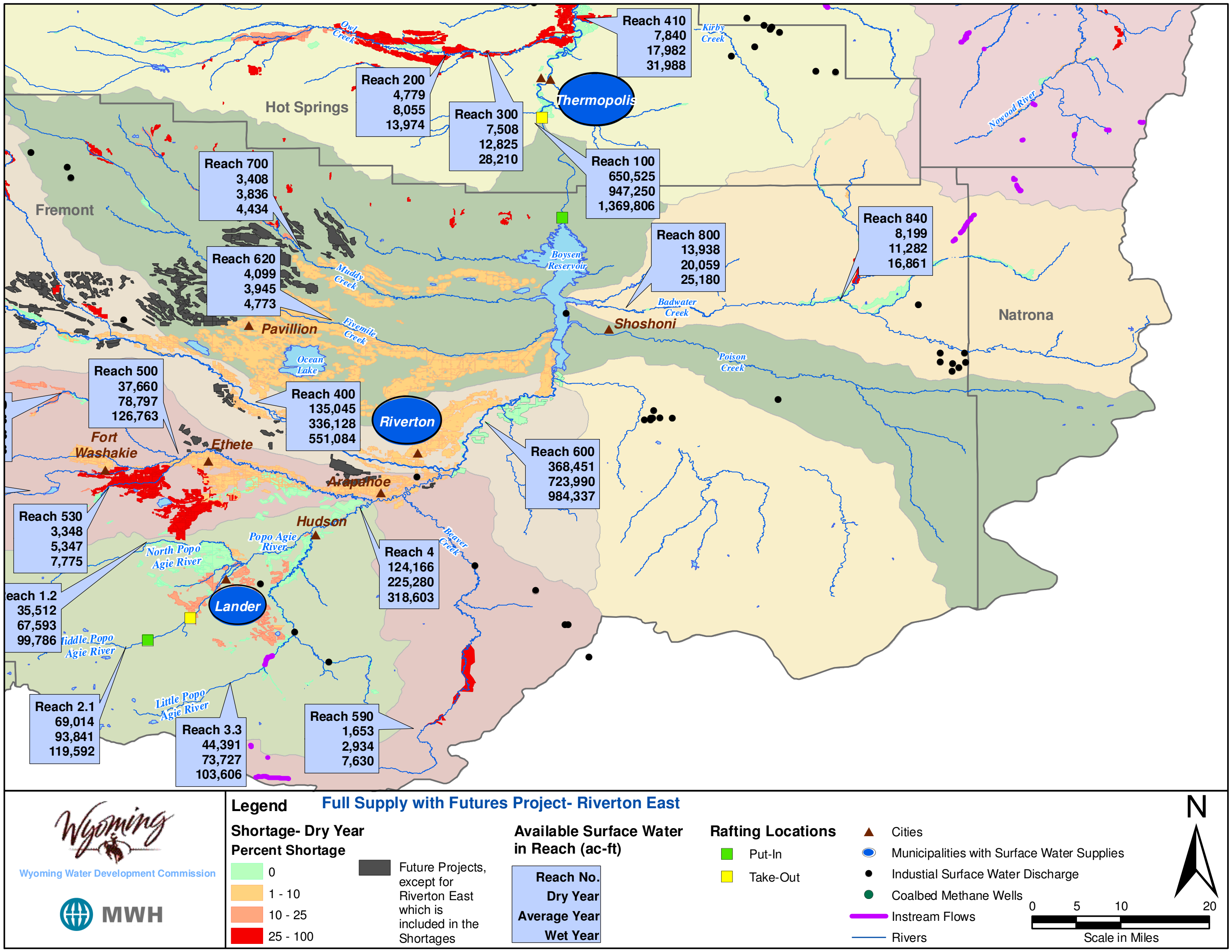

Figure 44. Wind River Basin East - Shortage and Available Flow Map

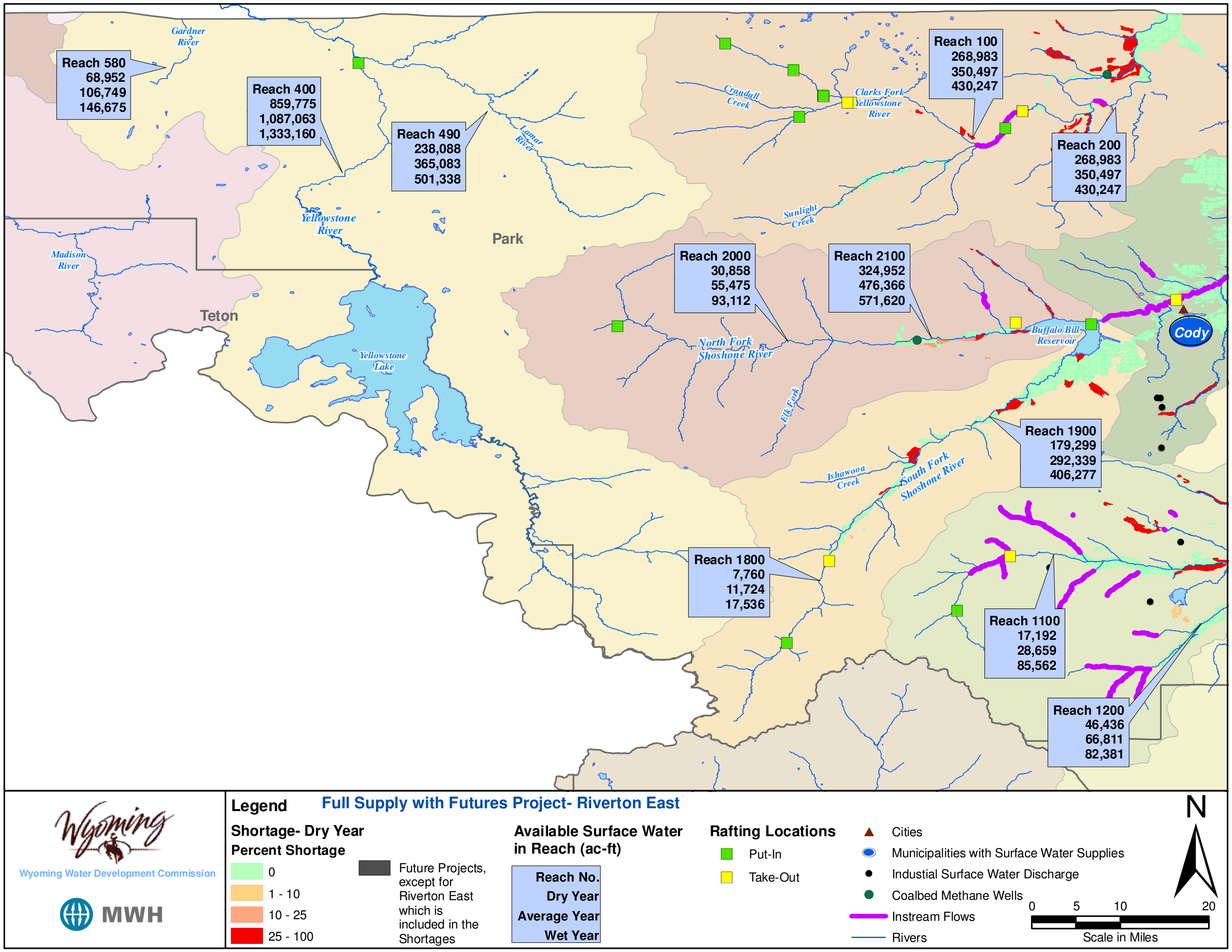

Figure 45. Clarks Fork and Bighorn Basin West - Shortage and Available Flow Map

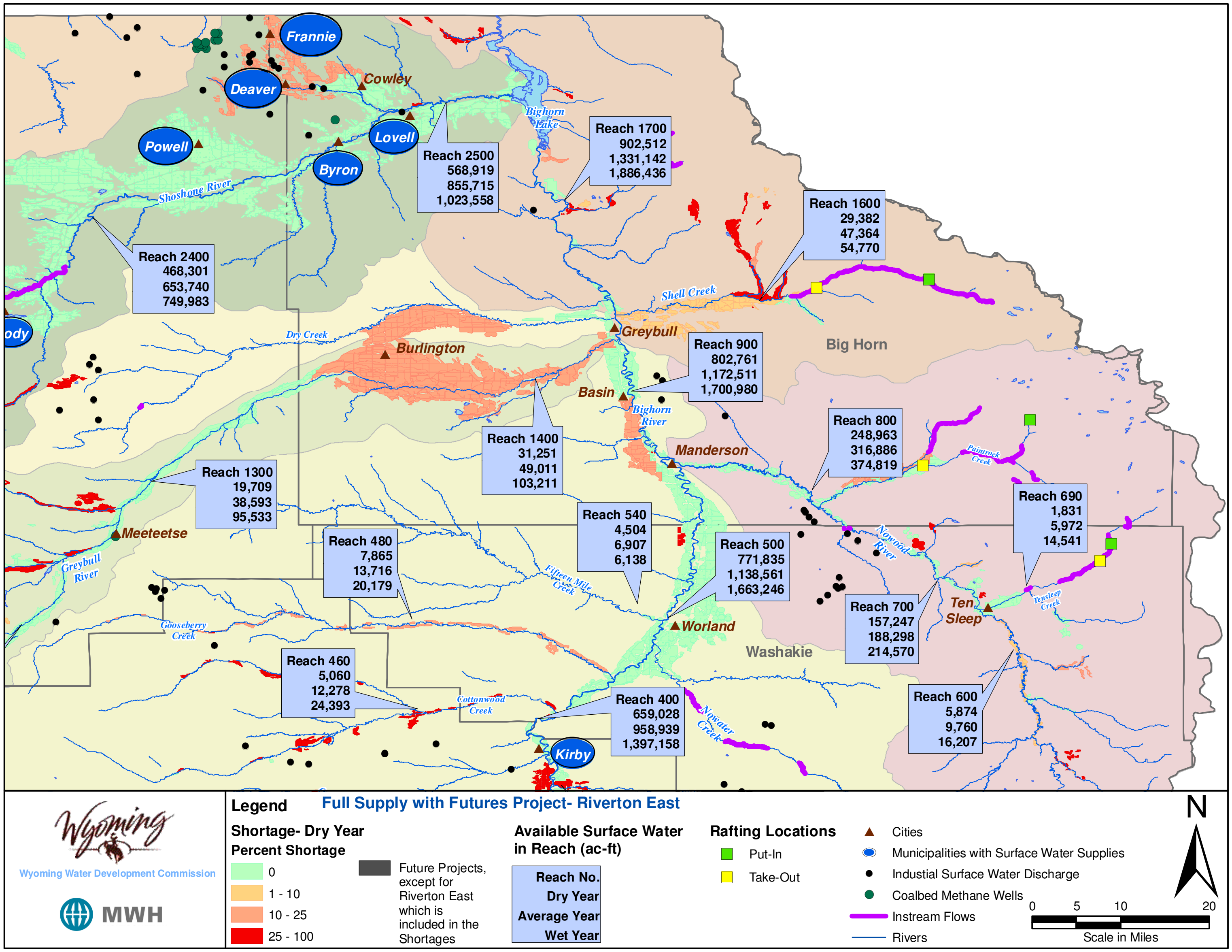

Figure 46. Bighorn Basin East - Shortage and Available Flow Map

The following sections provide available surface water, shortage and existing and future water use summary information for each basin and sub-basin. In some graphs, shortages appear during the same time periods of available flow, which occurs because there may be shortages in some locations within the basin, but available flow at the same time in other portions of the basin, typically in the downstream reaches of the basin. It is important to note that available flow represents flow on the mainstem and shortages may occur in locations where available flow is inaccessible, such as in the tributary regions.

7.4.1 Madison/Gallatin and Yellowstone Basins

The Madison, Gallatin and Yellowstone River Basins are located within the study area of the Basin Plan Update, but are located nearly entirely within the boundaries of Yellowstone National Park. Use of surface water in Wyoming within these sub-basins is primarily limited to use by wildlife and other environmental uses, and uses for potable and non-potable supplies at campgrounds and visitors centers. Spreadsheet models were developed for these sub-basins. However, no diversions or consumptive uses were simulated.

One whitewater rafting reach was identified within these Basins. The reach is located on the Yellowstone River from the confluence with the Lamar River (Tower Junction) to Gardiner, Montana. The flow range for this reach of 350 to 25,000 cfs is met during all months and all hydrologic conditions.

Future water use within these Basins is anticipated to be consistent with historical water uses. No additional uses of water within the Basins were identified, and no issues were identified by the BAG or consultant team regarding current or future water use.

7.4.2 Clarks Fork Basin

Water use within the Clarks Fork Basin in Wyoming is primarily for irrigation, stock water, recreation and environmental uses. A summary of the spreadsheet model available flow and shortage calculations for the Clarks Fork Basin is shown in Figure 47. There are minor shortages within the Basin, primarily on diversions from smaller tributaries such as Paint, Bennett and Line Creeks. There is water available on the mainstem during all times of the year, and in nearly all tributaries especially during runoff events.

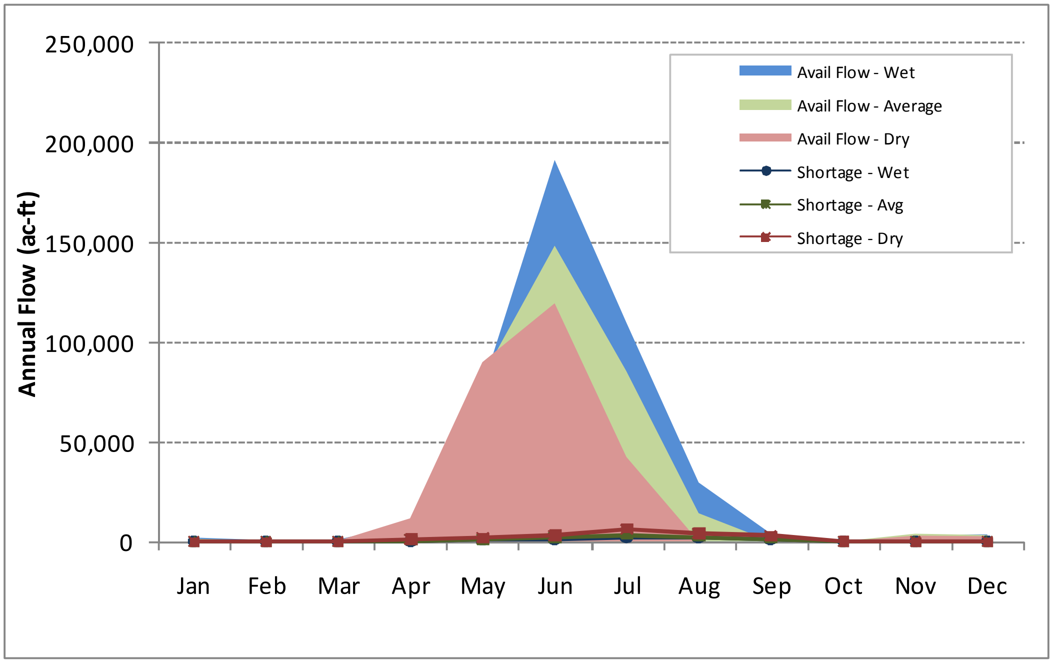

Figure 47. Clarks Fork Basin - Summary of Available Flow and Shortages

There is one permitted instream flow reach on the mainstem of the Clarks Fork. The reach is located on the Clarks Fork downstream of Sunlight Creek and has a target minimum flow rate of 162 cfs. Target instream flows of 200 cfs are met during most months of the year, but are occasionally not met during the fall months in all hydrologic conditions. In addition to the state permitted instream flows, most of the tributaries to the Clarks Fork that are within the Shoshone National Forest have federal reserved bypass flow rights.

Five whitewater rafting reaches were identified on the Clarks Fork, including the Upper, Honeymoon, The Box, Lower and the Styx and Stones segments. Minimum recommended flows in The Box segment of 500 cfs are typically met through August, except for dry years, where flows are met through July. The maximum recommended flow of 1,200 cfs for this segment is exceeded for many months of the year. The four other whitewater rafting reaches on the Clarks Fork have target flows that are not flow based (i.e. they are either based on stage or are not given), and thus not shown. It is expected that these target flows are met in a pattern similar to that shown for The Box.

Future water use within the Clarks Fork Basin in Wyoming is anticipated to be consistent with historical water uses. No additional uses of water within the Basins were identified, and no issues were identified by the BAG or consultant team regarding current or future water use.

7.4.3 Wind River Basin

The Wind River Basin includes the Upper Wind, Little Wind, Popo Agie and Lower Wind sub-basins. Each of these sub-basins was simulated separately by the spreadsheet models. However, existing and future water uses within these sub-basins are interconnected, and thus the discussion that is presented for each sub-basin may have application to the other sub-basins within the Wind River Basin.

Upper Wind

The Upper Wind Basin includes diversions by the "Big 3" districts located near Riverton (Midvale, Riverton Valley and LeClair), diversions for the Upper Wind, Johnstown and Lefthand Units of the Wind River Irrigation Project, and several other smaller ditches. A summary of the spreadsheet model available flow and shortage calculations for the Upper Wind Basin is shown in Figure 48. There are minor early and late season shortages throughout the Upper Wind Basin. In dry years, shortages are more persistent throughout the year, especially in tributary locations. For the Full Supply with Riverton East Futures Project scenario, there is water available on the mainstem during average and wet years, especially during peak runoff conditions. Most tributary locations have minor amounts of water available during dry and average hydrologic conditions, and more substantial amounts during wet hydrologic conditions. It should be noted that although the spreadsheet model, which operates on a monthly timestep, does not show effects of the Riverton East Project on other water users in the Basin, there may be certain days within a month when existing water users would need to bypass flows to meet Riverton East diversion requirements.

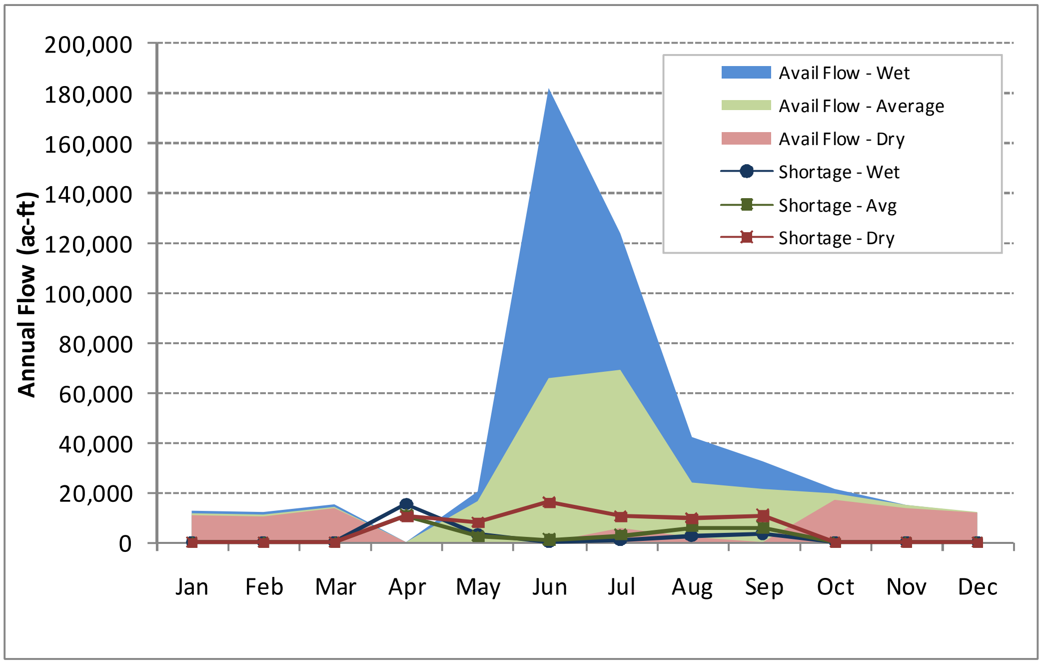

Figure 48. Upper Wind Sub-Basin - Summary of Available Flow and Shortages

There are two state permitted instream flow segments in the Upper Wind Basin. The Wind River instream flow segment is located between Torrey Creek and the East Fork Wind River. The target flows in this reach are 102-110 cfs are met in this reach during all months and hydrologic conditions. The other instream flow location is located on Jakeys Fork. Target flows of 3 cfs are also met during all months and all hydrologic conditions. In addition to the state permitted instream flow segments, several of the tributaries to the Wind River and East Fork Wind River that are within the Shoshone National Forest and on the Wind River Indian Reservation have federal reserved bypass flow rights.

There are several whitewater rafting locations within the Upper Wind Basin, including the Wind River in approximately the same location as the state permitted instream flow reach, the East Fork Wind River and Bull Lake Creek above Bull Lake. None of these locations have recommended flow ranges identified, thus, comparisons to simulated flows are not presented. There are designated public fishing sites scattered throughout the Upper Wind Basin.

Current municipal surface water use within the Upper Wind Basin is primarily limited to the City of Riverton, which diverts water from the Wind River via LeClair Canal during summer months. The City of Riverton depends on water supply from bedrock aquifers for its baseload water supply. There are also some scattered industrial water uses in the Upper Wind Basin, including several with permitted industrial discharge of several thousand acre-feet per year.

The most significant future water use in the Upper Wind Basin (and in the study area as a whole) is the potential full development of Tribal Futures Projects. Tribal Futures Projects could ultimately result in an additional 53,760 acres of irrigated lands (including lands in the Little Wind, Popo Agie and Lower Wind Basins) requiring an additional 209,300 acre-feet of diversions. The Upper Wind Basin is the most affected sub-basin from this potential development. Figure 49 presents a summary of simulated shortages and surface water availability from the spreadsheet models for the Full Supply with All Futures Projects scenario. Model results show that shortages would increase for all hydrologic conditions, but be the most pronounced during dry hydrologic conditions. During dry years, shortages would increase to approximately 26 percent for the Upper Wind Basin as a whole, but would increase to nearly 40 percent for Reach 400, which encompasses the “Big 3” irrigation districts. In addition to greater shortages, the amount of water available for storage would decrease. However, there would still be water to store, especially in wet hydrologic conditions that could be used to meet much of the shortage in demand during dry years.

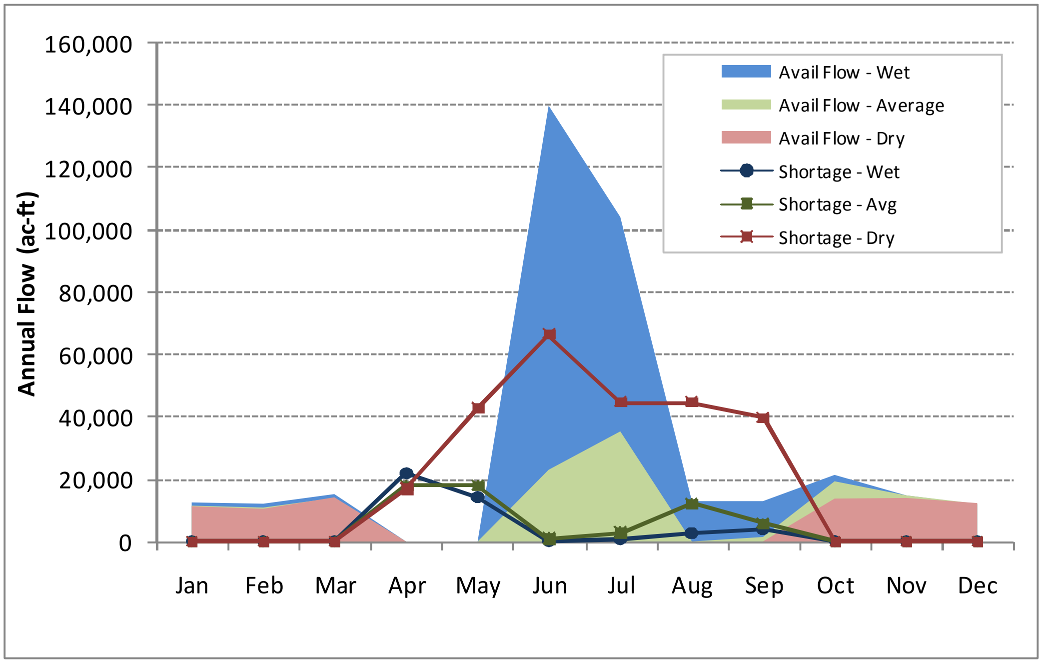

Figure 49. Upper Wind Sub-Basin - Summary of Available Flow and Shortages Full Supply with All Futures Projects Scenario

In addition to Tribal Futures Projects, future water use in the Upper Wind Basin would occur due to additional municipal growth, especially in Riverton, and due to potential expansion of industrial uses.

Although the amount of water required to serve expected municipal, domestic and industrial growth is relatively minor when compared to hydrology and other uses in the Upper Wind Basin, the development of Tribal Futures Projects could present issues with the reliability of this water supply, especially during drought conditions. Expanded industrial uses could occur primarily as a result of increased petroleum based extractions.

The public and WGFD have identified the Wind River through Dubois as a potential future instream flow segment. In addition, the Tribes have expressed interest in the past in having instream flow segments designated on the Wind River within the Reservation.

Flow in the Upper Wind River is dependent upon glacial melt from the Dinwoody glaciers and other glaciers in the northwestern Wind River Range. Research conducted back to the 1930's has shown that the glaciers are receding, and several studies are on-going to further examine rates of recession (Tootle et al. 2007). It is estimated that the glaciers in the Wind River Range contribute approximately 8 percent of the flow volume in the Upper Wind River. Therefore, if full melt out of the glaciers were realized, it can be concluded that flow volume in the Upper Wind and its tributaries could be reduced by up to 8 percent (Pochop et al. 1990). This could decrease future water supply availability and increase future shortages. See Technical Memorandum 6C for more information on glaciers.

<u>Little Wind</u>

The Little Wind Basin primarily serves the Little Wind Unit of the Wind River Irrigation Project on the Wind River Indian Reservation. There are several smaller ditches on tributaries and on the Little Wind mainstem. A summary of simulated diversion shortages and water supply availability in the Little Wind Basin is presented in Figure 50. Diversion shortages occur in the Little Wind Basin during all hydrologic conditions and peak in the later summer and early fall. Diversion shortages for August and September average 35 percent, 23 percent, and 21 percent for dry, average and wet hydrologic conditions, respectively. The analysis shows that there is adequate water availability during peak runoff events in average and wet years to meet at least a portion of these late season shortages if adequate storage were developed.

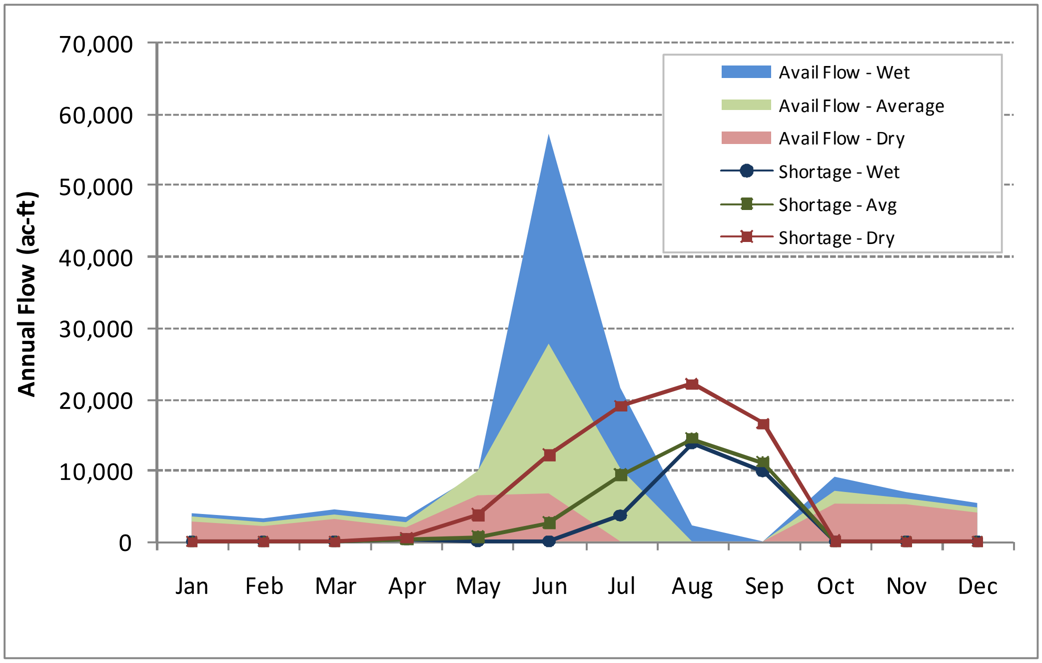

Figure 50. Little Wind Sub-Basin - Summary of Available Flow and Shortages

As the Little Wind Basin is nearly entirely located within the Wind River Indian Reservation, there are no state permitted instream flows in the Little Wind Basin. Federal reserved bypass flow rights are located on a couple of small streams located fairly high in the basin. Additionally, there are no substantial municipal surface water diversions, and industrial uses are fairly limited. There are tribal uses of water within the Little Wind Basin, including recreational and environmental uses, and water uses for cultural purposes. There are also designated public fishing sites scattered throughout the sub-basin, primarily in the higher headwaters streams of the North Fork and South Fork of the Little Wind.

Future water use within the Little Wind Basin would primarily be a result of development of Tribal Futures Projects. Impacts to upstream uses within the Little Wind Basin would be fairly limited because the diversions from the Little Wind for Futures Projects are fairly minor and diversion points for these projects are downstream of the Wind River Irrigation Project return flows.

Popo Agie

The Popo Agie Basin serves several minor to mid-sized agricultural diversions, as well as municipal, recreational and environmental uses. A summary of simulated shortages and available flow within the Popo Agie Basin is presented in Figure 51. Simulated shortages are fairly minor, although shortages do exist on the upper portions of the mainstem and some tributaries, especially on the Middle Popo Agie and Roaring Fork. The analysis shows that there is available flow for development during all hydrologic conditions and at most locations.

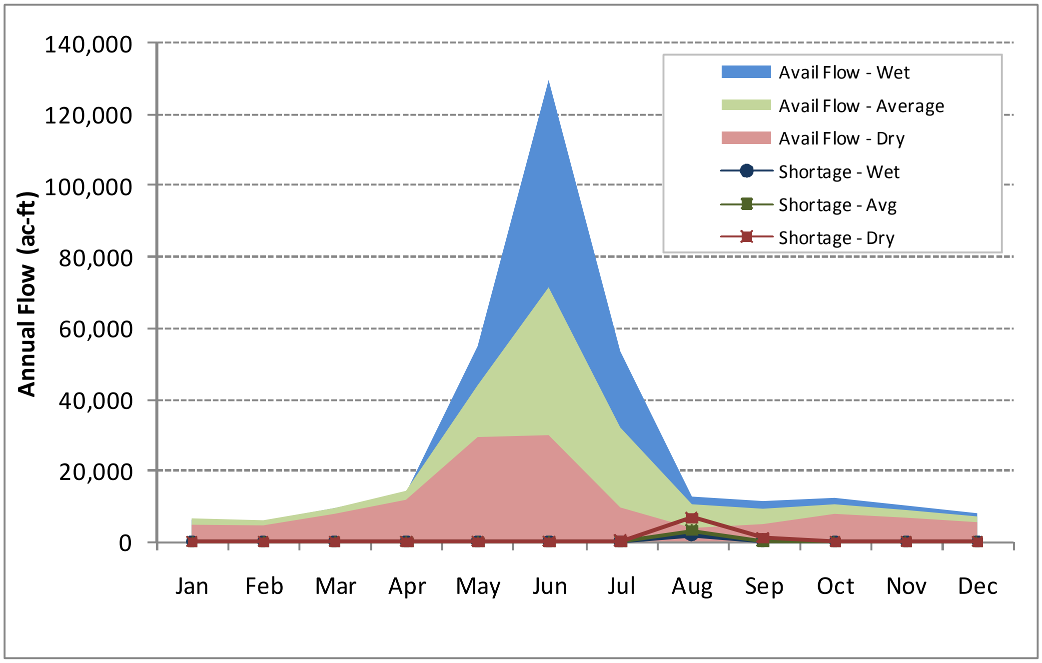

Figure 51. Popo Agie Sub-Basin - Summary of Available Flow and Shortages

There is one permitted instream flow segment within the Popo Agie Basin. The segment is located on the Little Popo Agie in the public fishing area near Lander. Target flows for this reach are 21 to 45 cfs. These target flows are nearly always met, with the exception of the late summer months during dry years when the 45 cfs target flow is not met. In addition to the one state permitted instream flow right on the Little Popo Agie above the Sinks, there are several tributaries within the Popo Agie Basin that have federal reserved bypass flow rights.

One whitewater rafting reach is located in the Popo Agie Basin on the Middle Popo Agie above the Sinks. Minimum recommended flows of 200 cfs are met during the early summer months, but are not met during the later months of the summer. The maximum recommended flow is 1,000 cfs, which is not exceeded on an average monthly basis, but may be exceeded on a daily basis. In addition to whitewater rafting opportunities, the North Fork of the Popo Agie River is classified as a Blue Ribbon fishery. There are designated public fishing sites scattered throughout the Popo Agie Basin.

The city of Lander diverts surface water for its municipal water supply. Diversions by Lander are relatively minor, and typically would not be affected by current or future water uses in the lower portion of the Popo Agie Basin. However, Lander did experience some water supply shortages during the 2000's drought. Lander is currently investigating potential groundwater supplies to supplement its surface water diversions (Weston 2007).

The most substantial potential future consumptive water use in the Popo Agie Basin is the Arapaho Canal Futures Project. This project would divert water in the vicinity of the existing Sioux Ditch on the North Popo Agie. Diversions for this project would decrease flow in this reach below the point-of-diversion. Furthermore, most return flows for this project do not accrue back to the Popo Agie Basin, so this magnitude of flow decrease would occur down the North Popo Agie and mainstem to its confluence with the Little Wind River. The most substantial effects are during late summer months when streamflows would decrease by approximately 50 percent.

In the future, it is expected that environmental and recreational water use will continue to expand. The WGFD has identified several other segments where the public has expressed interest in instream flow water rights within the Popo Agie Basin, including segments on the Middle Fork through Lander, the North Popo Agie and Red Canyon Creek. The area continues to grow as a center for outdoor recreational opportunities, including fishing, whitewater rafting and kayaking, and other water related activities.

Lander will continue to grow in the future, possibly leading to increased surface water diversions. However, Lander is also investigating the possibility of drilling wells into the Tensleep formation for supplemental supplies (Boyce 2009). Because Lander's primary surface water is on the Middle Popo Agie, which does show some shortages during all hydrologic conditions, there does remain the possibility for shortages under increased surface water diversions especially in drought years.

<u>Lower Wind</u>

The Lower Wind Basin encompasses the Wind River below the Little Wind confluence through Boysen Reservoir, and tributaries to the Wind River within this reach. A summary of water supply availability and surface water shortages is presented in Figure 52. Shortages primarily occur on tributaries both east and west of the river north of Riverton. Shortages occur during all months of the year on several of these tributaries even during average and wet years. A significant amount of available flow exists on the mainstem of the Wind River. However, this water would be unavailable to most of the tributaries experiencing shortages without extensive and likely expensive conveyance infrastructure. There are small amounts of available flow on tributaries, primarily in spring months, if storage were available.

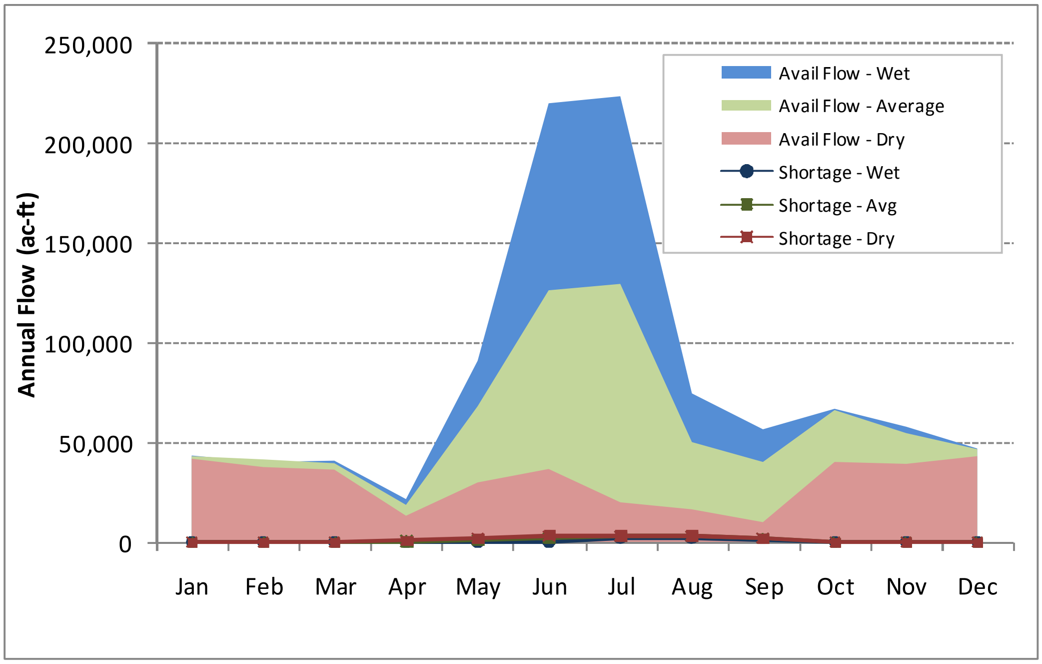

Figure 52. Lower Wind Sub-Basin - Summary of Available Flow and Shortages

There are no state permitted instream flows within the Lower Wind Basin. There is an identified whitewater rafting reach on the Wind River below Boysen Reservoir. Recommended flows for this whitewater rafting reach are not flow based, and thus streamflow is not presented. Because of streamflow regulation by Boysen Reservoir, flows within this boating reach are typically more reliable than other natural flow whitewater reaches. In addition to whitewater reaches, flat water recreation on Boysen Reservoir is an important water use within the Lower Wind Basin.

There are no significant municipal water uses in the Lower Wind Basin. There are a significant number of industrial wells and permitted industrial discharges within the Lower Wind Basin. Most of these wells are associated with oil and gas production in the Gas Hills region at the eastern portion of the Basin. Produced water from these uses could present a surface water use opportunity if water quality of the produced water was adequate for the potential use.

As with the Upper Wind Basin, the most significant potential future water use within the Lower Wind Basin is Tribal Futures Projects. Because return flows from Futures Projects enter this Lower Wind Basin, diversions in the mainstem are not significantly affected by Futures Projects. As discussed in Tech Memo 4C, there is the possibility of Futures Projects affecting storage in Boysen Reservoir over the long term. The other most substantial future water use and potential water producer is produced water from oil and gas extraction. The high water use scenario suggests that oil and gas production would increase beyond existing levels, which would likely result in an increased level of produced water in the eastern portions of the Lower Wind Basin.

The public and WGFD have identified the Wind/Bighorn River from Boysen Reservoir to Thermopolis as a potential future instream flow segment.

7.4.4 Bighorn Basin

The Bighorn Basin includes the Upper Bighorn, Old Creek, Nowood, Lower Bighorn, Greybull and Shoshone Basins. As with the Wind River Basin, each of these basins was simulated separately by the spreadsheet models. However, existing and future water uses within these basins are interconnected, and thus the discussion presented for each basin may have application to the other basins within the Bighorn Basin.

The spreadsheet models do not show any impacts of Futures Projects development downstream of Boysen Reservoir. As previously discussed, this is because Boysen Reservoir acts as a "buffer" between the Wind and Bighorn Basins. More storage within the reservoir can be used to meet downstream demands. The spreadsheet models do not simulate carryover storage. Analysis of simulated storage contents for the Full Supply with All Futures Projects scenario show that the amount of storage in Boysen Reservoir could potentially be affected by Futures Projects development. More detailed carryover storage analysis is necessary to estimate effects of Futures Projects development in the Bighorn Basin.

Upper Bighorn

The Upper Bighorn Basin includes the Bighorn River downstream of the Wind River Canyon and associated tributaries except the Owl Creek Basin and the Nowood Basin. Major diversions on the mainstem include the Bighorn Canal, Upper and Lower Hanover Canals, and flows in the Bighorn River are highly regulated by Boysen Reservoir, which is operated to minimize shortages for several of the canals and smaller ditches on the mainstem of the Bighorn River. A summary of simulated available flow and shortages within the Upper Bighorn Basin is presented in Figure 53. Shortages exclusively occur on tributary streams, including Kirby Creek, Cottonwood Creek, Grass Creek and Gooseberry Creek. Shortages on some of these tributaries exceed 50 percent during dry years and 30 percent during average years. Flow is available within some of the major tributaries to meet most or all of the annual shortages if adequate storage facilities were in place.

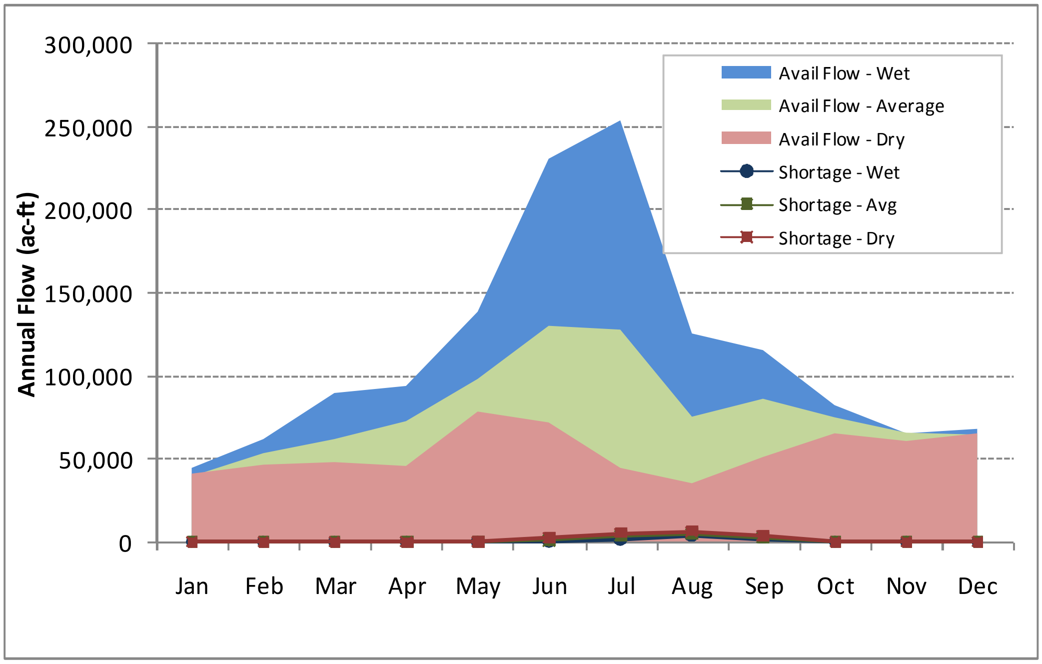

Figure 53. Upper Bighorn Sub-Basin - Summary of Available Flow and Shortages

There are no state permitted instream flows or federal reserved bypass flow rights within the Upper Bighorn Basin. Furthermore, there are no whitewater rafting reaches. However, the Bighorn River is a designated Blue Ribbon Stream Reach from Wedding of the Waters to Black Mountain Road. There are also several designated public fishing sites along the Bighorn River within this Blue Ribbon Stream Reach.

Municipal surface water uses within the Upper Bighorn Basin are primarily by the town of Thermopolis and the communities that it serves. Most of the water supply for the town is diverted from the Bighorn River. Industrial water uses and surface water discharges are substantial, especially those in the Hamilton Dome area of the Cottonwood Creek drainage and in the Gooseberry Creek drainage as a result of oil and gas production. Permitted discharges exceed several thousand acre-feet per year.

The largest potential future water use within the Upper Wind Basin is the proposed Westside Project, which would divert water from the Bighorn River and irrigate new lands in the Worland area west of the river. This project has the potential to irrigate 9,300 acres with a diversion requirement of approximately 18,600 acre-feet (BLM 2008). These diversions have not been included in the Full Supply with All Futures Projects scenario[9]. Based on the surface water availability calculations, the

[9] The Westside Project was not included in the spreadsheet model because its diversion requirements are much less than the available flow within this reach for all scenarios, and its impact on other water users and available flow for other opportunities was determined to be negligible.

diversion requirements are within the water supply availability estimates calculated on the Bighorn River for all conditions.

Increases in municipal water use are likely to occur due to growth in the town of Thermopolis. However, this increased municipal water use is minor compared to the flow in the river, and because of storage in Boysen Reservoir, the diversions are unaffected by seasonal low flows or drought conditions.

Changes in industrial uses within the Upper Wind Basin are possible. However, the economic projections show that in the mid-use (or most likely) scenario, there is a possibility of decreased future oil and gas production. Decreases in oil and gas production, and associated decreases in produced water, could have a negative effect on streamflow in the smaller tributaries. It should be noted that watershed planning has occurred in both the Cottonwood/Grass Creek drainage and the Gooseberry Creek drainage to identify potential storage opportunities (see Chapter 3). The public and WGFD have identified the Bighorn River below Worland as a potential future instream flow segment.

Owl Creek

Surface water uses within the Owl Creek Basin are primarily for agricultural purposes, including irrigation and stock water uses. A summary of simulated irrigation shortages and available surface water within the Owl Creek Basin is presented in Figure 54. Shortages within the Old Creek Basin are substantial and occur during all hydrologic conditions and during all months of the year. Furthermore, the amount of available flow is limited. Although there is some flow available in wet and average years, this available flow is inadequate to meet shortages in the wet and average years. Therefore, there is little opportunity to carry over flow from wet and/or average years for use in dry years. Shortages in the Owl Creek Basin are 46 percent of Full Supply diversion requirements in dry years, 29 percent in average years and 20 percent in wet years.

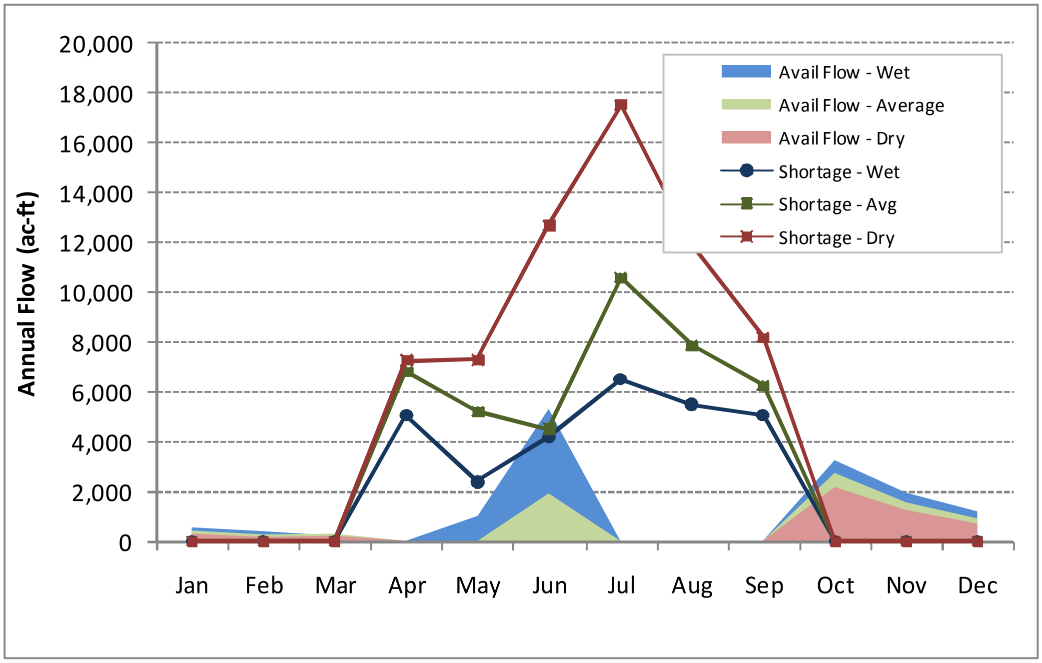

Figure 54. Owl Creek Sub-Basin - Summary of Available Flow and Shortages

There are no state permitted instream flows within the Owl Creek Basin. There are some federal reserved bypass flow rights in the high reaches located in the Shoshone National Forest. There are no whitewater rafting reaches within the Owl Creek Basin.

There are no significant municipal water uses within the Owl Creek Basin, and industrial water uses are limited.

Future water use within the Owl Creek Basin is anticipated to be approximately the same as existing water use. None of the economic growth factors used to develop future water uses show significant changes within the Owl Creek Basin.

Nowood

Water use in the Nowood Basin is primarily small and mid-sized irrigation diversions and several upland stock ponds for stock and wildlife. There are recreational and environmental uses on some of the tributaries, especially Tensleep Creek. There are a few smaller reservoirs on tributaries, but no large reservoirs. Figure 55 presents a summary of available flow and shortages within the Nowood Basin. Shortages occur in summer months for all hydrologic conditions. Shortages occur in several tributaries as well as the upper reaches of the Nowood River above Tensleep Creek. There is some available flow on most tributaries during spring months during all hydrologic conditions and larger amounts of available flow on the mainstem, especially below Tensleep Creek.

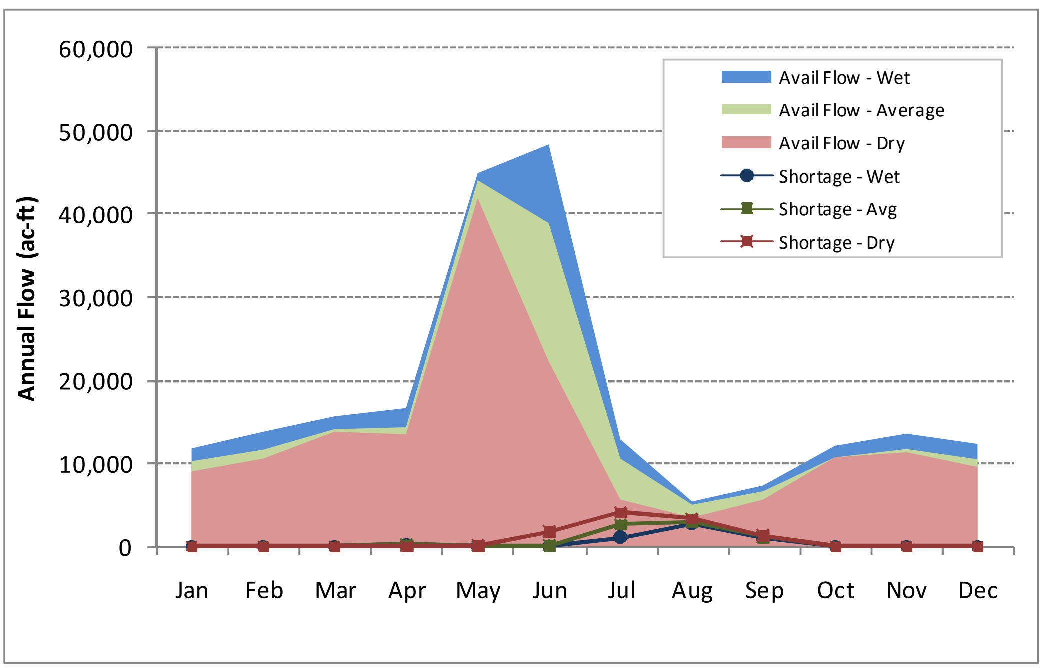

Figure 55. Nowood Sub-Basin - Summary of Available Flow and Shortages

The upper instream flow segment on Tensleep Creek is from the confluence of the East and West Fork of Tensleep Creek to the Bighorn National Forest boundary. The target flow rate in this reach of 22 cfs is met during runoff conditions and typically is not met during the winter months during all hydrologic conditions. The lower segment (just upstream of Canyon Creek) has a less restrictive target flow rate (4.76 cfs) and flows are always met. The Medicine Lodge Creek instream flow segment (9-20 cfs) was permitted in February 2010[10]. In addition to the state permitted instream flow segments, there are several federal reserved bypass flow rights on small tributaries in the upper portions of the Tensleep Creek Basin within the Bighorn National Forest.

There is also a whitewater rafting reach identified in Tensleep Creek along Highway 16 to the bottom of the switchbacks. The minimum target flow for this reach is 250 cfs. This target flow is met during the early summer months during wet years, during June in average years and is not met during dry years. A whitewater rafting segment has also been identified on Paintrock Creek. However, its target flows are not based on flow rates, and thus it is not compared to model results. There are also several designated public fishing sites in the Nowood Basin, primarily located on Tensleep Creek, Paintrock Creek, and tributaries to Paintrock Creek.

There is some minor groundwater municipal water use in the Nowood Basin by Tensleep and Hyattville and no municipal surface water use. Worland's wells used in the Big Horn Regional Water Supply System are located within the Nowood Basin, although the use of these wells is primarily in the Upper and Lower Bighorn basins. Industrial water use is related to oil and gas extraction wells.

Future water use within the Nowood Basin is anticipated to be approximately the same as existing water use. There will likely be additional development of groundwater resources to serve growth in municipal areas. None of the economic growth factors used to develop future water uses show significant changes within the Nowood Basin. The public and WGFD have identified the Nowood River below Harmony Ditch as a potential future instream flow segment.

Lower Bighorn

Major water uses in the Lower Bighorn Basin are for small and mid-sized irrigation diversions primarily on tributaries to the Bighorn River between the Greybull River and Bighorn Lake, and environmental and recreational water uses, especially along Shell Creek. The largest of the tributaries are Shell Creek and Beaver Creek. A summary of shortages and available flow in the Lower Bighorn Basin are presented in Figure 56. Shortages are relatively minor when compared with the available flow in the Bighorn River. However, much of the available flow on the mainstem is unavailable to tributaries that experience shortages. Shortages on several of the minor tributaries to the Bighorn River exceed 50 percent for all hydrologic conditions. Shortages on Shell Creek are minor, with only a very small shortage during dry years. Beaver Creek experiences shortages of slightly more than 50 percent during dry years, 19 percent during average years and 5 percent during wet years. There is available flow on most tributaries during spring, including both Shell Creek and Beaver Creek. However, some of the smaller tributaries have very limited available flow.

[10] Due to the recent approval of this instream flow water right, available flow estimates in this document for Medicine Lodge Creek upstream of this segment do not include reduced water availability as a result of the water right.

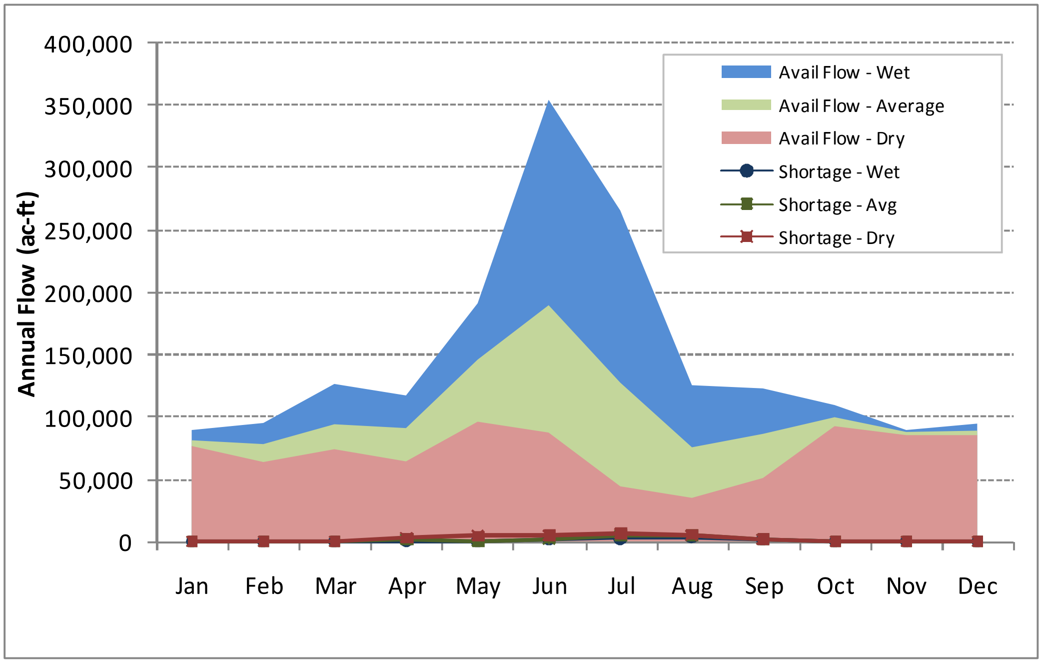

Figure 56. Lower Bighorn Sub-Basin - Summary of Available Flow and Shortages

There are two state permitted instream flow segments within the Lower Bighorn Basin, both on Shell Creek. The first is from Adelaide Creek to Shell Falls and varies from 19 to 70 cfs, while the second is from Shell Falls to the Forest Service boundary just upstream of White Creek and varies from 23 to 40 cfs. For the Adelaide Creek to the Shell Falls segment, target flows are typically met, with the exception of April during wet years and October during average and dry years. For the downstream segment, target flows are nearly always met, with the only exception during October in dry years. In addition to the state permitted instream flow segments, there are also several federal reserved bypass flow rights on several of the tributaries within the Bighorn National Forest.

There is one identified whitewater rafting segment on Shell Creek. The segment is from Cabin Creek to the Forest Service boundary, and recommended flows vary from 200 cfs to 1,000 cfs. Streamflow exceeds minimum recommended values during early summer months for all hydrologic conditions, and diminishes below minimum recommended values during late summer months. There are no designated Blue Ribbon fisheries in the Lower Bighorn Basin. However, there are several designated public fishing sites along the Bighorn River, Shell Creek and at Bighorn Lake.

Municipal water use in the Lower Bighorn Basin is primarily from deep bedrock wells. There are no significant municipal surface water uses in the Basin. Greybull has experienced water shortages during drought conditions due to capacity limitation in its wells at the time (EA 2003a). Industrial water use is primarily groundwater for oil and gas extraction and associated surface water discharges. However, the amount of industrial use is less in the Lower Bighorn Basin than other sub-basins in the Bighorn Basin.

Future water use within the Lower Bighorn Basin is anticipated to be approximately the same as existing water use. There will likely be additional development of groundwater resources to serve growth in municipal areas. None of the economic growth factors used to develop future water uses show significant changes within the Lower Bighorn Basin. The public and WGFD have identified a segment on Shell Creek below the Whaley Ditch headgate as a potential future instream flow segment.

Greybull

Water uses in the Greybull Basin include diversions for irrigation throughout the Basin, and recreational and environmental water uses in the upper portion of the Basin. A summary of shortages and available flow within the Greybull Basin as simulated by the spreadsheet models is shown in Figure 57. Overall simulated shortages in the Greybull Basin are 15 percent in dry years, 5 percent in average years and 1 percent in wet years. All simulations in the Greybull Basin were conducted assuming full operations of the newly constructed Greybull Valley Reservoir. Although this reservoir significantly reduces shortages to the single largest user in the Greybull Basin, the Greybull Valley Irrigation District, there are still some shortages simulated within the district, especially during dry hydrologic conditions, when shortages are nearly 20 percent. However, it should be noted that the spreadsheet model was not optimized to coordinate operations of Upper and Lower Sunshine Reservoirs and Greybull Valley Reservoir. It is likely that these shortages would be reduced in the model if these operations were optimized. It should also be noted that the spreadsheet models do not consider water rights, and allocate water to upstream uses first. Therefore, a portion of the shortages simulated in the Greybull Valley Irrigation District may also occur in upstream reaches. Shortages in the Greybull Basin are reported by local water users to be low with Greybull Valley Reservoir in place. The remaining simulated shortages occur in minor tributaries, especially in dry and average hydrologic conditions. There remains some available flow in most tributaries and the mainstem primarily during wet hydrologic conditions.

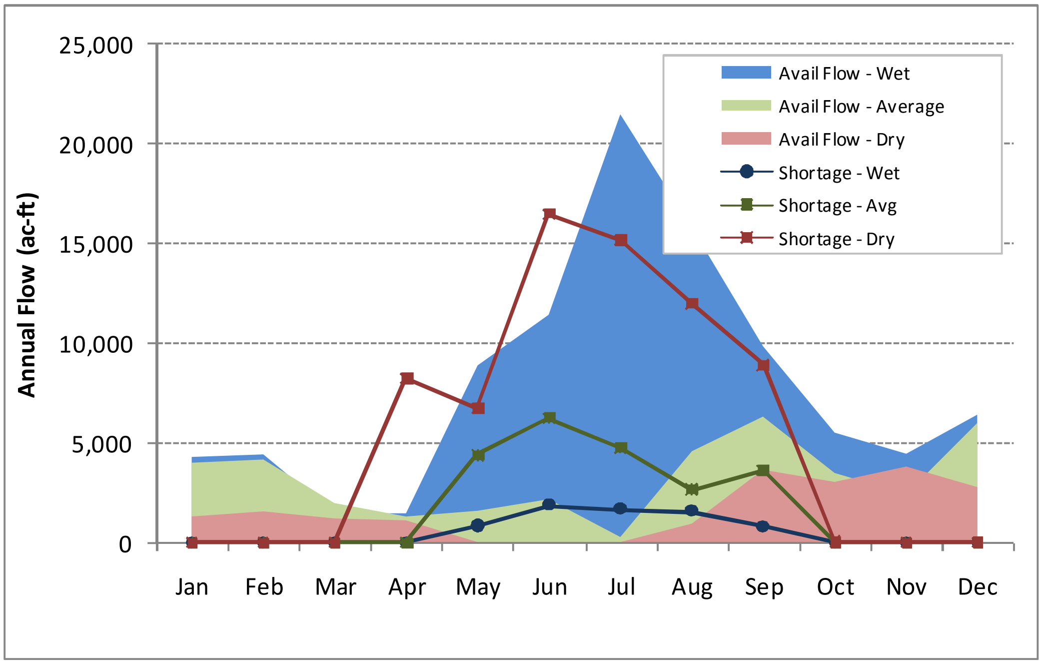

Figure 57. Greybull Sub-Basin - Summary of Available Flow and Shortages

There are several instream flow segments in the headwaters area of the Greybull River Basin, including segments on the Greybull River, Piney Creek, Francs Fork, Timber Creek, Jack Creek, two segments on Pickett Creek, the South Fork and Middle Fork of the Wood River, and two segments on the Wood River. The frequency of which the target flows are met varies by location, hydrologic condition, and month, with several locations showing that target flows are not met during several months and in several hydrologic conditions. In addition to the state permitted instream flow segments, there are federal reserved bypass flow rights on most of the smaller tributaries within the Shoshone National Forest.

There is one whitewater rafting segment in the Greybull River from Venus Creek to the Forest Service boundary. Recommended minimum and maximum streamflows for this segment are not available. There are a several designated public fishing sites, primarily in the lower portion of the Greybull River.

There are only minor municipal water uses within the Greybull Basin primarily from groundwater resources, and industrial water uses are limited.

Future water use within the Greybull Basin is anticipated to be approximately the same as existing water use. There will likely be additional development of groundwater resources to serve growth in municipal areas. None of the economic growth factors used to develop future water uses show significant changes within the Greybull Basin. The public and WGFD have identified additional segments as potential locations for future instream flows, including two segments on the Greybull River and one segment on Franc Creek.

<u>Shoshone</u>

The Shoshone Basin contains several major irrigation diversions, substantial municipal uses and significant environmental and recreational water uses. Major irrigation diversions and most municipal uses are provided water from Buffalo Bill Reservoir. A summary of spreadsheet model simulated shortages and water availability is shown in Figure 58. Shortages only occur on tributaries – there are no simulated shortages on the North Fork, South Fork, or the Shoshone River below Buffalo Bill Reservoir. Shortages in tributaries can be substantial, exceeding 60 percent in some locations. Although there is a significant amount of available flow on the mainstem, for some of the tributaries with significant shortages, the available flow to meet shortages is limited.

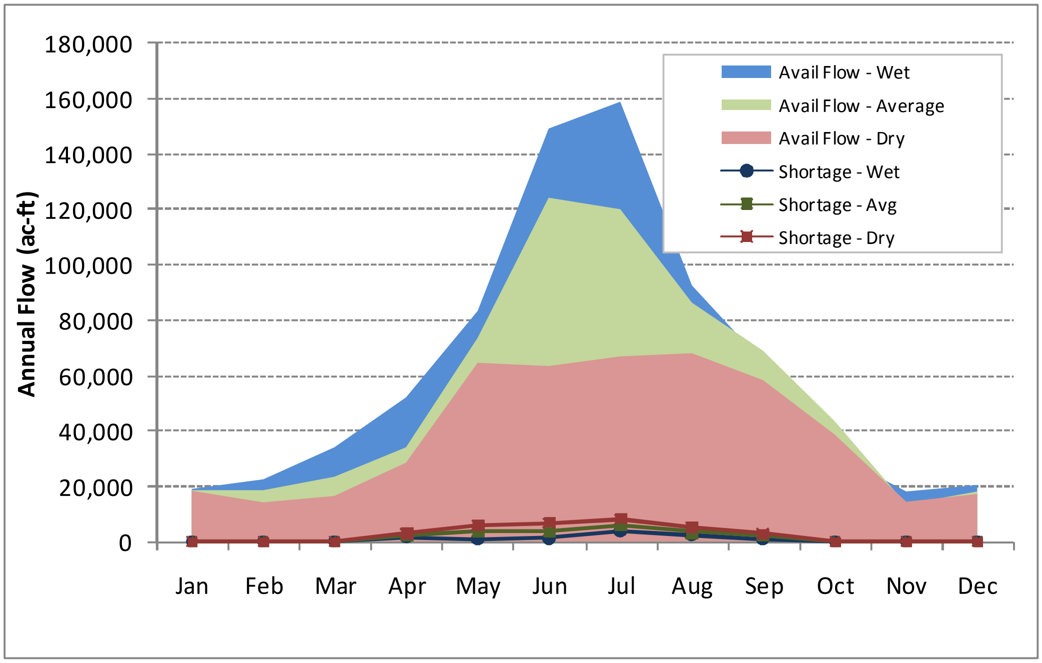

Figure 58. Shoshone Sub-Basin - Summary of Available Flow and Shortages

There is one stream segment on which an instream flow application has been received but has not yet been permitted by the WSEO in the Shoshone Basin from Buffalo Bill Dam to the Corbett Diversion. Proposed target flow ranges from 162-350 cfs. Available flow calculations within the Shoshone Basin were not limited by this instream flow segment since it is not permitted at this time. In addition to the state permitted instream flow segments, there are federal reserved bypass flow rights on most of the smaller tributaries within the Shoshone National Forest.

There are three whitewater rafting reaches in the Shoshone Basin, including one segment on the South Fork, one segment on the North Fork, and one segment on the mainstem below Buffalo Bill Reservoir. Simulated streamflows are greater than the minimum recommended streamflow in both reaches for nearly all months of the whitewater rafting season and hydrologic conditions. The exception is on the South Fork during dry years, when flows are less than minimum recommended flows in August. Maximum recommended flows for these reaches are 5,000 cfs for the South Fork and 7,000 cfs for the North Fork. Recommended flows for the Shoshone River below Buffalo Bill Dam are not available.

In addition to the whitewater rafting reaches, the area is a popular fishing destination. Blue Ribbon stream reaches are located on the North Fork from its headwaters to Buffalo Bill Reservoir, on Trout Creek, and on the Shoshone River from Buffalo Bill Reservoir to just south of Powell. There are also designated public fishing sites on the South Fork along its entire reach, as well as within the Blue Ribbon stream reaches.

Municipal use within the Shoshone Basin is primarily surface water use from Buffalo Bill Reservoir through the Shoshone Municipal Pipeline. Several communities have connections to this pipeline, including Cody, Powell, Lovell, Deaver and Frannie. Industrial uses are in the eastern portion of the Basin and associated with oil and gas production. There are several large permitted discharges within this area. This area also includes the largest concentration of CBNG wells within the Wind-

Bighorn Basin, although the concentration is minor when compared with those in other parts of Wyoming.

Future uses within the Shoshone Basin vary by sector. Agricultural uses are expected to remain consistent with historical uses. There are no expected future agricultural projects at this time. It is expected that municipal uses will continue to increase with population increases in the area. Most of this use will be surface water through the Shoshone Municipal pipeline. However, the amount of this increased use is minor when compared with total runoff and available flow, and the capacity of Buffalo Bill Reservoir. Industrial uses within the Shoshone Basin could vary, but are not expected to increase substantially. It is expected that environmental and recreational water use will continue to develop and expand. The public and WGFD have identified additional segments within the Shoshone Basin as potential locations for future instream flows, including the South Fork Shoshone below Cody Canal and the Shoshone River below Willwood Dam.

7.5 Summary of Surface Water Availability and Shortages

This chapter documents results of the spreadsheet models that were updated and improved as part of the Wind-Bighorn Basin Plan Update. Results presented in this document include shortages and available flow both by reach throughout the Basin and under the Yellowstone River Compact. It should be noted that because calculation methods were changed along with hydrologic information during the Basin Plan Update, not all changes between the previous Basin Plan and the Basin Plan Update can be attributed to differences in hydrology alone.

In general, Basin level shortages were lower in the Basin Plan Update for dry years than the previous Basin Plan, and within one to two percent of the previous Basin Plan for average and wet year conditions. This is consistent with changes in streamflow described in Section 4.3. A summary of sub-basin level full supply diversion requirements and simulated shortages for the model sub-basins is presented in Figure 59. Differences in shortages occur because of the reclassification of dry, average and wet years based on the new hydrologic study period, differences and increased availability of data used to estimate natural flows, and differences in the methods used for estimating consumptive irrigation requirements for crops.

Available flows between the previous Basin Plan and Basin Plan Update generally increased for dry years, decreased for wet years and were mixed for average years. A comparison of available flows for selected reaches is presented in Figure 60. Reasons for the differences are the same as those presented for shortages.

Available surface water calculations show that there is adequate surface water availability for most of the new uses described in Chapter 6 for the medium (or most likely) future water use scenario. Water availability for potential new irrigation in the high water use scenario (both Tribal Future Projects and other unidentified projects) is more unknown. Development of Tribal Futures Projects would have effects on existing water users, especially if new storage were not developed. Development of the other unidentified new irrigation projects would need to consider water availability and storage requirements. On larger mainstem streams in the Bighorn Basin, adequate water supplies do exist for additional development. However, in the Wind River Basin and on smaller tributary rivers and creeks, water availability is more limited.

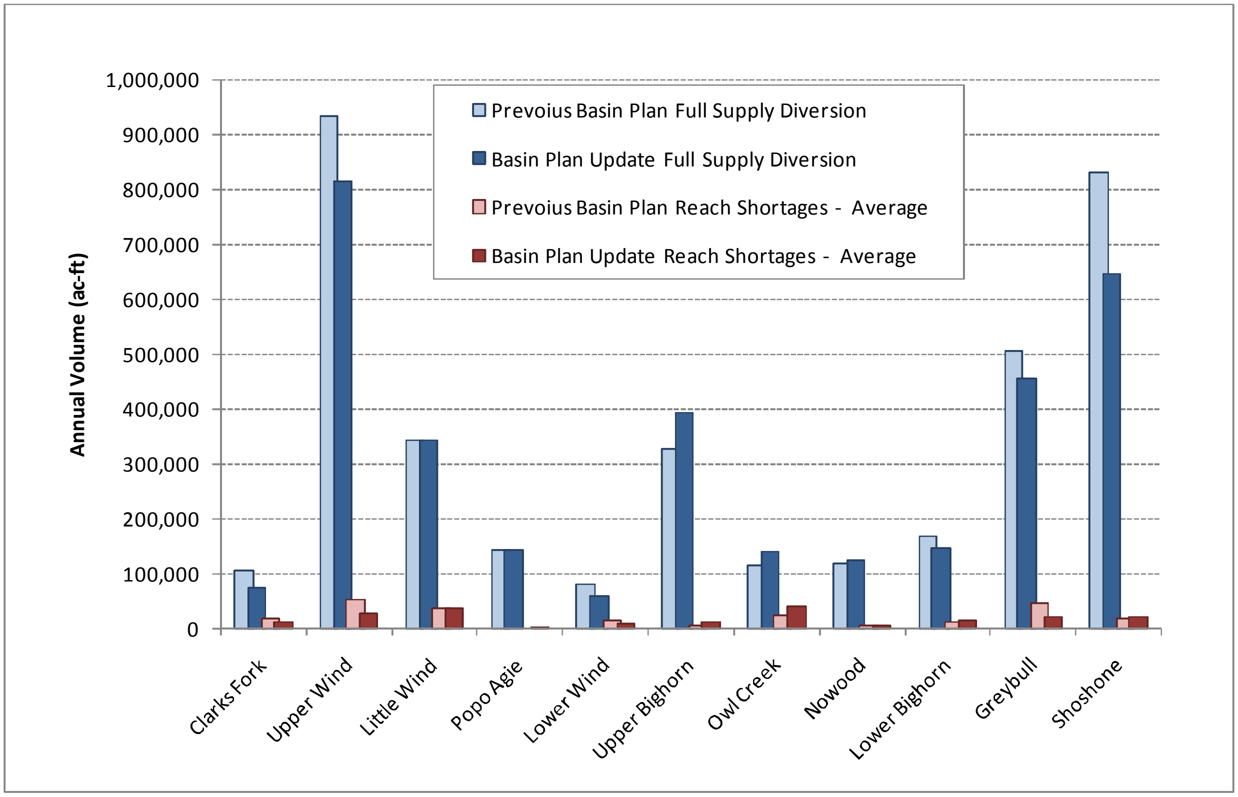

Figure 59. Sub-Basin Full Supply Diversions and Shortages for Previous Basin Plan and Basin Plan Update

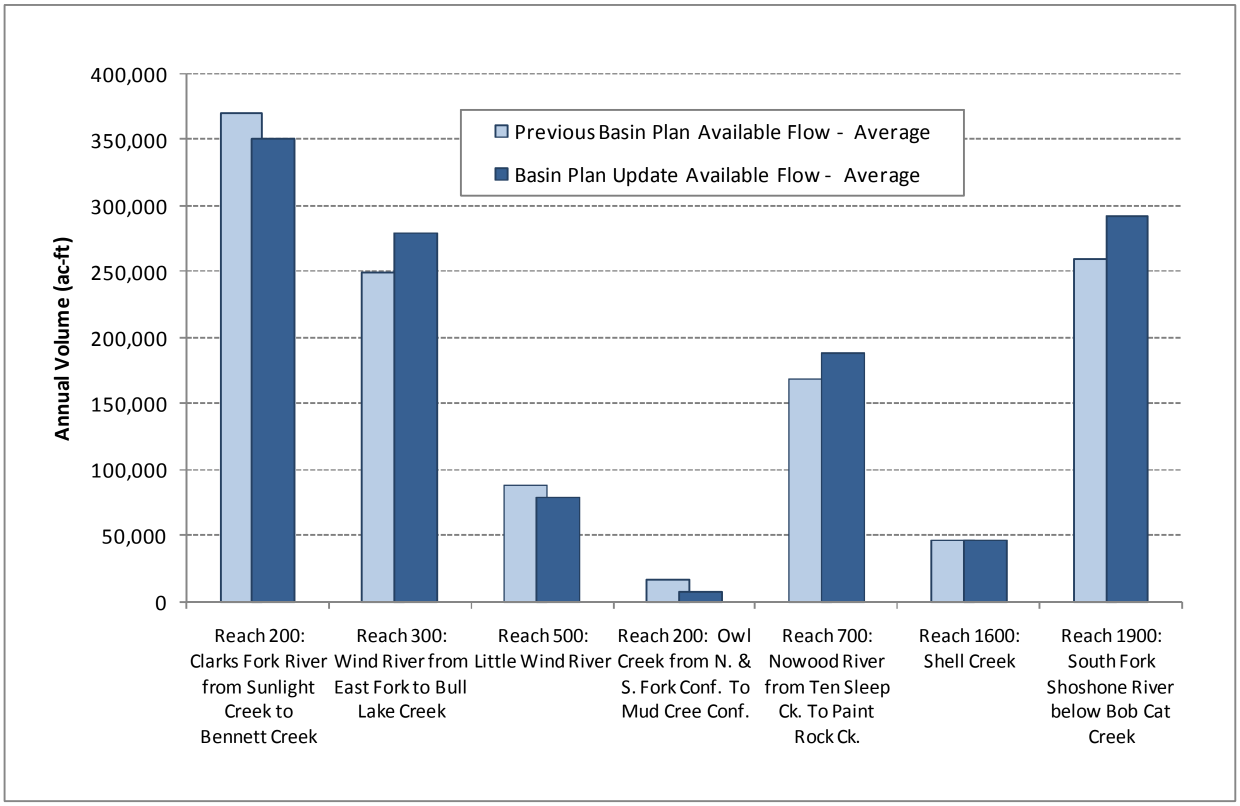

Figure 60. Selected Available Flow for Previous Basin Plan and Basin Plan Update