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III Available Surface Water and Groundwater Determination

This chapter presents estimates of the availability of both surface water and ground water for future uses. Surface water availability is determined by naturally available water at various points in the Basin, minus existing uses. Groundwater availability is a function of hydrogeologic conditions and current use as described in existing reports and well records.

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

- Surface Water Data Collection and Study Period Selection
- Surface Water Data Synthesis and Spreadsheet Model Development
- Available Surface Water Determination
- Available Groundwater Determination

A. Surface Water

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

Study Period Selection

Modeling the Green River Basin requires selection of an appropriate period of record for hydrologic analysis. The feasibility study determined that three 12-month spreadsheet models (one each representing normal-year, dry-year, and wet-year streamflows) constitute an appropriate level of detail for a modeling tool to verify existing uses and evaluate future surface water uses. Gage flows used in the three spreadsheets are to be typical of three different conditions and are to be developed by averaging observed streamflows that occurred during historical normal, wet, or dry years. Accordingly, the objectives of this task were to:

- determine the study period to be used to develop normal, wet, and dry year flow estimates for the Green River Basin spreadsheet models;
- select index gages and identify the historical normal, wet, and dry years out of the study period;
- assemble surface water information required for the spreadsheet.

Review of Reservoirs

Because a single annual cycle will be used to model each hydrologic condition, the normal data developed for input to the model is best derived from an operationally consistent time period. Construction or major modification of a reservoir during the study period would influence the downstream gages, hence reservoir history places significant control on selection of the study period. For this reason, major reservoirs (greater than 10,000 acre-feet) that have been constructed or modified during the past fifty years were reviewed to consider their influence on selection of the study period, with the following summarized results:

- Upper Green River - Construction of Fontenelle Reservoir was completed in April 1964 and the reservoir became fully functional during the late 1960's. During the late 1980's, Fontenelle Reservoir was drawn down for repair. This was taken into consideration during modeling, but not for selection of the proposed study period. Other major reservoirs (>10,000 ACRE-FEET) within the Upper Green River Basin, including Big Sandy, Eden, New Fork, Willow, Fremont and Boulder, were permitted and constructed prior to Fontenelle Reservoir. Fremont Lake was modified in the 1990's. As with the work on Fontenelle Reservoir, the impacts of this modification were taken into consideration during modeling.
- Blacks Fork River – Viva Naughton Reservoir was completed in 1960 and raised to its present level in 1967. Meeks Cabin Reservoir was completed in June 1971. Stateline Reservoir was completed in May 1979.
- Little Snake River –There are no major reservoirs currently in operation in this sub-basin. High Savery Dam, currently under design, can be included in future scenarios but does not influence choice of the historical study period.
- Henrys Fork River – There are no reservoirs within the Henrys Fork Basin of sufficient size to impact the study period selection.

Initial screening of current basin operations suggests that the study period begin in 1971 and end in 1998. By 1971, every major existing reservoir except for Stateline was in place. A twenty-year study period (1979-1998) consistent with the post-construction period of Stateline Reservoir may be too short for a quantitative analysis. An alternative is to select 1971 through 1998 and adjust the gage below Stateline Reservoir (09220000 – East Fork of Smith Fork below Robertson) from 1971 to 1979 to reflect representative operations of Stateline Reservoir, had it existed during this time period.

Review of Streamflow Records

Analysis of available streamflow data consisted of reviewing the USGS Water-Data Report, Volume 1, Surface Water. This report lists discontinued and active surface water discharge, water quality, sediment and biological stations. This information was supplemented by a review of data reported in the SEO Annual Hydrographers Report.

Review of Hydrologic Conditions

The reservoir history and availability of gage records led to a preliminary conclusion that 1971-1998 should serve as the study period. Ideally, the modeling study period should be representative of long-term hydrologic conditions in the Basin. To analyze this aspect of the proposed study period, annual flows were reviewed for the USGS gage 09188500 Green River at Warren Bridge near Daniel (Figure III-1 p.III-29). This gage has the longest record of the Green River Basin gages in Wyoming (1932-1998, excluding 1993), and as an indicator of long-term versus short-term statistics, is assumed applicable to the entire Basin. Characteristics of the long-term record and the proposed study period are tabulated below:

Characteristics of Annual Flow Series for 091885500 Green River at Warren Bridge near Daniel

	1932-1998 (excluding 1993) Record	1971-1998 (excluding 1993) Record
Mean (AF)	367,426	368,744
Standard Deviation	82,724	99,929
Three highest years	1986 / 1997 / 1971	1986 / 1997 / 1971
Three highest values (AF)	556,150 / 513,080 / 499,510	556,150 / 513,080 / 499,510
Three lowest years	1977 / 1934 /1992	1977 / 1992 / 1988
Three lowest values (AF)	203,260 / 208,720 / 213,910	203,260 / 213,910 / 232,330

The table shows that the means of the two periods are very similar. The standard deviation for the shorter period is higher due to the smaller sample size. Most notably, the short period includes the three highest annual flows of record, as well as two of the three driest. Furthermore, Figure III-1 shows that the most enduring drought of record (1987-1992) is captured in the model study period. Usually the concern is that the short period does not include extremes found in the longer record, but in this case, extremes of both wet and dry are clearly included in the proposed study period.

Selected Study Period

Based on available records, existence of reservoirs, and representativeness of the period, 1971-1998 is selected as the modeling study period. This 28-year period, on average, appears similar to long-term conditions, and includes wet, dry and normal years.

In this evaluation, traditional hydrologic techniques were used to estimate missing data. Typically, this means beginning by looking for a strong linear relationship between data that overlap in time at gages with similar hydrology. The basis of success for this procedure hinges on finding similarity in runoff characteristics between two streams, then using that similarity to "rebuild" missing data values at the deficient gage for the years when no overlap exists.

Index Gage Selection

The objective of this work was to identify gages to be used to identify normal, wet and dry years by ranking of annual flows. The gages selected as representative for this purpose were termed "index" gages. Ultimately, the top (largest annual flow amounts) 20 percent of the years were designated as wet years, the middle 60 percent designated as normal years, and the 20 percent with lowest annual flows designated as dry years. The purpose of this subtask was to select gages for this ranking task that provided coverage of the Basin, were relatively free of influence by man's activities, and which were relatively complete during the study period. Gages in operation during most, if not all, of the study period were selected for evaluation as index gages. Additionally, if a gage was in operation seasonally throughout the study period, it was included in the evaluation as a potential index gage.

Results

The index gages and corresponding wet and dry year selection are shown in Table III-1. There was no exact duplication of hydrologic condition (i.e. wet and dry years did not correspond at all gages all the time), so all seven index gages were used, applied to geographical areas as follows (see Figure III-2 through Figure III-5 beginning on p.III-30):

- 09188500 Green River at Warren Bridge - Upper Green River mainstem and tributaries located upstream of this gage
- 09196500 Pine Creek above Fremont Lake - New Fork River and its tributaries
- 09210500 Fontenelle Creek near Herschler Ranch, near Fontenelle - Upper Green River tributaries that rise in the Wyoming Range
- 09216050 Big Sandy River at Gasson Bridge - Big Sandy River and its tributaries
- 09218500 Blacks Fork near Millburne - Blacks Fork, Smiths Fork and Henrys Fork and their tributaries
- 09223000 Hams Fork below Pole Creek near Frontier - Hams Fork and its tributaries.
- 09229500 Henrys Fork near Manila – Henrys Fork and its tributaries
- 09253000 Little Snake near Slater, CO - Little Snake River and its tributaries.

Table III-1 Wet, Normal and Dry Years for Green River Basin Index Gages

Gage No.	Gage Name	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
09188500	Green River at Warren Bridge	Wet	Wet	Normal	Normal	Normal	Normal	Dry	Normal	Dry	Normal	Dry	Wet	Normal	Normal	Normal	Wet	Normal	Dry	Normal	Normal	Normal	Dry	Normal	Dry	Normal	Wet	Wet	Normal
09196500	Pine Creek above Fremont Lake	Wet	Wet	Normal	Normal	Normal	Normal	Dry	Normal	Normal	Normal	Dry	Wet	Wet	Normal	Normal	Wet	Normal	Dry	Dry	Normal	Normal	Dry	Normal	Dry	Normal	Normal	Wet	Normal
09210500	Fontenelle Creek near Herschler Ranch, near Fontenelle	Wet	Wet	Normal	Normal	Normal	Normal	Dry	Normal	Normal	Wet	Dry	Normal	Wet	Normal	Normal	Wet	Normal	Normal	Normal	Dry	Dry	Dry	Normal	Dry	Normal	Normal	Wet	Normal
09216050	Big Sandy River at Gasson Bridge	Normal	Normal	Normal	Normal	Normal	Normal	Dry	Normal	Normal	Wet	Normal	Normal	Wet	Wet	Normal	Wet	Normal	Dry	Dry	Dry	Normal	Dry	Dry	Normal	Wet	Normal	Wet	Normal
09218500	Blacks Fork near Millburne	Normal	Normal	Normal	Normal	Wet	Dry	Dry	Normal	Dry	Normal	Normal	Normal	Wet	Wet	Normal	Wet	Normal	Dry	Dry	Normal	Normal	Normal	Normal	Dry	Wet	Normal	Normal	Wet
09223000	Hams Fork below Pole Creek near Frontier	Wet	Wet	Normal	Normal	Normal	Normal	Dry	Normal	Normal	Normal	Dry	Wet	Wet	Wet	Normal	Wet	Normal	Dry	Normal	Dry	Normal	Dry	Normal	Dry	Normal	Normal	Normal	Normal
09229500	Henrys Fork near Manila	Wet	Normal	Wet	Normal	Wet	Dry	Dry	Normal	Dry	Normal	Normal	Normal	Wet	Wet	Normal	Normal	Normal	Normal	Dry	Dry	Normal	Normal	Normal	Dry	Normal	Normal	Normal	Wet
09253000	Little Snake near Slater, CO	Wet	Normal	Normal	Wet	Normal	Normal	Dry	Normal	Normal	Normal	Normal	Wet	Wet	Wet	Normal	Normal	Dry	Normal	Dry	Dry	Normal	Dry	Normal	Dry	Normal	Normal	Wet	Normal

Wet year Normal Year Dry Year

Spreadsheet Model Development

Spreadsheet models were developed to determine average monthly streamflow in the Basin during normal, wet, and dry years. The purpose of these models was to validate existing basin uses, assist in determining the timing and location of water available for future development, and help to assess impacts of future water supply alternatives.

This work resulted in the creation of twelve spreadsheet workbooks, one for each of the three hydrologic conditions and four distinct sub-basins:

- Upper Green River Basin from the Green River headwaters to Flaming Gorge
- Blacks Fork River Basin from the Blacks Fork and Smiths Fork headwaters to Flaming Gorge

- Henrys Fork River Basin from the Henrys Fork headwaters to Flaming Gorge, and
- Little Snake River Basin from the Little Snake headwaters to the USGS stream gaging station at Little Snake near Lily, CO.

The three workbooks for each sub-basin are yoked together with a simple menu-driven graphical user interface (GUI), effectively creating four sub-basin models.

Model Overview

For each Green River sub-basin, three models were developed, reflecting each of three hydrologic conditions: dry, normal, and wet year water supply. The spreadsheets each represent one calendar year of flows, on a monthly time step. The modelers relied on historical gage data from 1971 to 1998 to identify the hydrologic conditions for each year in the study period, as discussed in the technical memorandum for ***Surface Water Data Collection and Study Period Selection.*** Streamflow, consumptive use, diversions, irrigation returns, and reservoir conditions are the basic input data to the model. For all of these data, average values drawn from the dry, normal, or wet subset of the study period were computed for use in the spreadsheets. The models do not explicitly account for water rights, appropriations, or Compact allocations nor is the model operated based on these legal constraints. It is assumed that the historical data reflect effects of any limitations that may have been placed upon water users by water rights restrictions.

To mathematically represent each sub-basin system, the river system was divided into reaches based primarily upon the location of major tributary confluences. Each reach was then sub-divided by identifying a series of individual nodes representing diversions, reservoirs, tributary confluences, gages, or other significant water resources features. The resulting network is the simplification of the real world which the model represents. Figure III-2 through Figure III-5 (beginning on p. III-30) present node diagrams of the models developed for the Green River. Each numbered node in the figure is a node in the model.

Natural or virgin flow for each month is supplied to the model by specifying flow at every headwater node, and incremental stream gains and losses within each downstream reach. Where available, upper basin gages were selected as headwater nodes; in their absence, flow at the ungaged headwater point was estimated outside the spreadsheet.

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

Model Development

The model was developed using Microsoft® Excel 97. The workbooks contain macros written in Microsoft® Excel Visual Basic programming language. The primary function

of the macros is to facilitate navigation within the workbook. There are no macros that need to be executed to complete computation of any formulas or results. In other words, whenever a number is input into any cell anywhere in the workbook, the entire workbook is recalculated and updated automatically.

The delineation of a river basin by reaches and nodes is more an art than a science. The choice of nodes must consider the objectives of the study and the available data. It also must contain all the water resource features that govern the operation of the Basin. The analysis of results and their adequacy in addressing the objectives of the study are based on the input data and the configuration of the river basin by the computer model.

The following reaches and nodes are contained in each basin model:

- Upper Green River Basin: 24 reaches, 111 nodes
- Blacks Fork River Basin: 13 reaches, 44 nodes
- Henrys Fork River Basin: 7 reaches, 16 nodes
- Little Snake River Basin: 16 reaches, 48 nodes

Gage Data

Monthly stream gage data were obtained from the Wyoming Water Resources Data System (WRDS) 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.

Headwater inflow at several ungaged locations is also on the Gage Data worksheet. Different approaches to estimating the flow were used, depending on the complexity of the stream system and availability of data. The model uses estimated flow at ungaged headwater nodes as if they were gages.

Diversion Data

Diversions in the Green River Basin Models are attributable either to Municipal and Industrial use, or Agricultural use. The spreadsheets model only the consumptive portion of all municipal and industrial diversions. Agricultural diversion nodes fall into two categories: explicitly modeled structures, and aggregated structures. Explicitly modeled structures were structures for which adequate historical diversion records and a high confidence estimate of irrigated area were available. These structures generally served as indicators of irrigation practice throughout the Basin. Their entire diversions and resulting return flows were included in the model. For the aggregate structures, consumptive use only was modeled.

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

Collection of agricultural diversion data is discussed in the technical memorandum ***Irrigation Diversion Operation and Description***. These data were reviewed and ditches that had sufficient diversion data for analysis of average dry, normal and wet year conditions were selected for explicit modeling. No attempts were made to fill missing records. Diversion data for explicitly modeled structures are the average dry, normal and wet year monthly diversions, calculated from the available records.

Diversions for aggregated structures were calculated as the product of estimated irrigated acreage, monthly consumptive irrigation requirement (CIR), and the fraction of the month in which diversion was practiced. Monthly CIR is estimated as a function of latitude, precipitation, and temperature, and therefore varies for dry, normal, and wet conditions.

Municipal and industrial diversions were taken from the technical memoranda ***Basin Water Use Profile – Municipal*** and ***Basin Water Use Profile – Industrial.*** Values reported in these memoranda represent the consumptive use portion of the municipal and industrial diversions. No attempts were made to estimate return flows. With the exception of the Cheyenne Stage I and II diversions discussed below, no attempts were made to develop dry, normal and wet year municipal and industrial diversions.

Surface Water Availability

The Green River Basin spreadsheet model is a tool for identifying flows that are available to Wyoming water users for future development, and evaluating yield and impacts of potential projects at a planning level. The purpose of this task is to analyze historical runs developed during spreadsheet calibration to determine location, quantity, and timing of available flows. The calibration spreadsheets represent conditions in the four sub-basins (Little Snake, Henrys Fork, Blacks Fork, and Green River) under current levels of development for three hydrologic conditions: Dry, Normal, and Wet year water supply. Background information on the spreadsheet model can be found in other technical memos prepared for this project.

<u>Available Flow</u>

Each basin model is divided into a number of reaches, each composed of several nodes, or water balance points. Reaches are typically defined by gages or confluences, and represent tributary basins or subsections of the mainstem. An output worksheet in each spreadsheet model summarizes monthly flow at the downstream end of each reach, and provides the basis of this analysis.

While simulated flow at the reach terminus indicates estimated amount of water physically present, it does not fully reflect availability. If a downstream diverter has

historically diverted the entire stream at its headgate, the water supply at the upper point is not available for future development; it is already needed to meet current requirements.

Available Water Determination

To determine how much of the physical supply is actually available to future uses, "available water" at a reach terminus was defined as the minimum of the physically available flow at that point, and "available water" at all downstream reaches. Thus available flow must be defined first at the most downstream point, with upstream availability calculated in stream order. These calculations were made on a monthly basis, and annual availability was computed as the sum of monthly availabilities. Note that calculating annual availability in this way yields a different value than applying the same logic to annual flows for each reach. The summation of monthly values is more accurate, reflecting constraints of downstream use on a monthly basis.

Instream Flow Right Considerations

Instream flow rights exert a demand on the river but do not affect physical supply, because the water is not removed from the stream. Thus any reach terminus located immediately upstream of a reach that contained an instream flow right had to be handled specially. That is, available flow at the upstream reach terminus was determined as the minimum of physical flow at that point, and "available water" *less the instream flow requirement* at the downstream reach terminus.

The two permitted instream flow rights and 32 pending instream flow applications were reviewed for applicability of the special handling described above. (See the technical memorandum—*Instream Flows in Wyoming*) Except for one, all the instream flow rights are located high enough in the Basin that they have no upstream reach in the model. The exception is a 1.5-mile long reach of the West Fork New Fork River, under permit #7IF. Available water at the downstream terminus of Reach 8 in the Green River sub-basin spreadsheet was calculated taking the instream flow demand into consideration.

Compact Considerations

The spreadsheet models do not contain logic to simulate curtailment of water rights on a priority basis in order to meet the State's obligations under the Upper Colorado River Basin Compact (the Compact). The models were developed to portray historical use over the study period 1971-1998. Never during that time, nor since the Compact was ratified, have diversions been curtailed pursuant to Article IV of the Compact. While the principles under which such administration should be conducted are set forth in the Compact, actual details of their application have not been worked out by the Upper Colorado River Commission. Accordingly, simulation of curtailment was outside the scope of this effort. The models could be used, however, to test the impacts of a future downstream demand representing a Compact delivery obligation.

Article XI of the Compact addresses the division of the waters of the Little Snake River, whose tributaries lie on both sides of the Colorado-Wyoming state line, and whose

mainstem crosses the boundary numerous times. The Compact identifies a point 100 feet below the mouth of Savery Creek, above which pre-Compact rights are not subject to calls emanating from below the point. This administrative nuance does not alter the definition of available flow for new or future uses above the so-called Compact point, however, since they could be regulated to satisfy senior pre-Compact priority date water rights below the Compact point. Post-Compact rights, including future uses, below the Compact point, "shall be administered on the basis of an interstate priority schedule prepared by the Commission in conformity with priority dates established by the laws of the respective States," according to Article XI. Therefore, calculation of "available water" in this part of the Basin must take into consideration the needs of downstream users in Colorado. To summarize, the method of calculating available water described above, when applied to the Little Snake including the Colorado sections of the river, is in accordance with Article XI of the Compact.

Results

Table III-2 through Table III-13 (beginning on p.III-11) summarize water availability for the four sub-basins and three hydrologic conditions on a monthly basis.

Figure III-6 through Figure III-8 (beginning on p. III-34) show the annual surface water physical availability for dry, wet, and normal year scenarios. The tabulations show annual available supply at the bottom of the system for each basin as follows:

Annual Available Supply—(acre-feet per year)			
Basin	**Dry Condition**	**Normal Condition**	**Wet Condition**
Little Snake	189,000	449,000	665,000
Henrys Fork	23,000	60,000	125,000
Blacks Fork	101,000	229,000	422,000
Green River	620,000	1,269,000	1,924,000

Table III-2 Available Flow for Little Snake River Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	436.	431.	814.	3582.	7442.	3351.	492.	70.	268.	577.	508.	438.	18409.
2	Middle Fork Little Snake River	679.	668.	1457.	7156.	14971.	6257.	492.	70.	268.	969.	826.	684.	34497.
3	Little Snake River between Middle Fork and South Fork	1406.	1382.	3015.	14810.	31471.	14517.	492.	70.	268.	2006.	1710.	1416.	72563.
4	South Fork Little Snake River	257.	253.	552.	2711.	5617.	2195.	289.	70.	177.	367.	313.	259.	13060.
5	Little Snake River between South Fork and Roaring Fork Little Snake	1663.	1635.	3567.	17522.	37074.	16665.	492.	70.	268.	2373.	2023.	1675.	85027.
6	Little Snake River between Roaring Fork and Battle Creek	1663.	1635.	8814.	20377.	49645.	21963.	492.	70.	268.	2373.	2023.	1675.	111000.
7	Battle Creek	967.	993.	2070.	8308.	11464.	3490.	429.	70.	268.	1431.	1292.	1109.	31890.
8	Little Snake River between Battle Creek and Slater Creek	2378.	2628.	10885.	28685.	59873.	21963.	492.	70.	268.	3802.	3315.	2783.	137143.
9	Slater Creek	986.	1010.	2022.	7878.	10768.	3119.	318.	70.	268.	1422.	1291.	1119.	30272.
10	Little Snake River between Slater Creek and Savery Creek	2378.	3221.	12906.	36563.	59873.	21963.	492.	70.	268.	3802.	4406.	2966.	148911.
11	Savery Creek	1685.	1712.	3687.	12045.	11530.	3561.	376.	70.	268.	1870.	1937.	1873.	40615.
12	Little Snake River between Savery Creek and Willow Creek	2378.	3221.	16851.	49518.	59873.	21963.	492.	70.	268.	3802.	4406.	2966.	165810.
13	Willow Creek	134.	145.	264.	911.	973.	0.	112.	82.	94.	195.	181.	141.	3230.
14	Little Snake River between Willow Creek and Muddy Creek	3644.	4549.	16851.	49518.	59873.	22629.	911.	520.	436.	4425.	5454.	4256.	173067.
15	Muddy Creek	24.	18.	3150.	1560.	1025.	718.	238.	79.	113.	461.	195.	39.	7618.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	4472.	5365.	19805.	49918.	59873.	28243.	2878.	644.	436.	6087.	6620.	5095.	189437.

Table III-3 Available Flow for Little Snake River Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	487.	482.	768.	3022.	14166.	12396.	2404.	629.	459.	605.	564.	518.	36500.
2	Middle Fork Little Snake River	784.	774.	1362.	6001.	28794.	24978.	4451.	1028.	617.	1027.	942.	848.	71608.
3	Little Snake River between Middle Fork and South Fork	1623.	1602.	2819.	12421.	60052.	52683.	10073.	1250.	617.	2126.	1950.	1754.	148971.
4	South Fork Little Snake River	297.	293.	516.	2274.	10847.	9329.	1569.	369.	260.	389.	357.	321.	26822.
5	Little Snake River between South Fork and Roaring Fork Little Snake	1921.	1895.	3335.	14694.	70882.	61977.	11611.	1250.	617.	2515.	2308.	2076.	175081.
6	Little Snake River between Roaring Fork and Battle Creek	1921.	3294.	11796.	17734.	75301.	75208.	17326.	1250.	617.	2515.	2308.	2076.	211345.
7	Battle Creek	1176.	1181.	2476.	8078.	28733.	19262.	3238.	667.	617.	1434.	1359.	1240.	69462.
8	Little Snake River between Battle Creek and Slater Creek	3097.	4475.	14272.	25812.	104034.	94470.	18004.	1250.	617.	3949.	3666.	3316.	276963.
9	Slater Creek	1182.	1187.	2403.	7663.	26974.	17985.	2961.	677.	617.	1424.	1354.	1242.	65669.
10	Little Snake River between Slater Creek and Savery Creek	4242.	5662.	16675.	33474.	130783.	111972.	18004.	1250.	617.	5275.	5020.	4558.	337534.
11	Savery Creek	2026.	1997.	3836.	12621.	34940.	22007.	3854.	1120.	617.	2073.	2101.	2048.	89242.
12	Little Snake River between Savery Creek and Willow Creek	4242.	7830.	20954.	47384.	160497.	120576.	18004.	1250.	617.	5275.	6134.	4616.	397380.
13	Willow Creek	180.	172.	449.	1289.	2226.	1688.	529.	218.	155.	216.	179.	177.	7478.
14	Little Snake River between Willow Creek and Muddy Creek	5619.	9450.	20954.	53211.	164610.	122097.	20187.	2176.	1117.	5459.	6569.	5945.	417394.
15	Muddy Creek	36.	30.	4765.	2871.	3080.	1180.	518.	132.	101.	400.	551.	109.	13772.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	6446.	10246.	24151.	56543.	168774.	127104.	25778.	4734.	2436.	7585.	8449.	6842.	449088.

Table III-4 Available Flow for Little Snake River Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	North Fork Little Snake River	657.	516.	818.	4190.	19920.	19855.	3965.	826.	680.	725.	631.	602.	53386.
2	Middle Fork Little Snake River	1133.	845.	1465.	8407.	40575.	40349.	7673.	1432.	1177.	1275.	1080.	1022.	106432.
3	Little Snake River between Middle Fork and South Fork	2346.	1748.	3032.	17398.	84631.	84445.	16714.	3115.	2448.	2639.	2234.	2115.	222864.
4	South Fork Little Snake River	429.	320.	555.	3185.	15284.	15160.	2794.	522.	445.	483.	409.	387.	39972.
5	Little Snake River between South Fork and Roaring Fork Little Snake	2775.	2068.	3587.	20583.	99890.	99571.	19478.	3631.	2889.	3122.	2643.	2502.	262740.
6	Little Snake River between Roaring Fork and Battle Creek	2775.	2068.	13301.	24224.	106992.	116728.	28786.	4799.	2889.	3122.	2643.	2502.	310829.
7	Battle Creek	1482.	1272.	2475.	8338.	38864.	27969.	5514.	1228.	1605.	2056.	1658.	1373.	93834.
8	Little Snake River between Battle Creek and Slater Creek	4257.	3341.	15776.	32561.	145856.	144697.	34300.	4799.	4366.	5178.	4302.	3874.	403306.
9	Slater Creek	1469.	1272.	2402.	7907.	36451.	26169.	5103.	1204.	1583.	2008.	1635.	1367.	88569.
10	Little Snake River between Slater Creek and Savery Creek	5726.	4613.	18178.	40468.	181986.	170408.	36612.	4799.	4366.	7186.	5937.	5241.	485518.
11	Savery Creek	2230.	2033.	3554.	12296.	48005.	33840.	6678.	1857.	2481.	2913.	2531.	2224.	120640.
12	Little Snake River between Savery Creek and Willow Creek	5974.	5981.	22288.	54464.	227350.	194067.	36612.	4799.	4366.	7857.	7732.	6221.	577710.
13	Willow Creek	255.	247.	558.	1700.	3139.	2611.	1004.	277.	266.	318.	250.	234.	10860.
14	Little Snake River between Willow Creek and Muddy Creek	7361.	7565.	23748.	63058.	240561.	211738.	42260.	5700.	5118.	8286.	8329.	7416.	631140.
15	Muddy Creek	36.	30.	4765.	2871.	3080.	1180.	518.	132.	101.	400.	551.	109.	13772.
16	Little Snake River between Muddy Creek and Little Snake River near Lily, CO gage	8177.	8373.	29155.	66325.	243117.	215717.	47410.	9398.	8268.	10852.	10250.	8303.	665345.

Table III-5 Available Flow for Henrys Fork Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	541.	473.	1000.	868.	1459.	3113.	236.	121.	59.	548.	626.	580.	9624.
2	Beaver Creek	965.	883.	1456.	1331.	1459.	3113.	236.	121.	59.	897.	1048.	1019.	12588.
3	Henrys Fork between Beaver Creek and Burnt Fork	1506.	1356.	2456.	1694.	1459.	3113.	236.	121.	59.	897.	1674.	1599.	16170.
4	Burnt Fork	464.	449.	495.	585.	2030.	2995.	581.	435.	298.	639.	562.	497.	10030.
5	Henrys Fork between Burnt Fork and Birch Creek	1970.	1805.	3049.	2279.	2030.	4004.	581.	435.	298.	1399.	2236.	2096.	22181.
6	Birch Creek	171.	166.	183.	216.	924.	1269.	419.	335.	199.	236.	207.	183.	4507.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	2116.	1939.	3231.	2336.	2030.	4004.	581.	435.	298.	1399.	2313.	2224.	22906.

Table III-6 Available Flow for Henrys Fork Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	844.	978.	1908.	1870.	6103.	9691.	3064.	1310.	588.	862.	1151.	937.	29305.
2	Beaver Creek	1259.	1388.	2378.	2418.	6439.	9150.	3620.	1397.	934.	1264.	1573.	1358.	33179.
3	Henrys Fork between Beaver Creek and Burnt Fork	2103.	2366.	4286.	4288.	8212.	12875.	3620.	1397.	1155.	2126.	2724.	2295.	47448.
4	Burnt Fork	532.	498.	551.	737.	3574.	6212.	2306.	1121.	612.	821.	654.	580.	18199.
5	Henrys Fork between Burnt Fork and Birch Creek	2636.	2942.	5179.	5112.	9994.	15472.	4599.	1954.	1666.	2841.	3379.	2874.	58645.
6	Birch Creek	196.	184.	203.	272.	1359.	2430.	959.	442.	259.	303.	241.	214.	7062.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	2817.	3126.	5382.	5384.	9994.	15472.	4599.	1954.	1666.	2841.	3547.	3042.	59821.

Table III-7 Available Flow for Henrys Fork Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Below Henrys Fork near Lonetree (09226000) and Beaver Creek	1343.	1012.	2405.	2735.	8557.	17944.	8138.	2781.	1586.	1904.	1583.	1244.	51233.
2	Beaver Creek	1760.	1420.	2886.	3668.	11101.	17226.	8992.	3459.	2162.	2301.	1999.	1653.	58627.
3	Henrys Fork between Beaver Creek and Burnt Fork	3103.	2433.	5291.	6403.	15595.	32654.	17072.	6193.	3742.	4205.	3582.	2897.	103169.
4	Burnt Fork	579.	535.	594.	925.	3501.	11749.	7713.	2618.	1359.	1000.	748.	644.	31963.
5	Henrys Fork between Burnt Fork and Birch Creek	3778.	3006.	6343.	7527.	18668.	38708.	20403.	7621.	4742.	5204.	4330.	3542.	123873.
6	Birch Creek	213.	197.	219.	341.	1328.	4454.	2940.	989.	511.	369.	276.	238.	12075.
7	Henrys Fork between Birch Creek and Henrys Fork near Manila, UT gage (09229500)	3992.	3204.	6562.	7868.	18668.	38708.	20403.	7621.	4742.	5286.	4554.	3750.	125358.

Table III-8 Available Flow for Blacks Fork Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	775.	1134.	3462.	3180.	4225.	3718.	2049.	840.	644.	1200.	1050.	982.	23260.
2	West Fork of Smiths Fork	331.	506.	1554.	1387.	2696.	1269.	937.	113.	499.	372.	452.	420.	10534.
3	East Fork of Smiths Fork	478.	549.	1108.	1124.	4093.	4766.	2049.	840.	644.	793.	600.	529.	17573.
4	Smiths Fork	848.	1139.	3018.	2794.	4505.	4766.	2049.	840.	644.	1884.	1312.	1016.	24816.
5	Cottonwood Creek	140.	194.	541.	610.	1306.	77.	0.	0.	0.	195.	191.	171.	3424.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	988.	1332.	3559.	3404.	5811.	4766.	2049.	840.	644.	2079.	1503.	1186.	28163.
7	Blacks Fork between Smiths Fork and Muddy Creek	1763.	2466.	7021.	6584.	6888.	4766.	2049.	840.	644.	2481.	2433.	2168.	40105.
8	Little Muddy Creek	308.	487.	600.	971.	450.	167.	81.	139.	90.	241.	547.	479.	4560.
9	Upper Muddy Creek	0.	18.	343.	449.	224.	61.	0.	0.	0.	0.	139.	0.	1234.
10	Muddy Creek below Little Muddy Creek	308.	505.	943.	1420.	674.	228.	81.	139.	90.	241.	686.	479.	5794.
11	Blacks Fork between Muddy Creek and Hams Fork	2071.	3071.	10130.	10111.	10946.	5218.	2166.	979.	734.	2772.	3207.	2647.	54053.
12	Hams Fork River	961.	1069.	7058.	7762.	16874.	7251.	1578.	1448.	259.	1668.	1376.	1052.	48355.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	2783.	4140.	17188.	17873.	27820.	12469.	3744.	1448.	832.	4439.	4583.	3622.	100941.

Table III-9 Available Flow for Blacks Fork Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	1366.	1738.	5347.	7403.	10309.	11695.	4814.	2740.	2111.	1806.	1735.	1249.	52313.
2	West Fork of Smiths Fork	500.	714.	2286.	2584.	4749.	4078.	957.	377.	493.	436.	633.	461.	18266.
3	East Fork of Smiths Fork	704.	751.	1657.	1978.	4964.	10491.	5081.	2546.	1688.	1358.	884.	670.	32772.
4	Smiths Fork	1324.	1625.	4537.	5629.	9858.	11907.	6448.	3047.	2589.	2008.	1738.	1231.	51942.
5	Cottonwood Creek	192.	267.	771.	910.	2362.	1710.	109.	112.	64.	228.	281.	205.	7211.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	1516.	1892.	5308.	6538.	12219.	13617.	6557.	3047.	2589.	2236.	2020.	1436.	58976.
7	Blacks Fork between Smiths Fork and Muddy Creek	2882.	3630.	10655.	13941.	21421.	23177.	7073.	3047.	2589.	3188.	3755.	2684.	98042.
8	Little Muddy Creek	469.	718.	2168.	5353.	2348.	1257.	545.	314.	264.	342.	298.	404.	14479.
9	Upper Muddy Creek	111.	369.	2804.	2259.	6962.	2862.	400.	0.	0.	322.	412.	258.	16759.
10	Muddy Creek below Little Muddy Creek	580.	1086.	4972.	7612.	9310.	4119.	945.	314.	264.	664.	710.	663.	31238.
11	Blacks Fork between Muddy Creek and Hams Fork	3626.	4910.	16842.	22773.	33457.	27878.	8176.	3361.	2853.	3914.	4696.	3347.	135832.
12	Hams Fork River	2030.	1988.	6676.	12840.	28300.	24186.	7099.	3041.	3040.	1947.	2099.	1683.	94931.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	5656.	6898.	23518.	35613.	61757.	52064.	15276.	5919.	4542.	5861.	6796.	4948.	228847.

Table III-10 Available Flow for Blacks Fork Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Blacks Fork	1773.	2157.	6603.	7841.	19093.	33210.	14269.	5162.	4046.	3109.	2517.	1755.	101534.
2	West Fork of Smiths Fork	649.	861.	2852.	2963.	6682.	9658.	4581.	1458.	1135.	890.	824.	600.	33152.
3	East Fork of Smiths Fork	849.	898.	1975.	2201.	6335.	18716.	12871.	4720.	3451.	1888.	1319.	882.	56104.
4	Smiths Fork	1654.	1964.	5553.	6185.	15240.	29056.	18554.	8654.	6329.	3775.	2693.	1639.	101297.
5	Cottonwood Creek	289.	346.	1009.	1081.	2367.	4688.	2107.	693.	563.	465.	427.	286.	14322.
6	Smiths Fork between Cottonwood Creek and Blacks Fork River	1943.	2310.	6562.	7266.	17607.	33744.	20661.	9347.	6892.	4240.	3120.	1926.	115619.
7	Blacks Fork between Smiths Fork and Muddy Creek	3717.	4467.	13164.	15107.	36700.	66954.	30869.	9998.	7379.	6365.	5531.	3680.	203932.
8	Little Muddy Creek	469.	718.	2168.	5353.	2348.	1257.	545.	314.	264.	342.	298.	404.	14479.
9	Upper Muddy Creek	111.	369.	2804.	2259.	6962.	2862.	400.	0.	0.	322.	412.	258.	16759.
10	Muddy Creek below Little Muddy Creek	580.	1086.	4972.	7612.	9310.	4119.	945.	314.	264.	664.	710.	663.	31238.
11	Blacks Fork between Muddy Creek and Hams Fork	4296.	5554.	18704.	22719.	46010.	77087.	33989.	11437.	8803.	7481.	6717.	4372.	247168.
12	Hams Fork River	4065.	5605.	8788.	14857.	46235.	62688.	21846.	6865.	5462.	3104.	3411.	2892.	185820.
13	Blacks Fork between Hams Fork and Blacks Fork nr Little America gage	7226.	9062.	27492.	32467.	89150.	139775.	55835.	18302.	14265.	10585.	10128.	7264.	421550.

Table III-11 Available Flow for Green River Basin and Dry Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	5935.	5567.	6802.	17403.	44939.	58043.	28074.	15919.	12146.	10460.	6890.	6658.	218836.
2	Beaver Creek	335.	305.	639.	2261.	1777.	870.	42.	39.	201.	277.	382.	359.	7487.
3	Green River between Beaver Creek and Horse Creek	6332.	5956.	7728.	19757.	44939.	58043.	28074.	15919.	12146.	10816.	7429.	7095.	224233.
4	Horse Creek	784.	899.	2417.	2513.	5072.	4289.	2453.	1634.	490.	1113.	1525.	916.	24105.
5	Green River between Horse Creek and Cottonwood Creek	7116.	6855.	10145.	22269.	48757.	58043.	28074.	15919.	12337.	11929.	8954.	8011.	238409.
6	Cottonwood Creek	856.	1012.	2842.	2638.	1597.	0.	1332.	525.	171.	1381.	1846.	1072.	15271.
7	Green River between Cottonwood Creek and New Fork River	7972.	7867.	12987.	24907.	49791.	58043.	28074.	15919.	12374.	13311.	10799.	9083.	251126.
8	West Fork New Fork River above Pine Creek	0.	0.	0.	1854.	15535.	29488.	7479.	0.	0.	1679.	617.	0.	56652.
9	Pine Creek	4218.	3460.	4645.	7507.	24818.	39148.	18092.	7787.	5583.	7520.	6270.	5319.	134368.
10	Pole Creek	5090.	4216.	5560.	9478.	24818.	39148.	20696.	8080.	5583.	9537.	7830.	6327.	146362.
11	Boulder Creek	5500.	4624.	6136.	10629.	42618.	66935.	30185.	11231.	7712.	11707.	8723.	6869.	212870.
12	East Fork New Fork River	2957.	3196.	4336.	3941.	21509.	17287.	8446.	4899.	4237.	4259.	4270.	3342.	82678.
13	New Fork River below confluence of West and East Forks	10873.	10550.	14118.	15055.	56830.	66935.	44057.	20146.	15270.	18493.	16228.	12823.	301380.
14	Green River between New Fork River and Piney Creeks	18969.	18586.	27678.	40148.	57368.	66935.	52932.	35771.	27534.	31961.	27341.	22062.	427285.
15	North Piney Creek	1112.	1274.	3429.	1858.	785.	0.	2204.	1629.	193.	1800.	2305.	1324.	17913.
16	Middle Piney Creek	992.	1213.	3496.	1527.	561.	0.	3435.	2653.	299.	1393.	2138.	1188.	18895.
17	South Piney Creek	902.	1035.	2786.	2888.	2800.	1062.	1282.	1426.	408.	1282.	1756.	1055.	18684.
18	Green River between Piney Creeks and LaBarge Creek	21967.	22102.	37383.	46416.	57368.	66935.	52932.	41508.	28513.	36476.	33556.	25624.	470781.
19	LaBarge Creek	2404.	2298.	3595.	4096.	6916.	3872.	2936.	2193.	1950.	2772.	3082.	2759.	38874.
20	Green River between La Barge Creek and Fontenelle Reservoir	24372.	24400.	40602.	50512.	57368.	66935.	52932.	43942.	30622.	39311.	36667.	28393.	496055.
21	Fontenelle Creek	1347.	1297.	1890.	3470.	4231.	2939.	610.	565.	934.	1793.	1607.	1413.	22095.

Table III-11 Available Flow for Green River Basin and Dry Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	50627.	41291.	40602.	61966.	57368.	66935.	52932.	51463.	39138.	47695.	49963.	53297.	613277.
23	Big Sandy River below Farson gage and Green River	1550.	1415.	3170.	2687.	2178.	2582.	2928.	3037.	2950.	3112.	2677.	1892.	30177.
24	Green River between Big Sandy River and Green River near Green River gage	50627.	42740.	44590.	63005.	57368.	66935.	52932.	51463.	39138.	47695.	49963.	53297.	619753.

Table III-12 Available Flow for Green River Basin and Normal Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	6689.	6159.	7726.	16510.	59720.	98850.	80423.	29914.	17985.	14043.	9305.	7553.	354878.
2	Beaver Creek	676.	635.	894.	7554.	6966.	3053.	48.	135.	197.	562.	813.	710.	22243.
3	Green River between Beaver Creek and Horse Creek	7391.	6842.	8780.	24321.	64490.	98850.	80423.	29914.	17985.	14618.	10216.	8300.	372130.
4	Horse Creek	1051.	1101.	2107.	6460.	15209.	16446.	5603.	3742.	1179.	1512.	1826.	1158.	57393.
5	Green River between Horse Creek and Cottonwood Creek	8442.	7943.	10887.	30782.	78265.	112263.	82733.	31262.	18595.	16129.	12042.	9458.	418801.
6	Cottonwood Creek	1299.	1350.	2752.	8430.	9787.	9073.	6528.	3599.	1256.	2043.	2302.	1430.	49850.
7	Green River between Cottonwood Creek and New Fork River	9741.	9293.	13639.	39212.	87407.	119973.	87781.	33785.	19595.	18172.	14344.	10888.	463832.
8	West Fork New Fork River above Pine Creek	0.	0.	39.	5777.	21286.	57224.	24194.	7536.	2124.	3047.	954.	0.	122181.
9	Pine Creek	4803.	4577.	5880.	11430.	34534.	98862.	51498.	16933.	10158.	8888.	6607.	5377.	259547.
10	Pole Creek	6169.	5857.	7252.	14054.	34828.	99118.	60537.	19678.	10158.	9275.	8057.	6754.	281736.
11	Boulder Creek	7262.	6806.	8348.	16319.	59468.	164908.	86225.	27205.	15343.	13019.	9694.	8022.	422619.
12	East Fork New Fork River	3188.	3237.	4597.	7165.	32042.	46727.	20547.	7246.	5110.	7659.	6468.	4232.	148218.
13	New Fork River below confluence of West and East Forks	12790.	12531.	16639.	27633.	80235.	181813.	116202.	39376.	23239.	25771.	21068.	15347.	572643.
14	Green River between New Fork River and Piney Creeks	22585.	21920.	30597.	67358.	163844.	246144.	196206.	73300.	42759.	43969.	35609.	26307.	970598.
15	North Piney Creek	1098.	1239.	2534.	4341.	4520.	8033.	8791.	5483.	1269.	1739.	2139.	1280.	42466.
16	Middle Piney Creek	756.	957.	2268.	3711.	2335.	3786.	8835.	6373.	1487.	1017.	1714.	906.	34147.
17	South Piney Creek	1207.	1265.	2425.	7428.	12187.	10004.	464.	2233.	254.	1736.	2100.	1331.	42636.
18	Green River between Piney Creeks and LaBarge Creek	25639.	25376.	37819.	82833.	163844.	246144.	196206.	88331.	46539.	48767.	41698.	29860.	1033054.
19	LaBarge Creek	3215.	3033.	4085.	7269.	13312.	9118.	6639.	4401.	3885.	4646.	4193.	3518.	67314.
20	Green River between La Barge Creek and Fontenelle Reservoir	28854.	28409.	41903.	90102.	163844.	246144.	196206.	93447.	51012.	53667.	45962.	33405.	1072953.
21	Fontenelle Creek	1643.	1537.	2084.	5729.	12740.	12740.	4518.	2062.	1765.	2086.	1925.	1751.	50583.

Table III-12 Available Flow for Green River Basin and Normal Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	56650.	56499.	65350.	95495.	163844.	246144.	196206.	105392.	61884.	59142.	55769.	54215.	1216590.
23	Big Sandy River below Farson gage and Green River	1980.	2034.	4730.	6111.	4234.	6747.	6033.	5123.	4542.	3822.	3171.	2484.	51011.
24	Green River between Big Sandy River and Green River near Green River gage	58891.	59204.	73947.	99523.	163844.	251899.	214389.	112609.	66028.	59142.	55769.	54255.	1269499.

Table III-13 Available Flow for Green River Basin and Wet Hydrologic Condition

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Upper Green River above Warren Bridge	7632.	6557.	8645.	16682.	82151.	179777.	94945.	42993.	23604.	11568.	9572.	9557.	493682.
2	Beaver Creek	723.	646.	877.	9492.	16816.	7275.	1228.	638.	348.	702.	913.	810.	40467.
3	Green River between Beaver Creek and Horse Creek	8418.	7285.	9937.	26213.	95856.	183091.	94945.	42993.	23910.	12427.	10633.	10403.	526110.
4	Horse Creek	1248.	1322.	3731.	6418.	22623.	31328.	10557.	6290.	3109.	2571.	2328.	1132.	92658.
5	Green River between Horse Creek and Cottonwood Creek	9667.	8607.	13667.	32631.	116449.	211532.	102314.	46854.	26812.	14998.	12961.	11535.	608028.
6	Cottonwood Creek	1294.	1442.	4508.	12234.	19033.	24265.	16016.	7683.	3902.	2985.	2790.	1284.	97436.
7	Green River between Cottonwood Creek and New Fork River	10961.	10048.	18176.	44866.	134569.	234500.	116898.	53446.	30622.	17982.	15751.	12819.	700637.
8	West Fork New Fork River above Pine Creek	376.	537.	1451.	9676.	21227.	73459.	46053.	13197.	7022.	5134.	3492.	1092.	182717.
9	Pine Creek	6218.	5813.	7292.	15574.	37566.	124681.	91686.	28635.	15055.	10975.	9145.	6934.	359575.
10	Pole Creek	8165.	7561.	8848.	18843.	43672.	126058.	108776.	35334.	15055.	12209.	10504.	8768.	403794.
11	Boulder Creek	9448.	9164.	10948.	22327.	69011.	206329.	154498.	49157.	24758.	15568.	11922.	9924.	593052.
12	East Fork New Fork River	2590.	1850.	6723.	8598.	31331.	85624.	18685.	4659.	5067.	7389.	5308.	4011.	181835.
13	New Fork River below confluence of West and East Forks	13607.	12003.	23205.	36400.	80518.	303150.	156347.	54412.	31838.	27207.	20962.	16785.	776433.
14	Green River between New Fork River and Piney Creeks	24696.	22216.	42209.	81345.	214246.	520231.	273410.	108286.	62924.	45501.	37010.	29676.	1461752.
15	North Piney Creek	1387.	1554.	5142.	2552.	6330.	21756.	16382.	9059.	4735.	3277.	2656.	1229.	76060.
16	Middle Piney Creek	1131.	1322.	5096.	1495.	2798.	14140.	13315.	9123.	4681.	2695.	2258.	879.	58934.
17	South Piney Creek	1436.	1521.	4299.	7373.	21350.	23087.	2666.	5132.	2480.	2958.	2679.	1301.	76282.
18	Green River between Piney Creeks and LaBarge Creek	28644.	26608.	56741.	92758.	228370.	520231.	307332.	132680.	75892.	54809.	44760.	33139.	1601962.
19	LaBarge Creek	3268.	3459.	5894.	9530.	25619.	22859.	10135.	8637.	6493.	4723.	3912.	2903.	107432.
20	Green River between La Barge Creek and Fontenelle Reservoir	31912.	30067.	62635.	102288.	228370.	520231.	318376.	140233.	81387.	59707.	47877.	36075.	1659158.
21	Fontenelle Creek	1792.	1628.	2520.	9443.	23982.	26841.	7484.	3402.	2854.	2072.	1858.	1710.	85586.

Table III-13 Available Flow for Green River Basin and Wet Hydrologic Condition (continued)

values in acre-feet

Reach	Reach Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
22	Green River Between Fontenelle Reservoir and Big Sandy River	55141.	53517.	77604.	118211.	228370.	520231.	345100.	140233.	81387.	79281.	47877.	55499.	1802451.
23	Big Sandy River below Farson gage and Green River	2232.	2192.	9553.	12503.	8413.	19093.	12192.	6503.	5445.	4322.	3995.	2623.	89067.
24	Green River between Big Sandy River and Green River near Green River gage	57303.	55888.	91293.	140212.	261167.	537167.	345100.	140233.	81387.	92410.	64343.	57857.	1924360.

B. Ground Water

The following subsections describe groundwater conditions, groundwater quality, and groundwater development potential in the Greater Green River Basin of Wyoming.

Basin Overview

There has been relatively little development of the groundwater resources of Wyoming's Green River Basin. As a result, information on well yield, aquifer properties, water quality, and recharge and discharge relationships is sparse relative to other, more developed areas of the State. Well yield and aquifer data were inferred from available information from the existing wells and previous studies.

Basin Groundwater Conditions

Eight major aquifer *systems* have been identified within the study area. These aquifer systems (or in some cases individual aquifers) are identified by the geologic formation within which they occur. This definition allows for a simplified presentation of the relatively abundant and complex aquifers that underlie the Greater Green River Basin.

The eight major water-bearing systems are, in *ascending* order:

1) Flathead aquifer;
2) Paleozoic-age aquifer system (including the Madison Limestone);
3) (Sundance-) Nugget aquifer system;
4) Upper Jurassic-Lower Cretaceous age aquifers;
5) Frontier aquifer;
6) Mesaverde-Adaville aquifers;
7) Tertiary-age aquifers;
8) Quaternary-age sands and gravels associated with major river courses through the Basin.

The major aquifer systems are also identified and described in Figure III-9 (p.III-43), a Generalized Hydrostratigraphic Column. The majority of the bedrock surface exposures are Cretaceous and Tertiary age rocks. These rocks are host to several important aquifers, including the Frontier aquifer (western part of the Basin), the Mesaverde aquifer system, and the Tertiary aquifer system. The Tertiary aquifer system includes a number of water-bearing formations, including the Green River, Wasatch, Battle Springs, and Fort Union Formations.

Groundwater resources of the Basin are largely undeveloped at this time. Ground water is principally used for drinking water supplies and industrial use. The majority of the

supplies are developed from Quaternary and Tertiary aquifers. Current groundwater use within the Greater Green River Basin is estimated to be between 5,300 and 7,200 acre-feet per year for all uses (estimates derived in this study).

A plot of well yields derived from the US Geological Survey's Groundwater Site Inventory, or GWSI database, vary over a broad range, as shown in Figure III-10 (p.III-44).

Basin Groundwater Quality

Water quality data were obtained from a groundwater quality database (GWSI database) maintained by the U.S. Geological Survey. Data were retrieved for 24 parameters including major cations, major ions, dissolved metals, dissolved solids, pH, and several other parameters that serve as useful indicators of the quality of water. The data obtained for this study contain reports for over 800 analyses obtained from a total of about 600 wells and springs.

A plot of the GWSI database shown in Figure III-11 (p.III-45) indicates no apparent tendencies in terms of the concentration of Total Dissolved Solids (TDS) by aquifer, nor does there appear to be a conspicuous tendency in the distribution of TDS concentrations across the Basin. Water quality likely varies by location within an aquifer, in relation to the depth of a well, and by aquifer.

Concentrations of TDS exceed the secondary drinking water standard in over one-half the wells sampled. Concentrations of sulfate exceed the secondary drinking water standards in about one-third of the wells sampled. Although these conditions do not necessarily prevent use of the water, there may be limitations on the types of uses for which this water is suitable. The quality of water at several locations is considered poor, and would require extensive treatment to render it suitable for drinking. There are insufficient data available to assess whether alternate groundwater sources of better quality might be available at these locations.

Groundwater Development Potential

There is virtually no information on the overall groundwater basin water budget, such that major inflow and outflow components may be quantified. Accordingly, it is difficult to evaluate the Basin's safe, long-term yield for purposes of defining future groundwater development potential.

The Basin has a total area of about 20,000 square miles (12.8 million acres). However, there are large areas of the Basin in which potential evapotranspiration (ET) significantly exceeds average rainfall. For purposes of this analysis, it is assumed that recharge is effectively zero in areas where ET significantly exceeds rainfall. In the remaining parts of the Basin, mainly the mountain and foothills areas, rainfall exceeds potential (ET). These areas have been mapped and are estimated to have an area of approximately 925,000 acres. The average "surplus" rainfall (where annual rainfall exceeds annual ET) is assumed to be about 6 inches. It is also assumed that approximately 10 percent of the

surplus rainfall recharges the groundwater system. This approach yields an estimate of about 50,000 acre-feet per year of groundwater recharge, and is considered to be an approximation of basin groundwater yield. These estimates neglect the potential for interbasin movement of ground water. They also neglect the large quantity of ground water in storage that could potentially be developed without experiencing significant basin-wide impacts.

By comparison, the USGS (Martin, 1996; Glover, et al, 1998) estimates approximately 100,000 acre-feet per year of groundwater recharge by precipitation to the Tertiary-age rocks. For planning purposes, it is concluded that basin yield is on the order of between 50,000 and 100,000 acre-feet per year.

Currently, there is no evidence to suggest over-development of the principal aquifer systems. It may be concluded that there is significant potential for additional development of these aquifer systems, with little risk of depleting this resource. In fact, the lack of over-development means there is a smaller chance that aquifer storage and retrieval techniques will be successful.

There are many factors that may affect future development and availability of groundwater resources. In the case of the Quaternary-age alluvial aquifers, any future development of groundwater resources may be expected to have a direct and near-immediate impact on the adjacent rivers and streams within the alluvial system. Another factor is the potential development of ground water associated with the coal bed methane (CBM) extraction industry.

The extent to which CBM resources are developed will depend on a number of factors, including current and forecasted energy costs, and the economics of the CBM projects. One important factor affecting a project's economics is the quality of water co-produced in the recovery process. The quality of water associated with the coals is reportedly significantly worse in the Greater Green River Basin than in the Powder River Basin. Water quality standards for salinity in the Colorado River System (adopted by each state and approved by the EPA in 1974) may require that the co-produced water be reinjected or treated before discharge. The impacts of the added costs of treatment or reinjection are unclear, but may render some CBM projects uneconomical. At this time, it appears unlikely that the level of development of CBM resources in the Greater Green River Basin will match the levels of development anticipated in the Powder River Basin given current market conditions and environmental mandates.

Figure III-1 Green River at Warren Bridge, near Daniel, WY

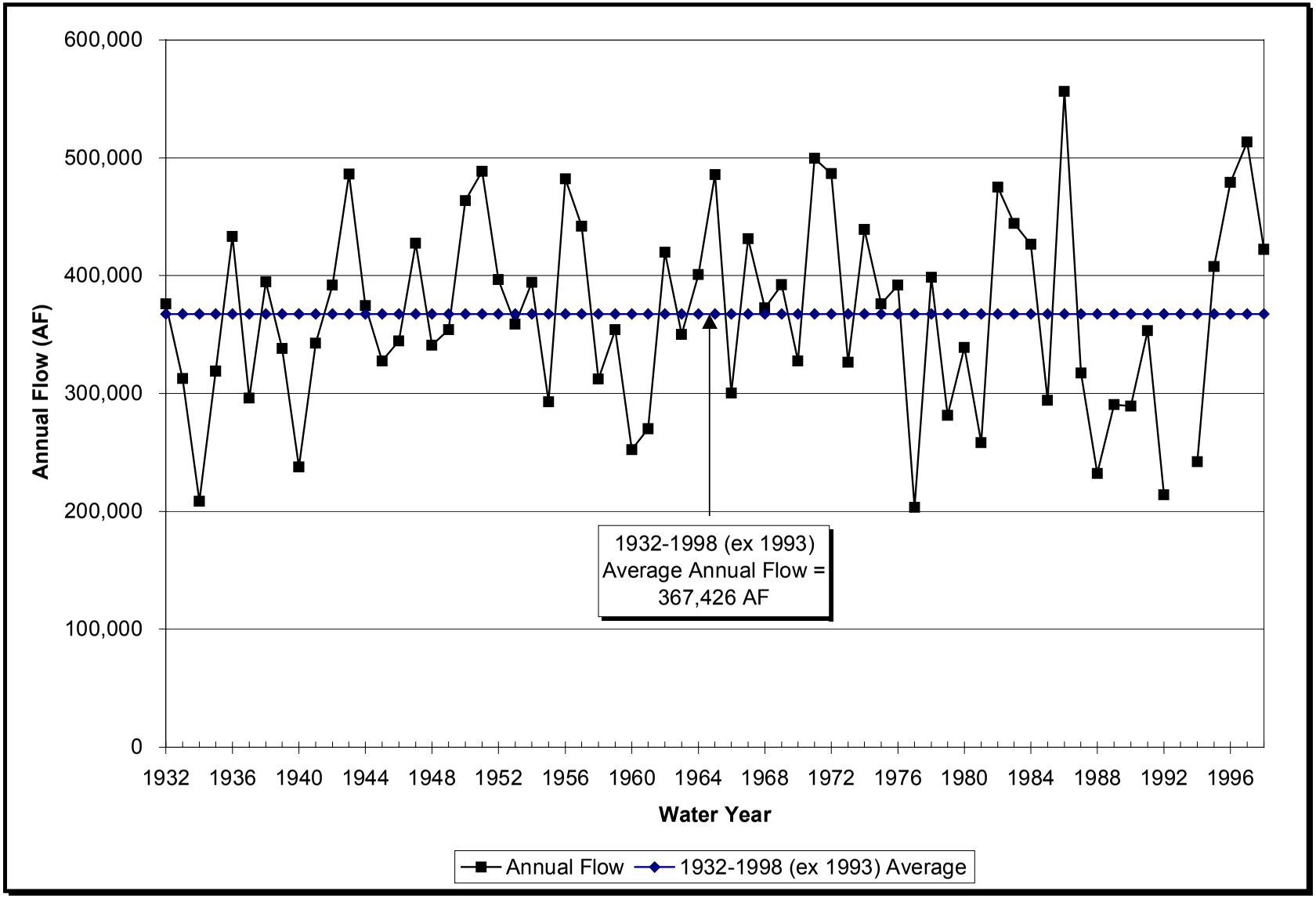


Figure III-2 Upper Green River Node Diagram

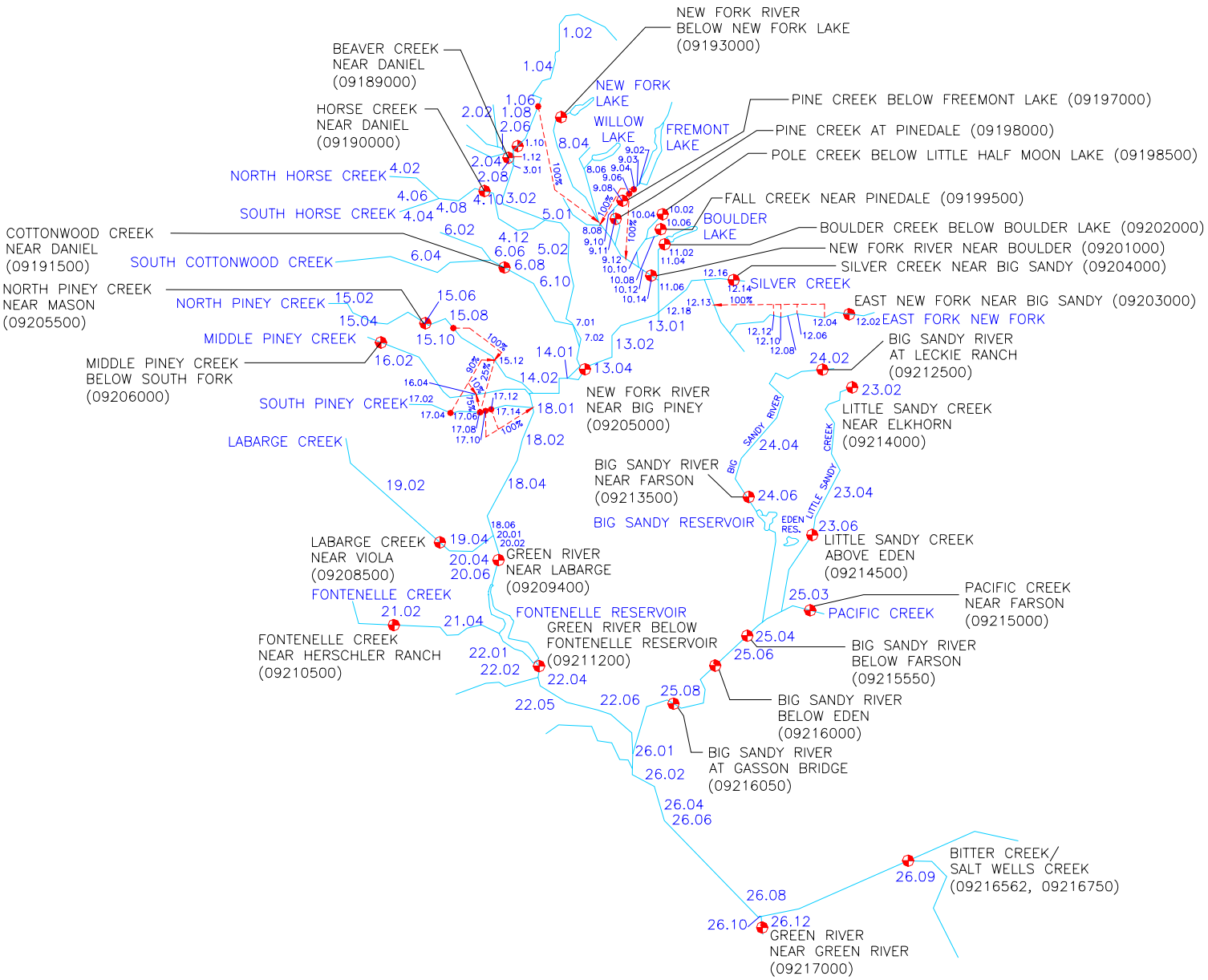


Figure III-3 Blacks Fork Node Diagram

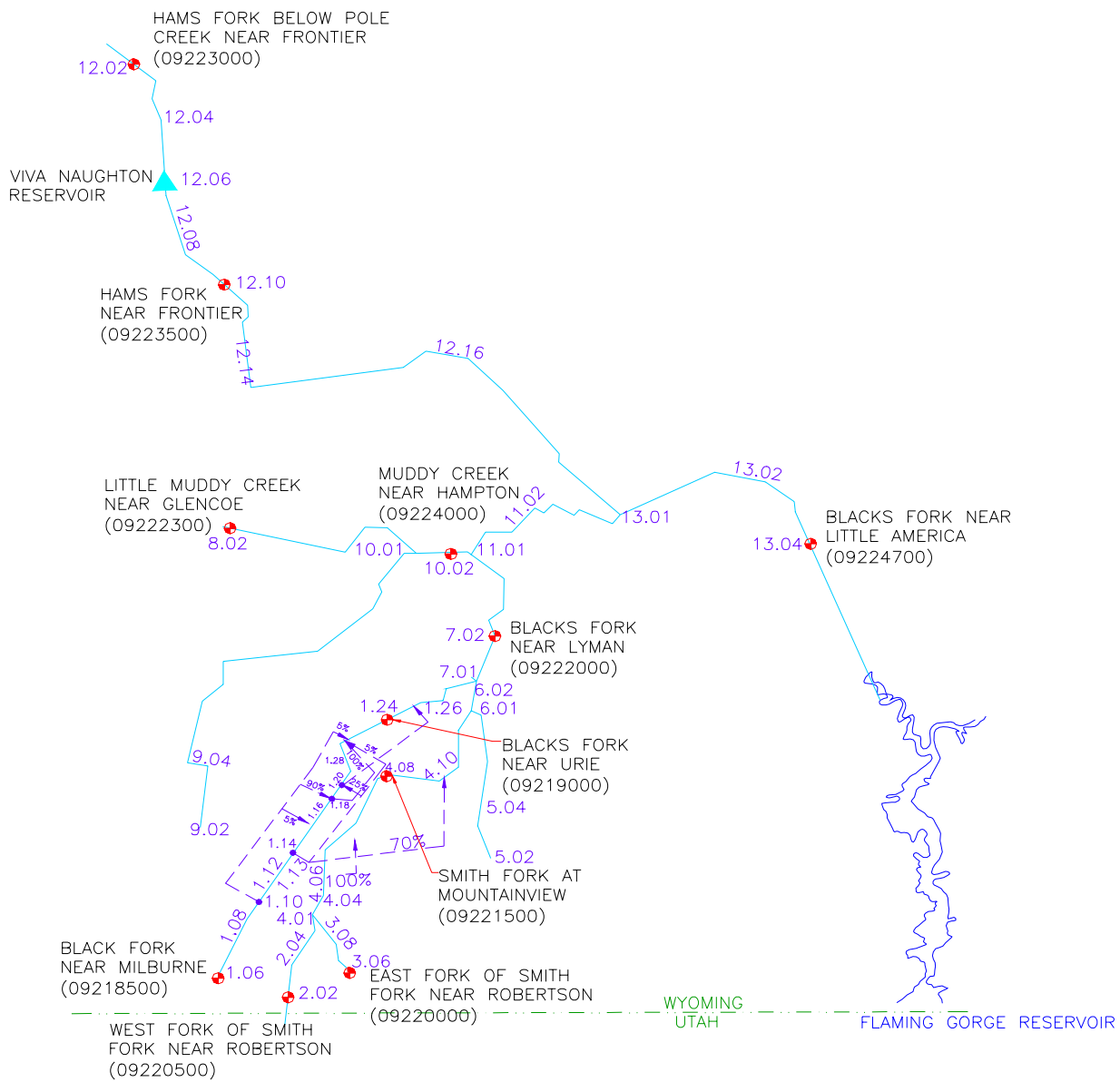


Figure III-4 Henrys Fork Node Diagram

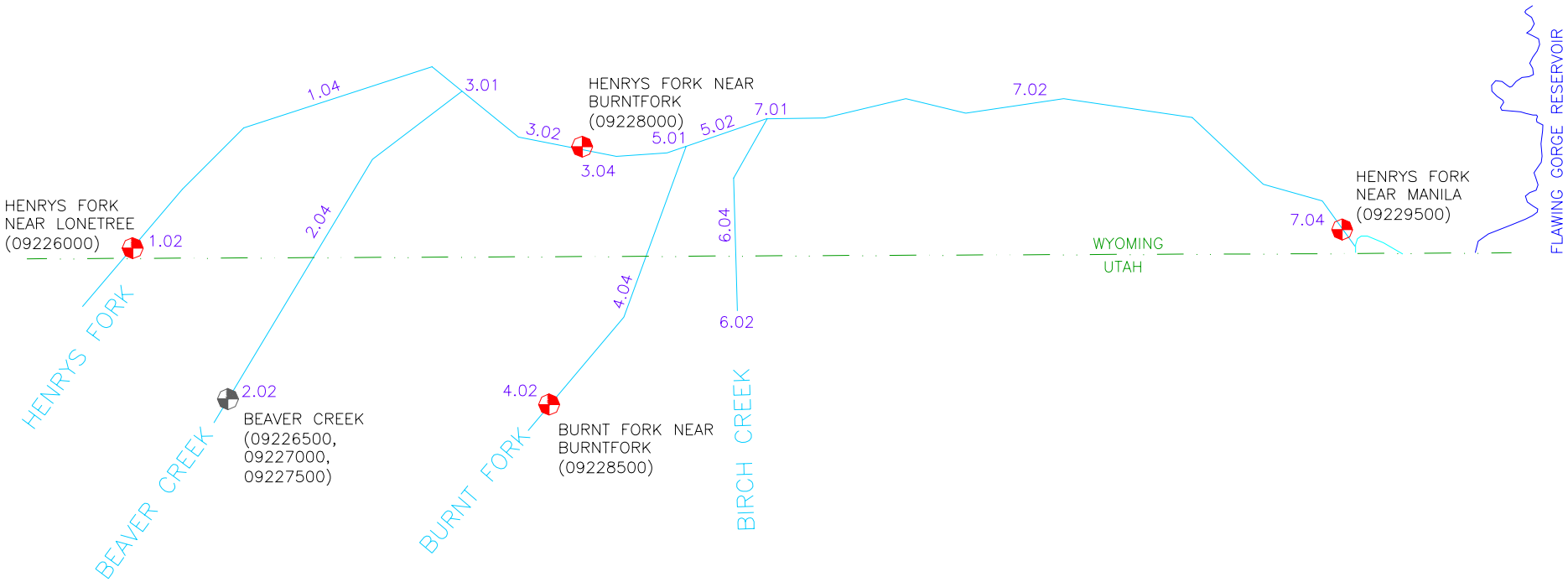


Figure III-5 Little Snake River Node Diagram

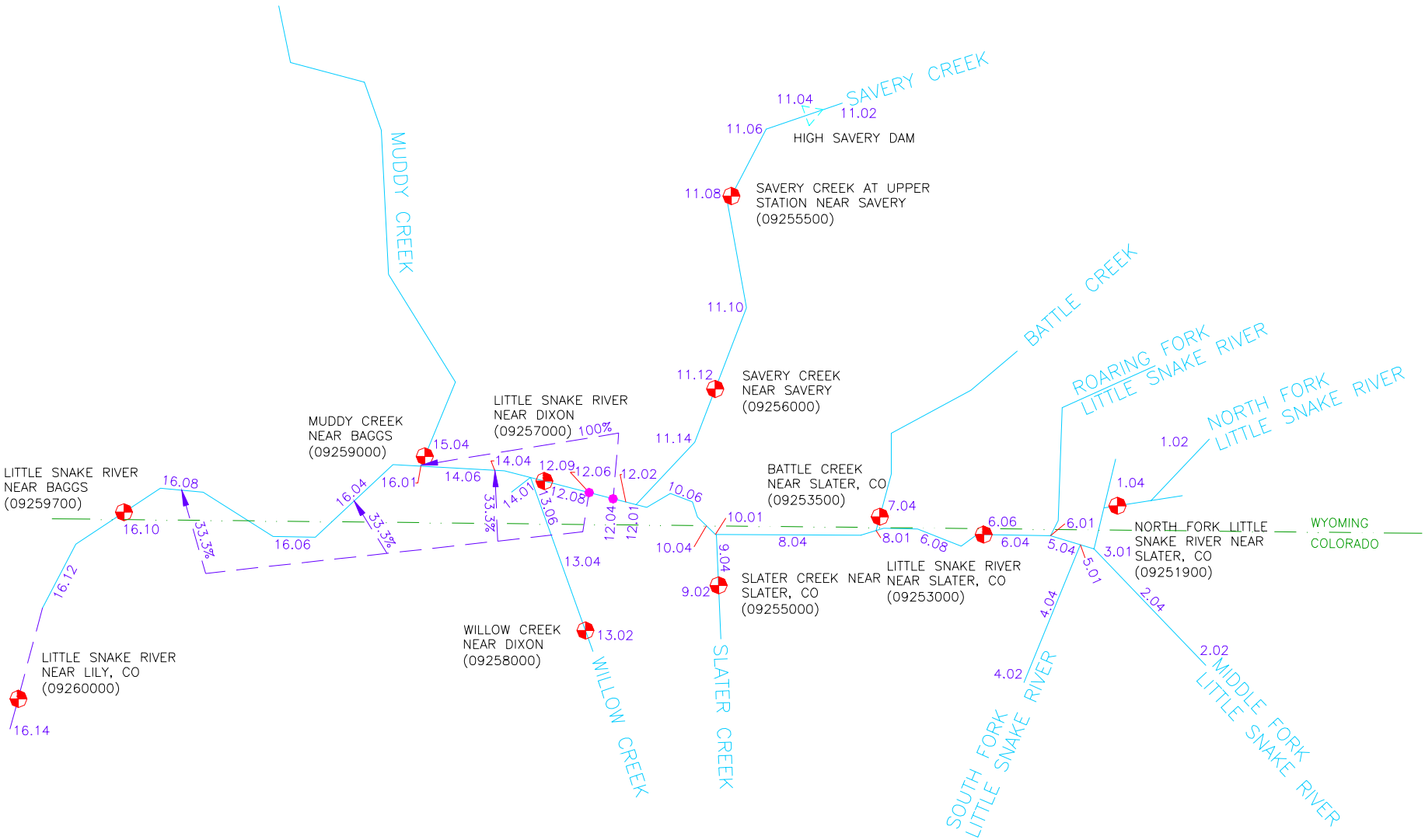
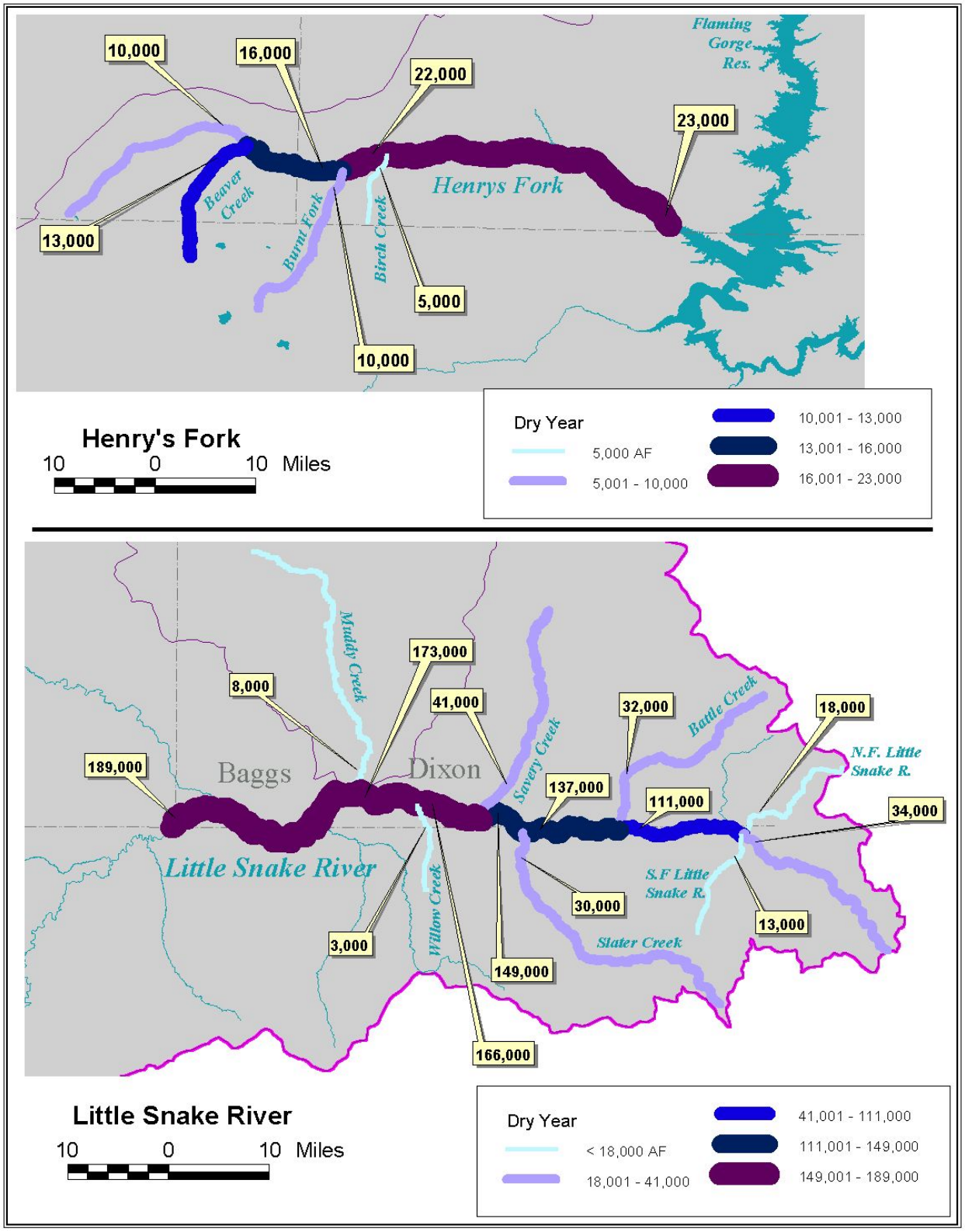
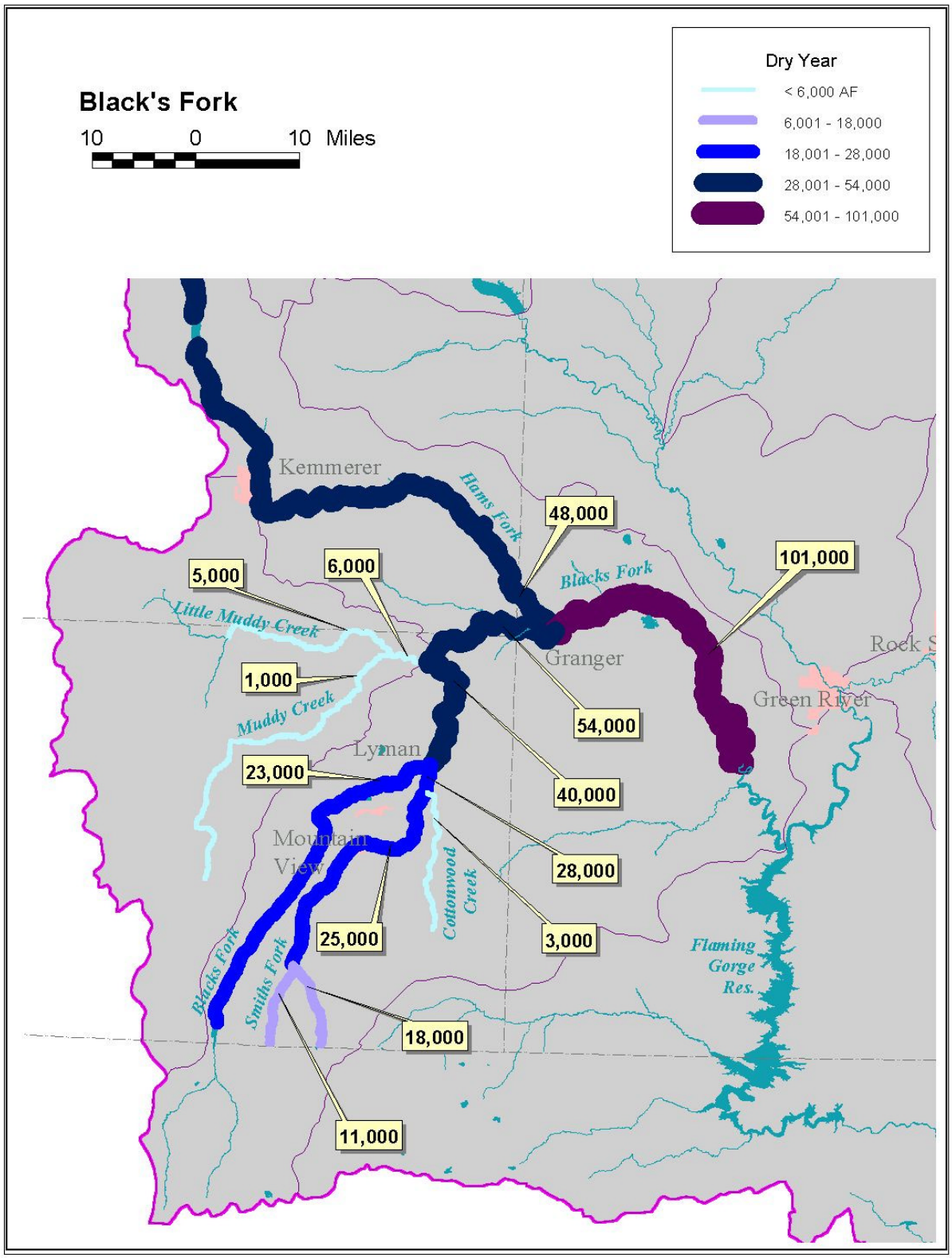


Figure III-6 Available Flow Modeling Results, Dry Year (3 pages)




Black's Fork
10 0 10 Miles
Dry Year
< 6,000 AF
6,001 - 18,000
18,001 - 28,000
28,001 - 54,000
54,001 - 101,000
Kemmerer
Hams Fork
48,000
6,000
5,000
Little Muddy Creek
Blacks Fork
101,000
Granger
Rock S
1,000
Muddy Creek
Green River
54,000
Lyman
23,000
40,000
Mountain View
28,000
Cottonwood Creek
25,000
3,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
18,000
11,000

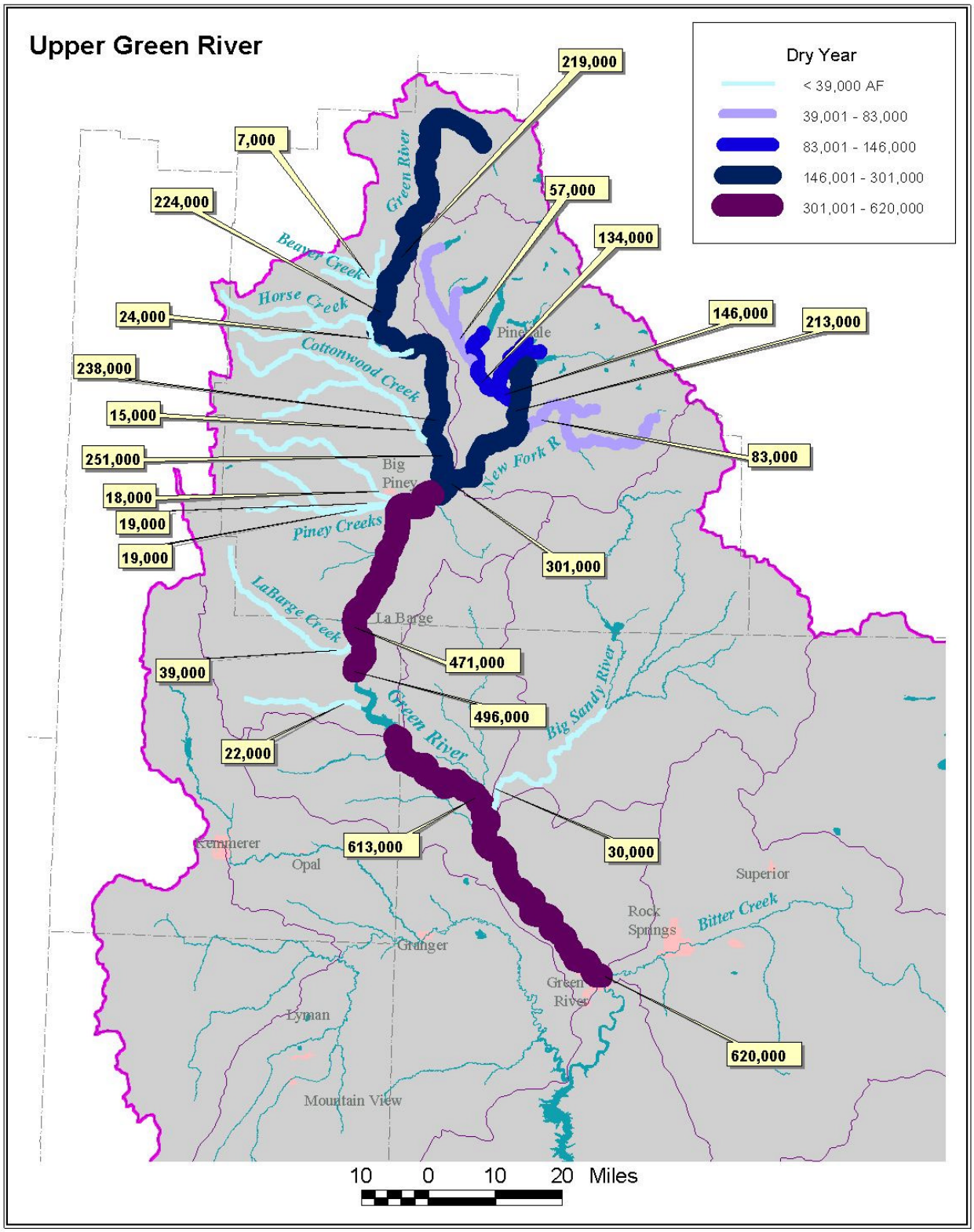
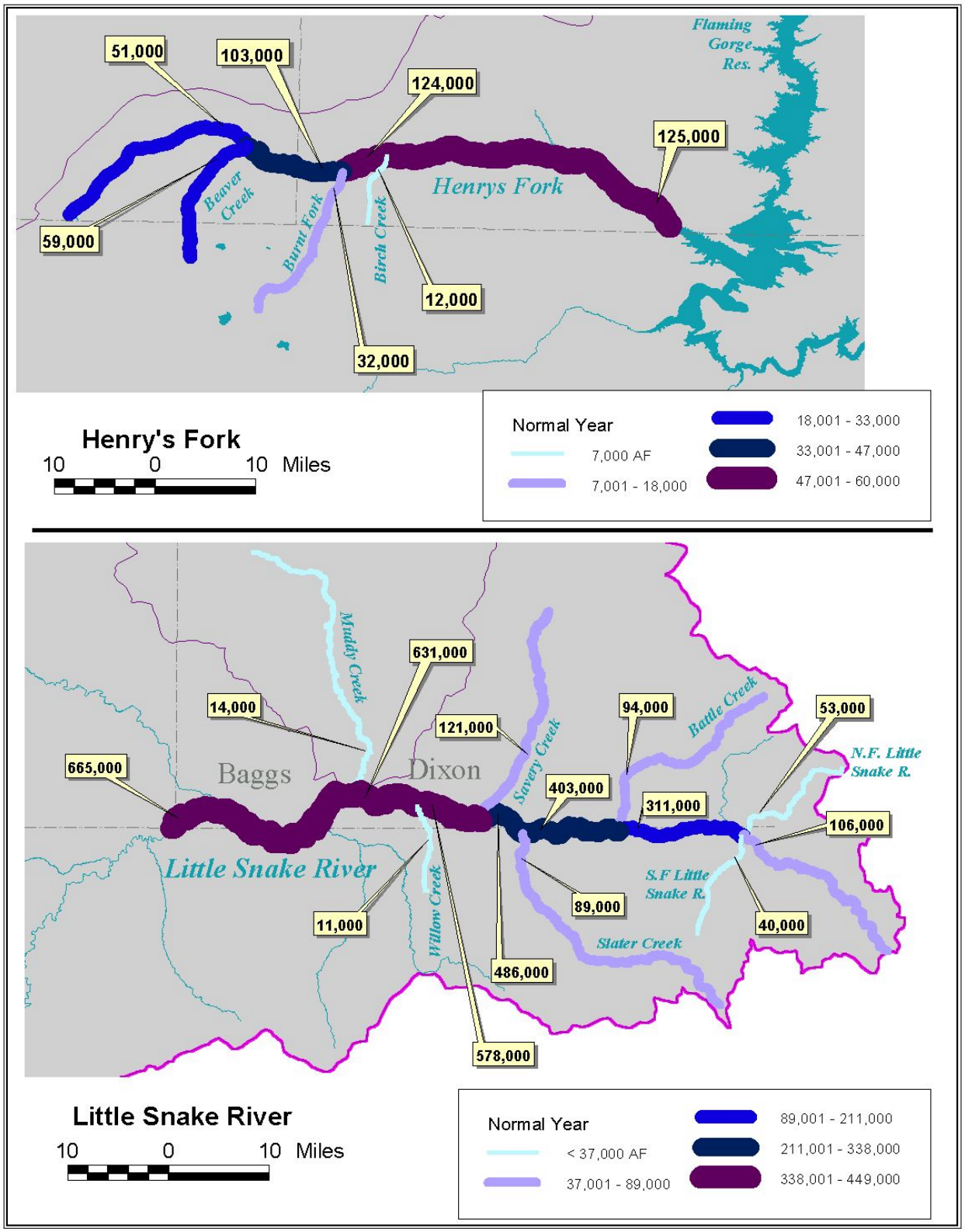
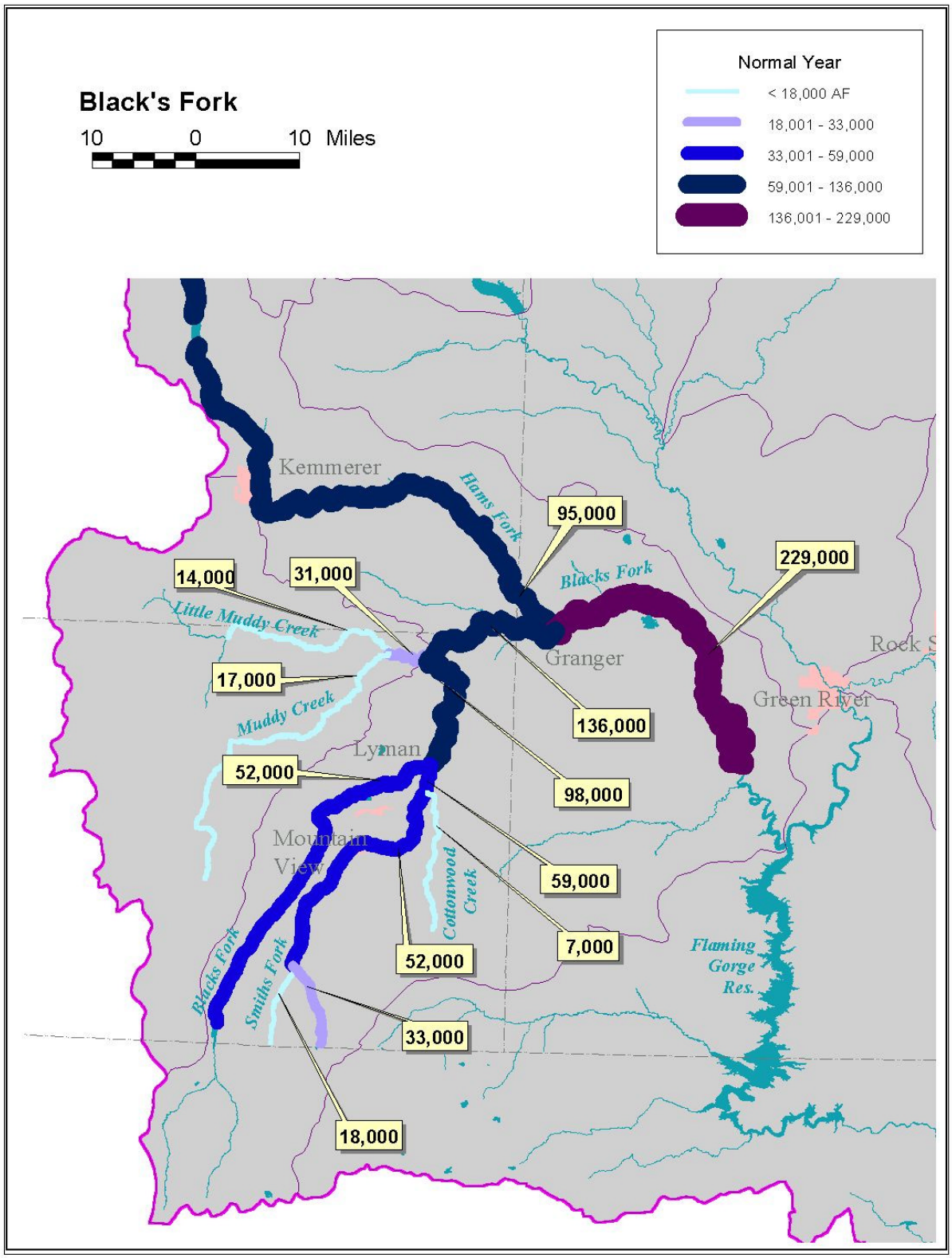

Upper Green River
Dry Year
< 39,000 AF
39,001 - 83,000
83,001 - 146,000
146,001 - 301,000
301,001 - 620,000
219,000
7,000
57,000
224,000
134,000
24,000
146,000
213,000
238,000
15,000
83,000
251,000
18,000
19,000
19,000
301,000
39,000
471,000
496,000
22,000
613,000
30,000
620,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
Pinedale
New Fork R
Big Piney
Piney Creeks
LaBarge Creek
La Barge
Big Sandy River
Green River
Kemmerer
Opal
Superior
Rock Springs
Bitter Creek
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

Figure III-7 Available Flow Modeling Results, Normal Year (3 pages)




Black's Fork
10 0 10 Miles
Normal Year
< 18,000 AF
18,001 - 33,000
33,001 - 59,000
59,001 - 136,000
136,001 - 229,000
Kemmerer
Hams Fork
95,000
229,000
Blacks Fork
14,000
31,000
Little Muddy Creek
Granger
Rock S
17,000
Muddy Creek
Green River
136,000
Lyman
52,000
98,000
Mountain View
Cottonwood Creek
59,000
7,000
52,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
33,000
18,000

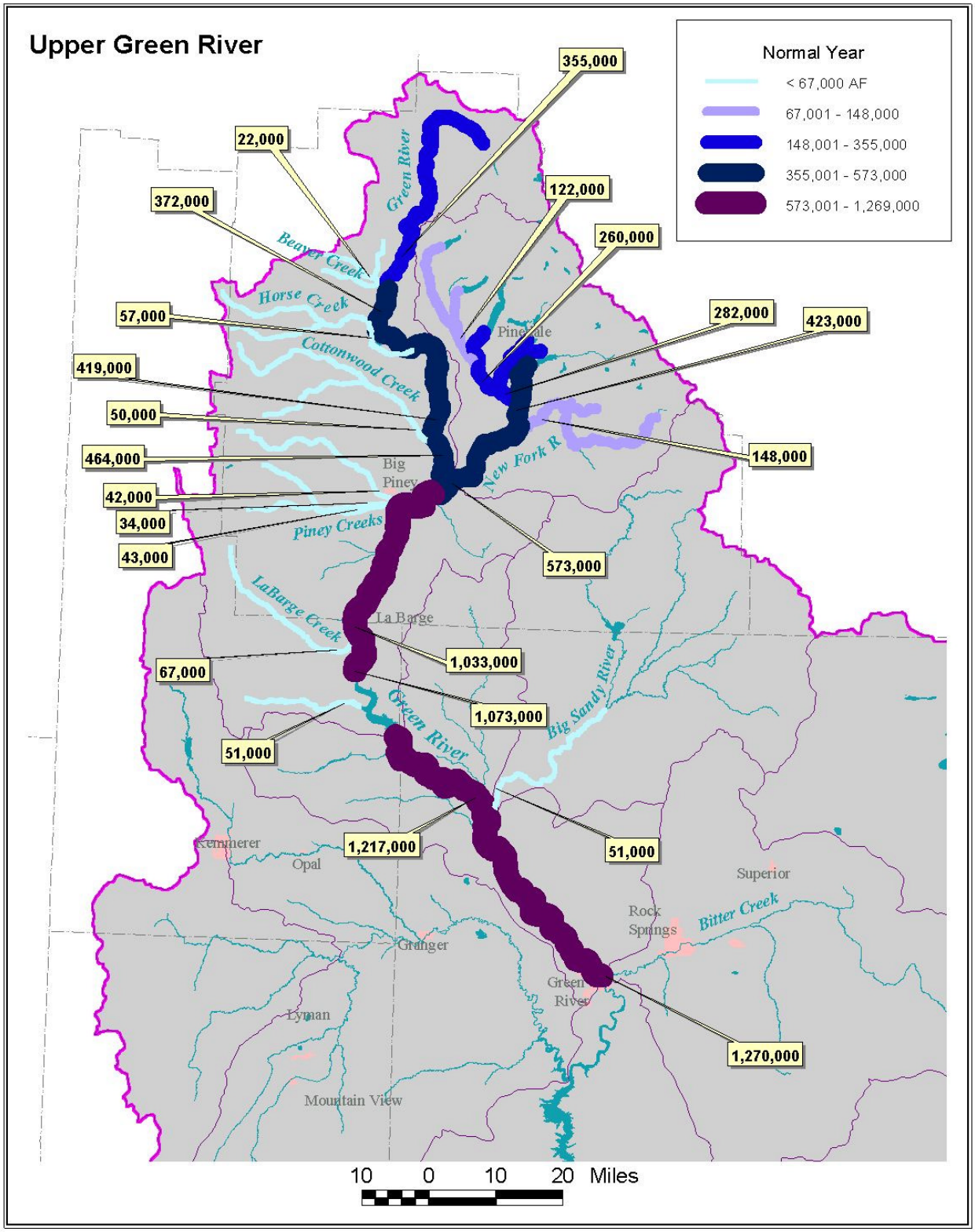
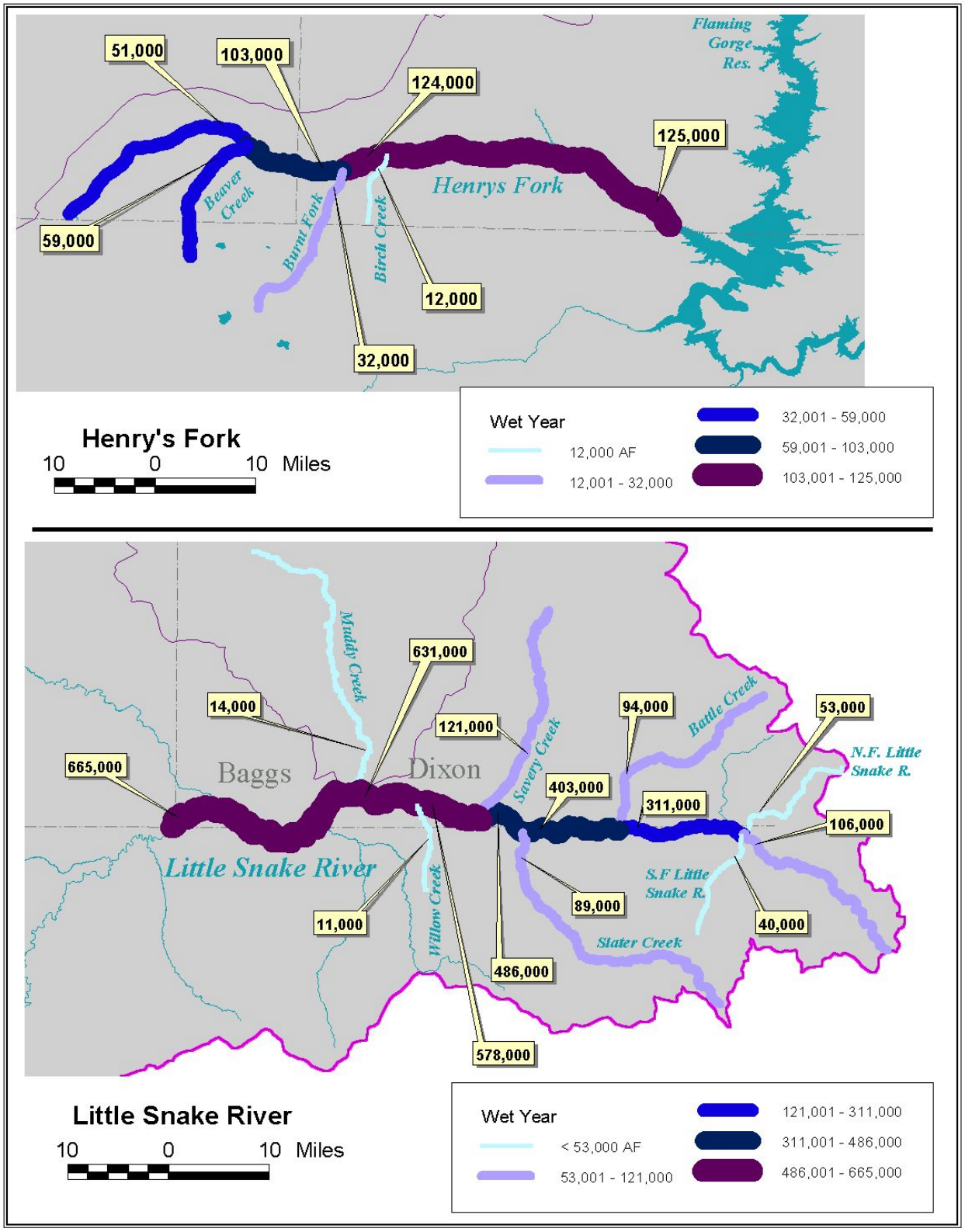
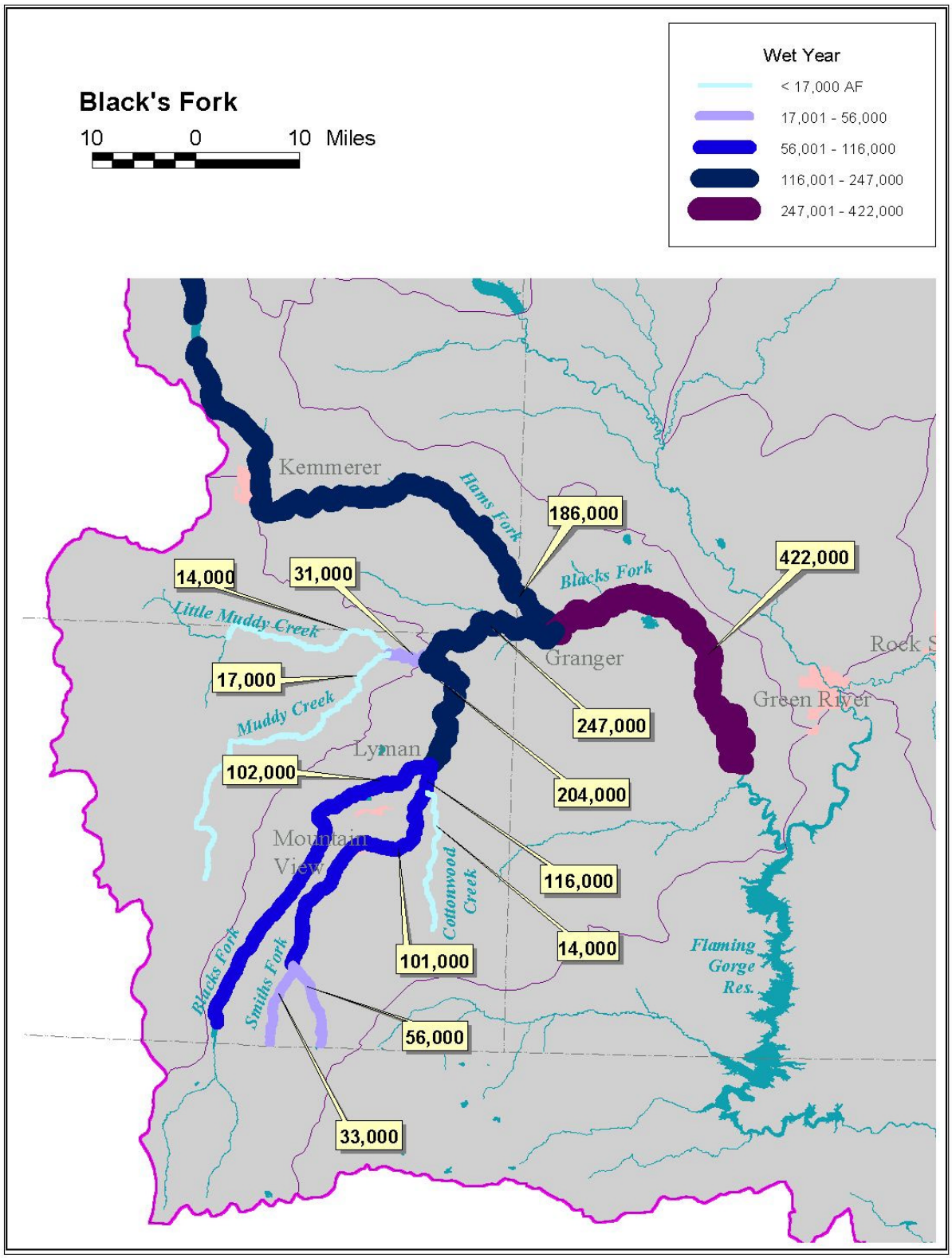
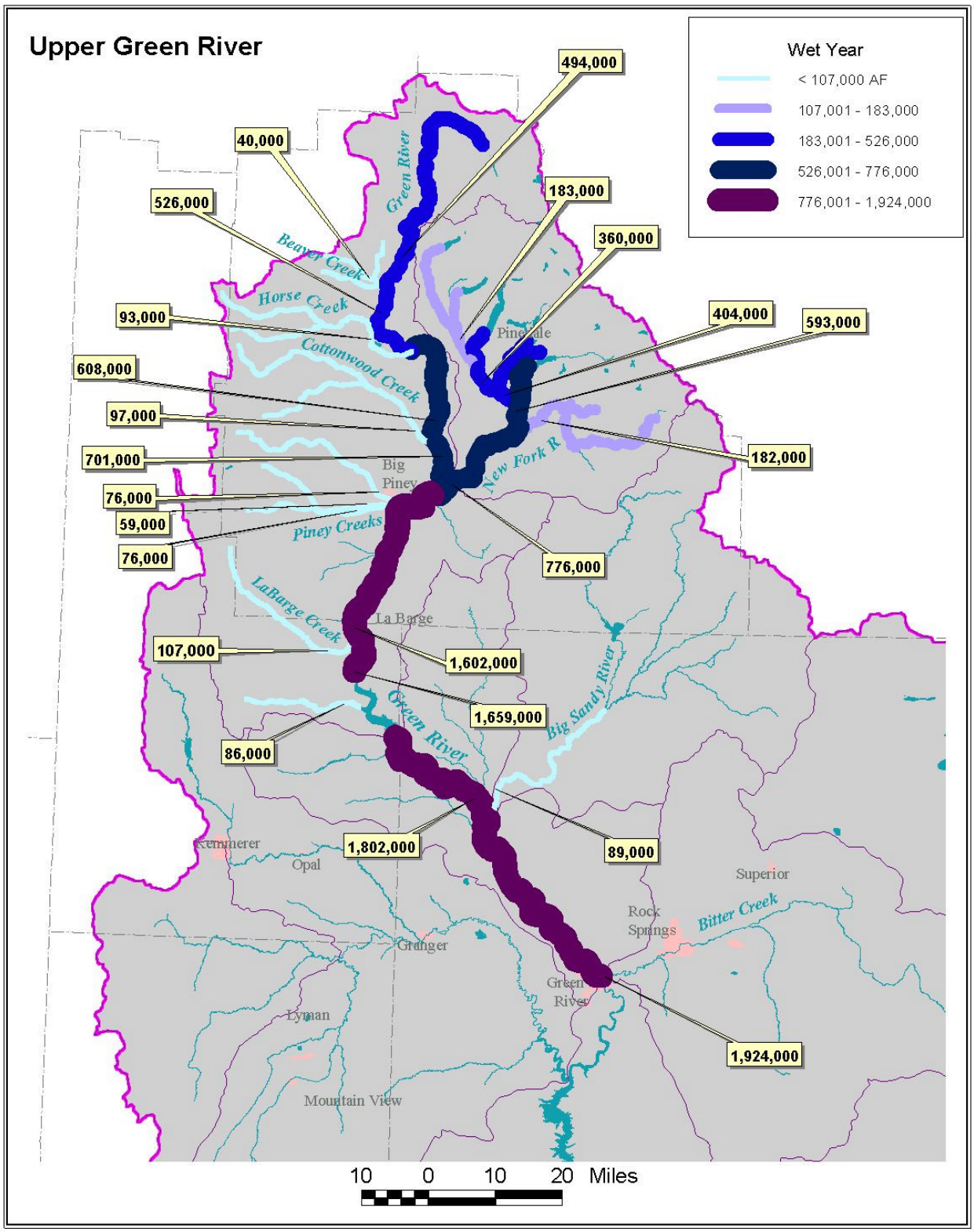

Upper Green River
Normal Year
< 67,000 AF
67,001 - 148,000
148,001 - 355,000
355,001 - 573,000
573,001 - 1,269,000
355,000
22,000
122,000
372,000
260,000
57,000
282,000
423,000
419,000
50,000
148,000
464,000
42,000
34,000
43,000
573,000
67,000
1,033,000
1,073,000
51,000
1,217,000
51,000
1,270,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
Pinedale
New Fork R
Big Piney
Piney Creeks
LaBarge Creek
La Barge
Big Sandy River
Kemmerer
Opal
Superior
Rock Springs
Bitter Creek
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

Figure III-8 Available Flow Modeling Results, Wet Year (3 pages)




Black's Fork
10 0 10 Miles
Wet Year
< 17,000 AF
17,001 - 56,000
56,001 - 116,000
116,001 - 247,000
247,001 - 422,000
Kemmerer
Hams Fork
186,000
422,000
Blacks Fork
14,000
31,000
Little Muddy Creek
Granger
Rock S
17,000
Muddy Creek
Green River
247,000
Lyman
102,000
204,000
Mountain View
Cottonwood Creek
116,000
14,000
Flaming Gorge Res.
Blacks Fork
Smiths Fork
101,000
56,000
33,000


Upper Green River
Wet Year
< 107,000 AF
107,001 - 183,000
183,001 - 526,000
526,001 - 776,000
776,001 - 1,924,000
494,000
40,000
526,000
183,000
360,000
93,000
404,000
593,000
608,000
97,000
182,000
701,000
76,000
59,000
76,000
776,000
107,000
1,602,000
1,659,000
86,000
1,802,000
89,000
1,924,000
Green River
Beaver Creek
Horse Creek
Cottonwood Creek
Pinedale
Big Piney
New Fork R
Piney Creeks
LaBarge Creek
La Barge
Big Sandy River
Kemmerer
Opal
Superior
Rock Springs
Bitter Creek
Granger
Green River
Lyman
Mountain View
10 0 10 20 Miles

[##] = thickness in feet

[1]Utah and Northwest Colorado terminology, used in Wyoming only in the subsurface.

Geologic Age	Overthrust Belt	Northwest Green River Basin	South & East Green River Basin	Great Divide, Washakie, and Little Snake River Basins	Hydrologic Unit	Description/Properties
Quaternary	Aluvial, terrace, glacial, landslide dep., slopewash and talus material. [50-410]	Alluvial, terrace, and glacial deposits [0-200]	Alluvial, floodplain, terrace, and glacial deposits [0-100]	Alluvial, dune, lacustrine, and glacial deposits [0-70]	Quaternary Aquifers	Discontinuous, major aquifer
Tertiary	Salt Lake Fm. [0-1000]	Camp Davis/Teewinot Fms. [2250-5200]	South Pass Fm. [0-200]	North Park/South Pass Fms. Browns Park/Bishop Conglomerate [0-1200]	Tertiary Aquifer System	North Park/South Pass is discontinuous, minor aquifer (topographically high and well-drained, predominantly).
		Browns Park/Bishop Conglomerate [~4400]	Browns Park/Bishop Conglomerate [0-200+]			
	Fowkes Fm. [500-2600]	Bridger Fm. [1700-2300]	Bridger Fm. [500-2300]	Bridger/Uinta Fms. [0-3200]		Complex intertonguing fluvial and lacustrine sediments. The Wasatch Formation, the Fowkes/Bridger Formations in the southwest Overthrust and Green River Basins near outcrop, as well as Ft Union in Great Divide, Washakie, and Little Snake Basins are major aquifers. Ft Union elsewhere, Evanston Formation, and Fox Hills SS are minor aquifers.
	Green River Fm. [400-600]		Green River Fm. (Wasatch-Cathedral Bluffs) [100-2800]	Green River Fm. (Interfingers with Wasatch) [0-1500]		
	Wasatch Fm. [2500-3600]	Wasatch Fm. [4100-5250]	Wasatch Fm. (Main Body) [0-7000]	Wasatch (South & West)/Battle Springs (Northeast) Fms. [0-4700]		
	Evanston Fm. [1350-2900]	Hoback Fm. [8000-18500]	Ft Union Fm. [0-2700]			
Upper Cretaceous		Harebell Fm.	Lance Fm./Fox Hills SS [0-4900]			
	Meeteetse Fm.		Lewis Shale [0-2700]		Aquitard	
		Mesaverde Fm.	Almond [0-1000] (Mesaverde Group)	Mesaverde Fm. [0-5600]	Mesaverde Aquifer	Major aquifer: Rock Springs and Ericson formations are the most permeable units, as is the basal member of the Adaville Formation (Lazeart Sandstone).
			Ericson SS [400-700] (Mesaverde Group)			
			Rock Springs [900-1700] (Mesaverde Group)			
	Adaville Fm. [1400-5000]		Blair [900-1800] (Mesaverde Group)			
	Hilliard Shale [3000-6800]	Baxter Shale [2700-4500]		Cody Shale (Great Divide)/Baxter Shale (West)/Steele Shale & Niobrara Fm. (East) [2000-5000]	Aquitard (Recent, unpublished work by the Wyoming State Geological Survey suggest the possibility that a number of wells yield a reasonable water supply from portions of the Hilliard Shale).	
	Frontier Fm. [1100-3000]	Frontier Fm. [1800-2700]		Frontier Fm. [190-900]	Frontier Aquifer	Minor aquifer, greatest potential in Overthrust Belt and Western Green River Basin.
Lower Cretaceous	Aspen Shale [400-2200]		Mowry/Muddy/Thermopolis Fms. [100-1000]	Mowry/Muddy/Thermopolis Fms. [200-900]	Aquitard	
	Bear River Fm. [800-1500]				Upper Jurassic-Lower Cretaceous Aquifers	Discontinuous, minor aquifer; Cloverly major aquifer (esp. sandstones & conglomerates of lower member) near recharge area in Great Divide & Washakie Basin.
	Gannett Group "Lakota Conglomerate" [800-5000]	Cloverly Fm. "Dakota Sandstone"		Cloverly Fm. "Dakota Sandstone," "Lakota Conglomerate" [45-240]		
Jurassic		Morrison Fm. [170-450+]			Aquitard	
	Stump-Preuss Fms. [160-530]	Curtis Fm./Entrada SS [35-530]		Sundance Fm. [130-450+]	(Sundance-) Nugget Aquifer System	Nugget Sandstone is the major aquifer throughout the area, although the Nugget is absent in the far southeast. The lower part of the Twin Creek Limestone, and the Thaynes Limestone are minor, regional aquifers in the Overthrust Belt.
	Twin Creek LS [150-725]					
		Gypsum Spring Fm. [0-725]				
	Nugget SS [750-1300]	Nugget SS [400-700]		Nugget SS (absent SE) [0-650+]		
Triassic	Ankareh Fm. [330-500]	Chugwater [900-1500]		Chugwater Group [900-1500]		
	Thaynes LS [0-500]					
Lower Triassic	Woodside Shale/Dinwoody Fm. [600-1300]	Dinwoody Fm. [250-450]		Dinwoody/Phosphoria Fms. (Goose Egg Fm.) [170-460]	Aquitard	
Permian	Phosphoria Fm. [200-400]				Paleozoic Aquifer System	Major aquifers are the Bighorn Dolomite, Darby Formation, Madison Limestone, Tensleep Sandstone, and Phosphoria Formation. These are primarily carbonate, so significant yields occur where there are solution openings and fractures, especially in the Madison with its well-developed paleokarst. The Amsden and Phosphoria are locally confining, minor aquifers.
Pennsyl-vanian	Wells Fm. [450-1800]	Tensleep SS [350-700]	Weber SS/Morgan Fm./Round Valley LS [650-1300][1]	Tensleep SS [0-840]		
	Amsden Fm. [300-700]			Amsden Fm. [0-260]		
Mississip-pian	Madison LS, Darby Fm., Bighorn Dolomite [780-1800]		Madison LS, Darby Fm. [650-1300]	Madison LS [5-325]		
Devonian						
Ordovician						
Cambrian	Gallatin LS [0-200]			Undifferentiated Cambrian/Flathead SS [0-800]		
	Gros Ventre Fm. [500-1000]				Aquitard	
	Flathead SS [175-200]				Flathead Aquifer	May be good source to exploit due to characteristic permeable sandstone, basal conglomerate and secondary permeability along bedding plane partings in outcrop and where the rocks are highly fractured.
Pre-cambrian	Precambrian Rocks					Minor aquifer where highly fractured and weathered in outcrop, or near the surface.

Figure III-9 - Generalized Hydrostratigaphic Column of the Greater Green River Basin, Wyoming

Modified from Ahern, et al, 1981, Collentine, et al, 1981, and Love, et al, 1993.

Figure III-10 Yields of Wells and Springs, GWSI Database

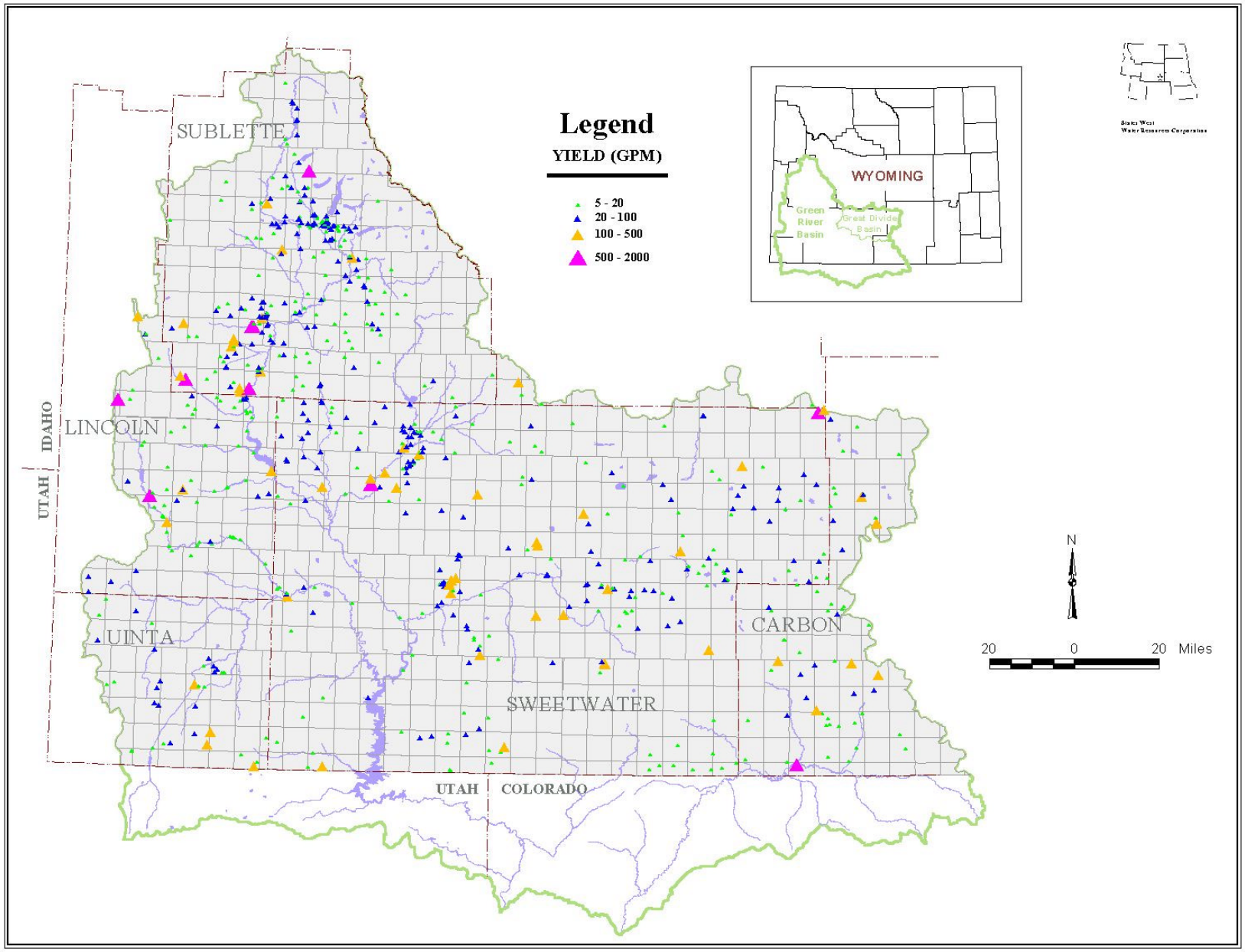
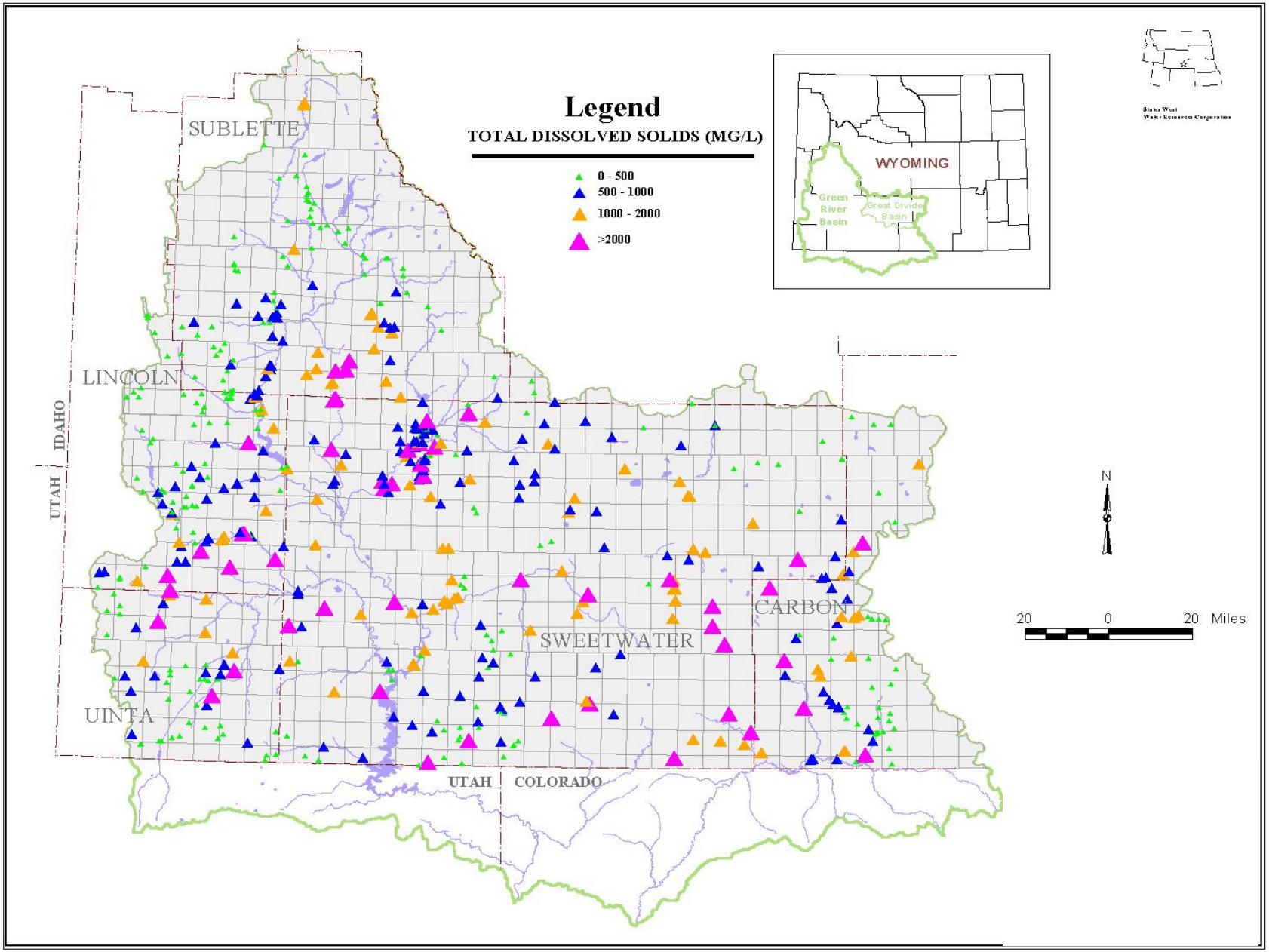



Figure III-11 Total Dissolved Solids, Wells and Springs in GWSI Database