4.0 WATER RESOURCES

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4.0 WATER RESOURCES

This chapter presents a discussion of the quantity and quality of surface water and groundwater in the Snake/Salt River Basin. Section 4.1 presents information on basin surface water resources, including the modeling methodology, surface water quantity, reservoir storage and surface water quality. Section 4.2 presents information regarding basin groundwater resources, including quantities and quality.

4.1 SURFACE WATER RESOURCES

Natural surface water flows are developed and defined by using spreadsheet models. Historic stream flow records form the basis for the spreadsheet models natural flow analyses. Model results provide estimates of surface water quantities within and leaving the basin.

Major and important reservoirs are inventoried as important water resources in the basin. However, they are not counted in the spreadsheet modeling analysis. Releases from Jackson Lake are considered as part of the basin water use determination and are combined with the model results (Chapter 7).

Water quality is important in the Snake/Salt River Basin and is important to a variety of water uses. Water quality information for this report comes from numerous sources, including data collected at select streamflow gaging stations and various site specific studies and monitoring programs.

4.1.1 SURFACE WATER MODELING METHODOLOGY

For the 2012 Update, the spreadsheet models prepared for the previous Basin Plan were revised to a new study period of record 1971 through 2010. Three 12-month spreadsheet models were analyzed for both the Snake and Salt River Basins, each representing newly classified dry, average and wet years. Inputs to the models were updated in terms of streamflow gage data, ungaged tributary inflow estimates and diversion data.

Revisions to the spreadsheet models for the 2012 Update involve integrating the models with a direct link to dataset queries contained within a new hydrologic database. Other changes include an update to the model map schematic and corresponding calculations that reflect the addition of Greys River into the Salt River Basin spreadsheet models.

A summary of key components to the spreadsheet models is presented below. Detailed information on the models is presented in Chapter 7.

4.1.1.1 STREAMFLOW GAGE DATA

The source of raw streamflow data used to build the historic streamflow records for the spreadsheet models was the U. S. Geological Survey (USGS) daily streamflow data. Daily streamflow data were loaded into a hydrologic database and queries were run to convert the daily data to monthly data. After performing the necessary data filling, further queries determined dry, average and wet years; and the data were formatted for integration into the spreadsheet models.

4.1.1.2 DIVERSION DATA

Diversion data in the spreadsheet models represents depletions to surface water supplies by irrigation activity. Updates to the diversion data employed a method for estimating crop irrigation requirements (CIR) that differed from the previous Basin Plan. For this study, StateCU was used, which is a public domain software model developed as part of Colorado's Decision Support System tools (State of Colorado, 2011). Crop water requirements calculated in this study reflect the climatic conditions within the basin during the new study period. More information on diversion data is presented in Chapter 5. For a detailed description on how diversion data for the spreadsheet models were determined, refer to *Technical Memorandum, Tab VII: Crop Water Requirements.*

4.1.1.3 UNGAGED TRIBUTARY INFLOW ESTIMATION

Several tributaries to the Snake and Salt Rivers, while included in the spreadsheet models, do not have gaging station records. For these tributaries, natural inflows were estimated using physical characteristics including basin area and mean basin elevation. As in the previous Basin Plan, mean annual flow for these watersheds was estimated using a regression equation derived for mountainous regions of Wyoming published in *USGS WRIR 88-4045* (Lowham, 1988). Once mean annual inflows were determined, monthly values were derived. A shift from mean annual inflows to monthly values was completed by correlation to a nearby gaged watershed with similar characteristics.

4.1.1.4 DRY, AVERAGE, AND WET YEARS CLASSIFICATION

Classification of dry, average and wet years was performed within a hydrologic database developed as part of the 2012 Update. After acquiring the updated gage records and performing the necessary data filling, the wettest and driest 20 percent of the study period years, based on an annual flow basis, were identified based on select indicator gages. The resulting dry, average, and wet year classifications are presented in Chapter 7.

4.1.1.5 PHYSICALLY AVAILABLE FLOW

Output from the spreadsheet models estimates the quantity, timing and location of surface water flows, which constitute the physically available supply as constrained by hydrologic supply and current water use within the basin. The spreadsheet models represent conditions in each basin under current levels of development for three hydrologic conditions; dry, average, and wet year water supply. Availability is a function of location analyzed within the models at "stream reach" levels and at a monthly timing level. These physically available flows, or "Reach Outflows" as predicted by the spreadsheet models, are presented and further discussed in Chapter 7.

4.1.1.6 ADJUSTED PHYSICALLY AVAILABLE FLOW

Flows predicted by the spreadsheet models do not account for Jackson Lake operations and existing instream flow rights. Deliveries of storage water from Jackson Lake to Palisades Reservoir occur throughout the Snake River mainstem. Also, flows are released from Jackson

Lake to satisfy fishery requirements. These reservoir releases, as well as existing instream flow rights, are not accounted for in the spreadsheet model. Therefore, adjustments were made to the "Reach Outflows" provided by the spreadsheet models. These adjusted physically available flows are presented and further discussed in Chapter 7.

4.1.2 SURFACE WATER QUANTITY

The objective of this section is to present basin estimates of total surface water supply resources or annual natural streamflow. A coarse estimate of these volumes can be made by simply adding the quantity of surface water leaving the state to estimates of surface water depletions and the existing instream flow rights that were accounted for in the adjusted available flow calculations. Equation 4-1 describes this relation. Instream flow quantities and estimates of water leaving the state can be derived from the adjusted physically available flow determinations that are described above and presented in Chapter 7. Estimates for surface water depletions come from the data as described and presented in Chapter 5.

EQUATION 4-1

$$NaturalFlow = AdjustedPhysicallyAvailableFlows + Depletions + InstreamFlows$$

The adjusted physically available flows at the most downstream reach in the spreadsheet models are shown on Table 4-1. These quantities represent a point in the model where surface water leaves the state. Table 4-2 shows the total annual irrigation supply-limited consumptive use or depletions, as determined by the spreadsheet models, upstream of the most downstream reach in the models. Table 4-3 displays the instream flow rights that were subtracted in the determination of adjusted physically available flows.

TABLE 4-1: ADJUSTED PHYSICALLY AVAILABLE FLOW

Sub-Basin	Dry Year (AFY)	Average Year (AFY)	Wet Year (AFY)
Snake River	1,775,752	2,717,548	4,049,867
Salt River	199,120	410,726	701,601
Greys River	117,292	278,374	488,441
Total	***2,092,165***	***3,406,648***	***5,239,909***

TABLE 4-2: SUPPLY-LIMITED IRRIGATION DEPLETIONS

Sub-Basin	Dry Year (AFY)	Average Year (AFY)	Wet Year (AFY)
Snake River	26,284	26,284	26,284
Salt River	53,935	54,278	54,294
Greys River	185	185	185
Total	***80,405***	***80,747***	***80,763***

TABLE 4-3: INSTREAM FLOWS

Sub-Basin	Dry Year (AFY)	Average Year (AFY)	Wet Year (AFY)
Snake River	0	0	0
Salt River	159,999	159,999	159,999
Greys River	174,044	174,044	174,044
Total	***334,043***	***334,043***	***334,043***

With respect to the instream flow quantities present in Table 4-3, it is important to note that permits for instream flows in Wyoming are awarded on the basis of cubic feet per second and can be specified as a different flow rate for each month. However, in order to keep the units consistent with the two previous tables, Table 4-3 presents the permitted instream flows as converted to an annual volume in acre-feet (AF). For example, the permitted instream flow right on the Greys River is 221 cfs, January through December. Converting 221 cfs to an annual quantity in acre-feet yields 159,999 acre feet per year (AFY) as exemplified in Equation 4-2.

EQUATION 4-2

$$\frac{221ft^3}{sec} * \frac{86,400sec}{day} * \frac{365days}{year} * \frac{1AF}{43,560ft^3} \cong 159,999AFY$$

Note that instream flow adjustments were only applicable to those segments located on the Salt and Greys Rivers. Instream flows for Snake River Basin are zero despite the existence of two instream flow segments on Fish Creek. Unlike the segments on the Salt and Greys Rivers, the Fish Creek instream flow segments are located on a tributary rather than the mainstem. In the adjusted available flow calculations, instream flows were only subtracted in reaches upstream from the instream flow segment. River reaches located downstream of the segment are not affected. The segments on Salt and Greys Rivers are located at or near the farthest downstream reach; therefore, all reaches upstream were affected by the adjustment and the instream flows must be counted as part of the natural flow. For more information on how adjustments were made for instream flows, refer to Chapter 7. Additional information on state instream flow water rights and those that exist in the Snake/Salt River basin, refer to *Technical Memorandum, Tab XIII: Instream Flows.*

Table 4-4 presents the resulting estimates of annual natural flows generated within each river sub-basin at a point where the flows leave the state (or enter Palisades Reservoir). The quantities shown in this table are for dry, average, and wet years and were determined by summing the values presented in the three preceding tables (Tables 4-1, 4-2 and 4-3).

TABLE 4-4: ESTIMATES OF NATURAL STREAMFLOW

Sub-Basin	Dry Year (AFY)	Average Year (AFY)	Wet Year (AFY)
Snake River	1,802,037	2,743,832	4,076,151
Salt River	413,055	625,003	915,894
Greys River	291,521	452,603	662,670
Total	***2,506,613***	***3,821,438***	***5,654,715***

4.1.2.1 COMPARISON TO PREVIOUS BASIN PLAN AND FRAMEWORK WATER PLAN

A direct comparison of estimated natural flow between the 2003 Plan and this Update is problematic. The 2003 Plan did not report estimates of annual natural streamflow as presented in the previous section, and Greys River was not included in that analysis. However, a rough comparison can be made by extracting the physically available flows, or "Reach Outflows," from the previous spreadsheet models and applying the same calculations to determine adjusted physically available flow and annual natural streamflow. A comparison between the previous Basin Plan and this Update of the annual natural streamflow estimates is presented on Table 4-5.

A direct comparison to the quantities presented in the Wyoming Framework Water Plan from 2007 is also difficult because a different methodology was used and it is unclear whether Greys River was included in the accounting. Nevertheless, a comparison between the Framework Plan and this Update is summarized in Table 4-6.

TABLE 4-5: ESTIMATES OF ANNUAL NATURAL STREAMFLOW, COMPARISON TO PREVIOUS BASIN PLAN

Description		Dry Year (AFY)	Avg. Year (AFY)	Wet Year (AFY)
Snake River Basin	**2012 Update**	**1,802,037**	**2,743,832**	**4,076,151**
	2003 Basin Plan	1,810,567	2,923,420	4,196,462
Salt River Basin	**2012 Update**	**413,055**	**625,003**	**915,894**
	2003 Basin Plan	430,797	676,656	915,507
Total: 2012 Update (Greys River Excluded1)		**2,215,091**	**3,368,835**	**4,992,045**
Total: 2003 Basin Plan (Greys River Excluded1)		2,241,363	3,600,076	5,111,969
Change		*-26,272*	*-231,242*	*-119,924*
Percent Change		*-1.2%*	*-6.4%*	*-2.3%*

1. Greys River was not considered in the previous Basin Plan

TABLE 4-6: ESTIMATES OF ANNUAL NATURAL STREAMFLOW, COMPARISON TO FRAMEWORK WATER PLAN

Description	Dry Year (AFY)	Avg. Year (AFY)	Wet Year (AFY)
Total: 2012 Update (Greys River Excluded1)	**2,215,091**	**3,368,835**	**4,992,045**
Total: 2007 Framework Water Plan (Greys River Excluded1)	2,179,000	3,540,000	5,047,000
Change	*+36,091*	*-171,165*	*-54,955*
Percent Change	*+1.7%*	*-4.8%*	*-1.1%*

1. It was assumed that Greys River was not considered in the Framework Water Plan

The 2012 Update shows a decrease in total annual natural streamflow from that presented in the previous Basin Plan. Decreases range from 1.2 percent in a dry year to 6.4 percent in an average year. In comparing the results of this study to quantities presented in the Framework Water Plan, a slight increase of 1.7 percent is noted in a dry year, and a slight decrease of 1.1 percent is noted in a wet year. A decrease of 4.8 percent is seen in an average year.

These noted differences can likely be attributed to the extended study period, which includes some very dry years as reflected in the streamflow records. Also, different methodologies were used to estimate CIR, obtain climatic data, and delineate irrigation zones as further described in Chapters 5 and 7.

4.1.3 MAJOR RESERVOIRS

All major reservoir facilities in the Snake/Salt River Basin are owned and managed by the USBR for irrigation and hydropower production in Idaho. Jackson Lake Dam and Grassy Lake Dam are managed as part of the Minidoka Project, which provides irrigation water for over one million acres of farmland in Idaho. Palisades Dam, part of the Palisades Project, is also managed in conjunction with the Minidoka Project. Table 4-7 summarizes information on the three major reservoirs in the basin. Additionally, an inventory of other important storage facilities is presented in Table 4-8. Further information is presented in *Technical Memorandum, Tab XII: Major Reservoirs and Reservoir Evaporation.*

TABLE 4-7: MAJOR RESERVOIRS IN THE SNAKE/SALT RIVER BASIN

Reservoir	Permit No.	Year Complete	Normal Capacity (Acre-Feet)	Dam Height (Feet)	Surface Area (Acres)
Grassy Lake	4631R	1939	15,182	70	310
Jackson Lake	Various	1911	847,000	65	25,530
Palisades	Idaho	1957	1,200,000	270	16,150

JACKSON LAKE NEAR JACKSON LAKE DAM

TABLE 4-8: OTHER IMPORTANT WATER STORAGE FACILITIES IN THE SNAKE/SALT RIVER BASIN

Water Storage Facility	Normal Capacity (Acre-Feet)
Afton Electric Reservoir (aka Swift Creek Reservoir)	48
Baldwin Reservoir	30
Bergman Lake Reservoir	201
Cottonwood Lake	70
Cottonwood Reservoir	487.55
Flat Creek Ranch Reservoir	151
Four Shadows Reservoir	78.69
Indian Lake Reservoir	904
Jackson Wastewater Treatment Plant	260
Leidy Lake	65
Leland's Reservoir	65.83
McLean Reservoir	16.4
Melody Ranch Pond	70
Porter Reservoir	52
Strawberry Creek Reservoir	11
Teal Reservoir	79
Teton Meadows Ranch Reservoir Enlargement	200.40
Timber Creek Reservoir	12
Tracy Lake	380
Tucker Ranch No. 23 Reservoir	146
Tucker Ranch No. 24 Reservoir	270
Two Ocean Reservoir	512
Uhl Reservoir	543
West Borrow Area Lake	96

4.1.4 SURFACE WATER QUALITY

Water quality is an important issue in the Snake/Salt River Basin. It was listed as one of the major issues for the basin in the 2007 framework water planning process (WWC Engineering, Inc, 2007). The issue expanded from the initial water quality concern by the Snake/Salt River BAG as listed in the issues for the 2003 Snake/Salt River Basin Plan Final Report (Sunrise Engineering, Inc., 2003), to the need for water quality monitoring during the framework water planning process.

Prior to preparation of the previous Basin Plan, there was no extensive water quality monitoring activities underway in the basin. Therefore, water quality discussions were based on the Wyoming 2002, 305(b) State Water Quality Assessment Report, which included 303(d) impaired stream listings, and the three USGS gaging stations where water quality samples were taken (Sunrise Engineering, Inc., 2003).

There were three stream segments listed on the 2002, 303(d) list as having water quality threats including: North Fork Spread Creek due to habitat degradation; Flat Creek between Snake River and Cache Creek due to habitat degradation; and Salt River near the Etna USGS gaging station due to fecal coliform bacteria. A channel rehabilitation project had been completed on the North Fork Spread Creek, but the stream remained on the 303(d) list because the riparian vegetation was not yet well established. It was stated in the 305(b) report that overall there were few threats to water quality in the basin, and there were no waters in the basin requiring establishment of a total daily maximum load (TMDL) (Sunrise Engineering, Inc., 2003).

Sunrise Engineering, Inc. (2002) reviewed data from the three water quality stations. These data indicated there were no water quality problems present, except the fecal coliform bacteria contamination at the gage station near Etna.

In the time period since the 2003 Snake/Salt River Basin Plan, a number of water quality monitoring programs have been implemented. Discussions, in *Technical Memorandum, Tab XIV: Surface Water Quality*, present the information and results from these monitoring programs to provide an overall description of water quality in the basin. The following sections summarize water quality within the major sub-basins of the Snake/Salt River Basin. These sub-basins are shown on Figure 4-1. Streams listed on the Wyoming Department of Environmental Quality, Water Quality Division 2012 303(d) list of impaired streams (WDEQ, WQD, 2012) are also shown on the figure.

GREYS RIVER AT ALPINE

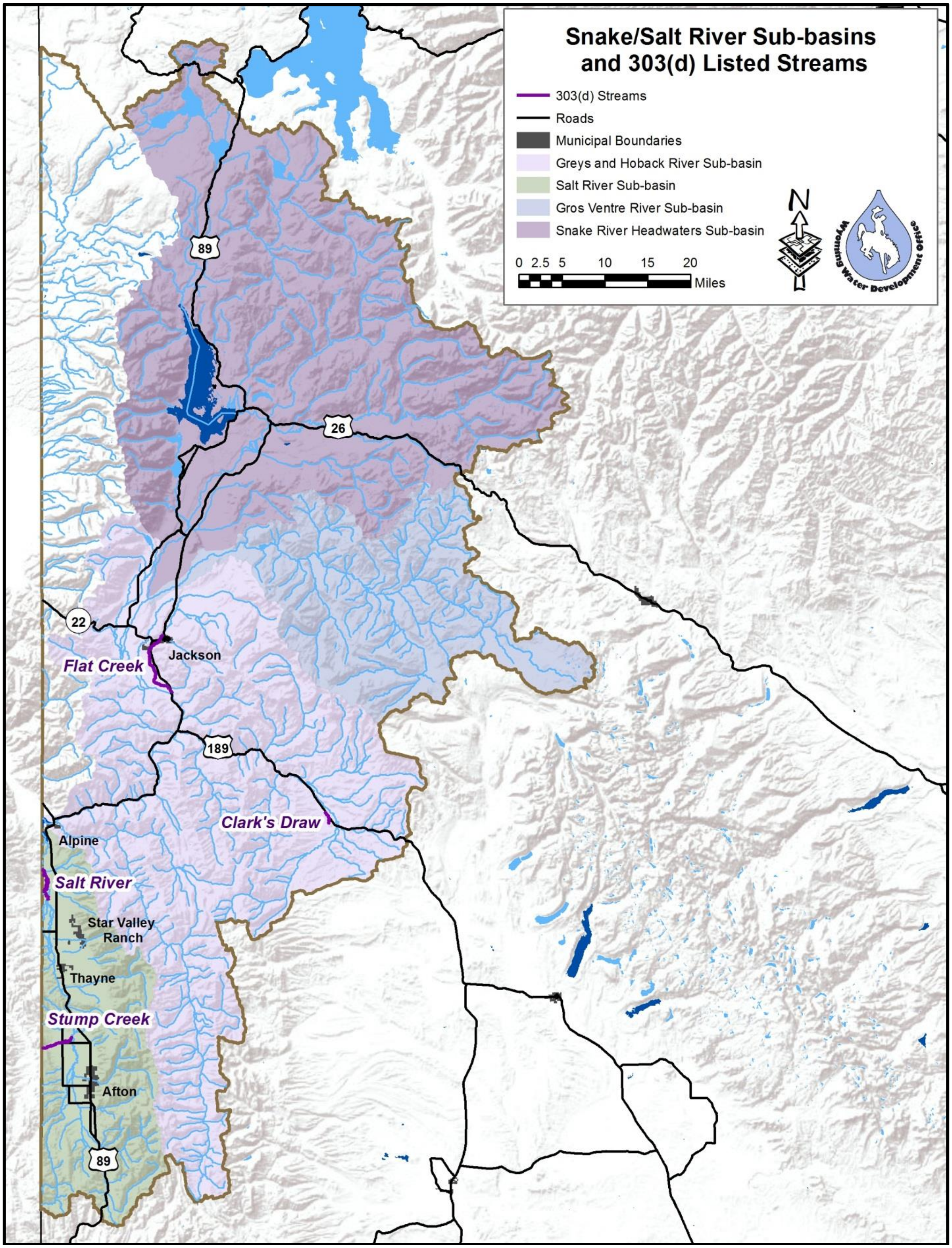

FIGURE 4-1: SNAKE/SALT RIVER SUB-BASINS AND 303(D) LISTED STREAMS

4.1.4.1 SNAKE RIVER HEADWATERS SUB-BASIN

Waters of the Snake River Headwaters Sub-basin originate in southern Yellowstone National Park, Grand Teton National Park, and the Grand Teton and Jedediah Smith Wilderness Areas (WDEQ, WQD, 2010). Many of the waters in this sub-basin are WDEQ, WQD Class 1 waters, including all waters within Yellowstone National Park, Teton National Park, Jedediah Smith Wilderness Area, and Teton Wilderness Area. Additionally, the Snake River main stem above Wyoming State Highway 22 bridge is a Class 1 water. Other waters in this sub-basin are class 2AB. Appendix A to *Technical Memorandum, Tab XIV: Surface Water Quality* and Appendix B of this report contain Wyoming's Surface Water Classification System (WDEQ, WQD 2007).

Monitoring data show that water quality is very good in the Snake River Headwaters Sub-basin, and there are few impacts from human activities (USDI. National Park Service, 2009).

4.1.4.2 GROS VENTRE RIVER SUB-BASIN

The Gros Ventre River Sub-basin originates in the Bridger-Teton National Forest with a large portion of the watershed arising in the Gros Ventre Wilderness Area. The main stem of the Gros Ventre River is Class 2AB (WDEQ, WQD, 2007). Streams within the Gros Ventre Wilderness Area, in addition to The Six Lakes and Clear Creek, are Class 1 waters. Other streams within the sub-basin are class 2AB.

Water quality with in the Gros Ventre River Sub-basin is considered good, and minimal development has occurred in the sub-basin. However, it is suspected the sub-basin may be impacted by wildlife grazing and browsing. Monitoring to determine use support has not been conducted in the sub-basin (WDEQ, WQD, 2010).

4.1.4.3 GREYS RIVER AND HOBACK RIVER SUB-BASIN

This sub-basin has been divided into three watersheds for this discussion; Lower Snake River Watershed, Greys River Watershed and Hoback River Watershed.

The Lower Snake River Watershed begins at the confluence of the Gros Ventre and Snake Rivers and continues to the confluence of the Snake and Hoback Rivers. The watershed then continues from this confluence to Palisades Reservoir. It is the most populated area within the sub-basin. The Town of Jackson, communities of Wilson and Teton Village, and the rural developed area between the Town of Jackson and Hoback Junction are all within this watershed.

Most streams in this watershed, including the main stem of the Snake River and Flat Creek, are classified as 2AB (WDEQ, WQD, 2007). All waters in the Fish Creek drainage are Class 1 to its confluence with the Snake River.

Water quality within this watershed is considered good because the quality of waters entering the watershed is good. There are impacts to this watershed from development that affect the water quality on a local basis. Flat Creek was listed on the 1996 303(d) list of impaired streams as being possibly impaired. Water quality assessments of Flat Creek indicated that urban runoff, primarily sediment from the Town of Jackson, limits aquatic habitat. Flat Creek was listed on the 2000 303(d) list because support for cold water game fishery and aquatic life other than fish was threatened from storm water runoff, and it remains on the 2012 303(d) list as threatened (WDEQ, WQD, 2012). The stream segment that is listed extends from the confluence with the Snake River to the confluence with Cache Creek. A project to rehabilitate Flat Creek is underway and portions of the stream have been rehabilitated. The project provides planning, design, and implementation of instream fish habitat structures to allow the stream segment to reach its ecological potential (Trout Unlmited, 2012).

Fish Creek is a Class 1 stream, and its headwaters are in Teton National Park. The creek flows south, parallel to the Snake River, through the valley, and passes through the community of Wilson. In the 1990s, residents began noticing excessive algal growth in the creek. Studies are underway to determine the source of nutrients promoting excessive algal growth.

The Greys River Watershed originates in the Bridger-Teton National Forest with very little private land and limited development within the watershed. The Greys River drains directly into Palisades Reservoir near the Town of Alpine. It is located between the Salt River Range and the Wyoming Range. The river and its tributaries are Class 2AB (WDEQ, WQD, 2007). There are fairly high rates of erosion from the sedimentary rocks forming these geologically young mountains (WDEQ, WQD, 2010). Although there has not been any reported monitoring in the watershed, the water quality is expected to be good due to lack of development.

The Hoback River Watershed begins in the Gros Ventre Mountains to the east and the Wyoming Range to the west. A ridge that extends between the two mountain ranges divides the Green River Basin from the Hoback River Watershed. Streams in the watershed are classified as 2AB, except those in the Gros Ventre Wilderness area and the full length of Granite Creek, which are Class 1 (WDEQ, WQD, 2007). Development is limited in the watershed to the upper basin near the community of Bondurant. The lower segment of river flows through Hoback Canyon which restricts the river and potential for development. U.S. Highway 191/189 follows the river through the canyon and is very close to the river in some locations.

Water quality within the Hoback River Watershed is considered good. The Sublette County Conservation District (SCCD) has been monitoring surface water quality in the Hoback River Watershed since 2000. No exceedances of the WDEQ, WQD surface water quality standards for chemical parameters have been found to date (Sublette County Conservation District, 2009).

Western Watersheds Project collected fecal coliform samples in 2010 on Clark's Draw, a small tributary to the Hoback River near Bondurant, and a five-sample geomantic mean exceeded the primary and secondary standards protective of recreational use. The source of the bacteria appeared to be from livestock grazing. A 1.9 mile segment of Clark's Draw adjacent to U.S. Highway 191/189 was placed on the 303(d) list of impaired streams in 2012 (WDEQ, WQD, 2012).

4.1.4.4 SALT RIVER SUB-BASIN

The Salt River Sub-basin drains Star Valley and the surrounding mountains and is tributary to Palisades Reservoir. Salt River and the majority of its tributaries are classified as 2AB. There are no Class 1waters in this sub-basin.

Water quality monitoring in the Salt River Sub-basin has primarily focused on bacterial contamination. Sunrise Engineering, Inc., reported that Salt River near the Etna USGS gaging station was on the 2000 303(d) list of impaired streams due to fecal coliform bacteria contamination (Sunrise Engineering, Inc., 2002). In 2002, the lower reach of Salt River was placed on the 303(d) list as threatened because of fecal coliform contamination (Ashworth, 2012). This segment was listed in 2008 as impaired and not fully supporting contact recreation uses. This stream segment remained on the 303(d) list in 2010 and 2012 due to fecal coliform contamination.

Stump Creek, a tributary to Salt River, was also placed on the 303(d) list in 2008 for fecal coliform contamination and non-support of recreational uses (Ashworth, 2012). Stump Creek has the highest concentration of fecal coliform bacteria of any of the sampling sites in the sub-basin. Many sampling sites show some level of fecal coliform bacteria contamination and additional segments may be placed on future 303(d) lists.

There are also concerns about potential high selenium (Se) concentrations in Crow Creek, a tributary to Salt River. Phosphate mining at the Smoky Canyon Mine in Idaho has impacted surface and groundwater resources through selenium contamination (WDEQ, WQD, 2012). Crow Creek originates in Idaho within the phosphate mining district and flows into the Salt River in Wyoming. A grab sample taken in 2006 from Crow Creek at the Idaho/Wyoming boarder during spring runoff had a total recoverable selenium concentration greater than Wyoming's chronic criterion (WDEQ, WQD, 2012). However, samples taken by WDEQ, WQD in 2008 at the state-line and near Fairview, Wyoming had concentrations below the state's chronic selenium criterion of five micrograms per liter.

4.1.4.5 SURFACE WATER QUALITY SUMMARY

Much of the Snake/Salt River Basin is comprised of wildland consisting of forests, sagebrush steppes and grasslands. There are several federally designated wilderness areas within the basin. These wildland watersheds provide high quality surface water to the basin. Environmental and recreational land uses are important in the basin; therefore, considerable monitoring has been conducted to evaluate and help protect these high quality water resources. Most water quality problems identified in the basin result from human activities and management. Because the area for development is relatively small, human activities have been concentrated. This leads to potential impacts on streams and water quality such as loss of stream habitat due to sedimentation and channel alteration along with bacterial contamination.

4.2 GROUNDWATER RESOURCES

The Snake/Salt River Basin is situated in the northwestern portion of the State of Wyoming with adjacent portions of the drainage basin located in Idaho. Calculations show there are more than

32.5 million acre-feet of groundwater resources potentially available in the Snake/Salt River Basin. The abundance of groundwater resources in the basin is primarily a function of the high annual precipitation rate and the local hydrogeology.

Topographic and geologic features of the basin are reflected in the low relief areas that are relatively flat-lying and generally underlain by Cenozoic unconsolidated deposits, and in mountainous bedrock formations and Volcanic and Intrusive Formations. The steeper mountain uplifts and ridges are commonly cored by older Paleozoic and Mesozoic bedrock formations in the Overthrust Belt or cored by Precambrian basement bedrock formation uplifts, which are partially overlain and flanked by younger Paleozoic and Mesozoic formations.

The hydrogeologic units are various aquifers and confining units within the basin and include unconsolidated sedimentary deposits and consolidated (lithified) bedrock formations ranging in age from Quaternary to Precambrian. The hydrogeologic units vary widely in lithology and water-bearing properties. Aquifers are described as occurring in five major aquifer groups based on geologic time, associated lithologies, and the stratigraphic columns for the basin areas. Major aquifers, minor aquifers, marginal aquifers, and confining units located within the basin were grouped on the basis of the four geologic eras; the Cenozoic, Mesozoic, Paleozoic and Precambrian, from youngest to oldest. A fifth unit: "Volcanic and Intrusive Formations" is also considered. Therefore, five major regional aquifer groups have been identified in the Snake/Salt River Basin. These five major aquifer groups are shown on Figure 4-2 by hydrogeologic unit, in descending geologic order:

- Volcanic and Intrusive Formations,
- Cenozoic aquifer group,
- Mesozoic aquifer group,
- Paleozoic aquifer group, and
- Precambrian aquifer group.

Volcanic and Intrusive Formations are a subset of the Cenozoic aquifer group. These igneous formations are of Middle Eocene age and younger.

This comprehensive major aquifer group classification, based on the geologic eras, allows any geologic unit to be included in one (or more) of these four major systems (Cenozoic, Mesozoic, Paleozoic, and Precambrian). This approach is applicable across the State of Wyoming, although there will be some discrepancies based on combinations of geologic time-transgressive units. For example, combined units are mapped such as Paleozoic-Mesozoic rocks, and other formations cross time boundaries like Permian-Triassic or Pliocene-Pleistocene. In these cases, a geologic evaluation of the thickest portion of the formations was conducted to assign a combined or geologic time-transgressive unit to an aquifer system corresponding to the majority of the geologic unit's thickness.

The Quaternary unconsolidated deposits, most of the Tertiary bedrock formations (Cenozoic aquifer group), and Volcanic and Intrusive Formations are relatively flat-lying and unconformably overlie the older, intensely deformed, Mesozoic and Paleozoic bedrock formations in the Snake/Salt River Basin. The contact between the relatively flat-lying geologic units with the underlying formations is commonly an erosional and angular unconformity. Structurally deformed Mesozoic and Paleozoic bedrock formations generally act as fault-severed, fault-bounded and structurally controlled groundwater compartments. However, in some local fold-fault structures, the fracture-enhanced permeability of the bedrock can greatly increase the yield of wells within these formations.

The most heavily used aquifer within the Snake/Salt River Basin consists of the Quaternary alluvial deposits located along the river and stream drainages and the associated Quaternary unconsolidated deposits. A second heavily used aquifer includes the Tertiary formations, especially the extensive valley-fill deposits including the Teewinot Formation and Salt Lake Formation. The Volcanic and Intrusive Formations are heavily used in the vicinity of Alta, Wyoming, on the western flank of the Teton Range.

Complex recharge-discharge interactions occur between the surface water and groundwater within some areas of the Snake/Salt River Basin. Surface water infiltrates permeable geologic units and groundwater discharges from the subsurface to surface water through springs and as underflow directly into stream drainages.

The inferred regional groundwater flow patterns would generally flow from the higher elevation areas towards the lowest topographic elevations located along the Snake/Salt River Valley and associated tributary streams.

GRAND TETON NATIONAL PARK, HWY 191

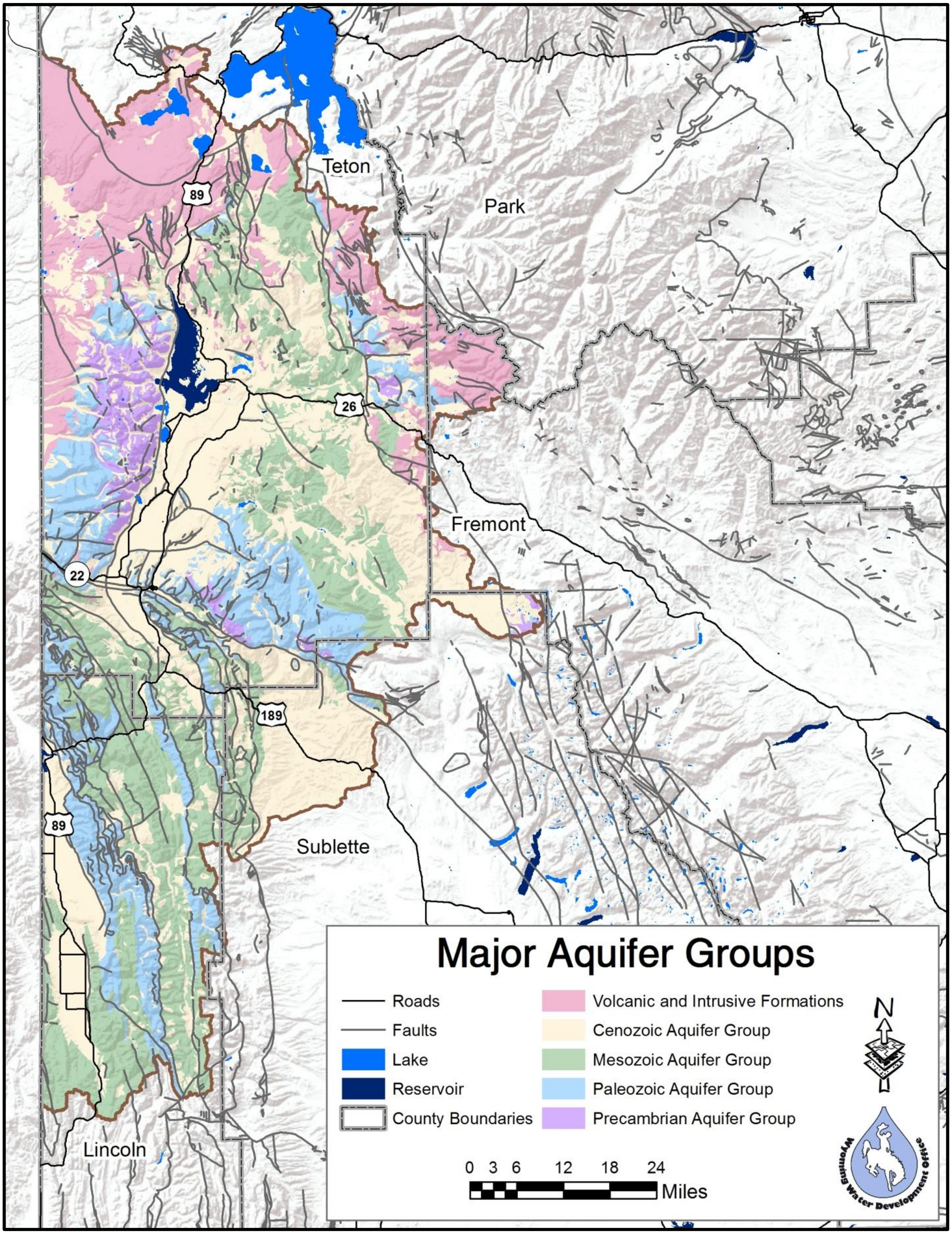

FIGURE 4-2: MAJOR AQUIFER GROUPS OF THE SNAKE/SALT RIVER BASIN

4.2.1 GROUNDWATER QUANTITY

Groundwater resources are generally available in abundance on most private land areas of the Snake/Salt River Basin. In order to calculate the amount of groundwater available in the bedrock aquifers (Mesozoic and Paleozoic aquifer groups) of the Snake/Salt River Basin, start with one-square mile section in the basin, and assume the ground surface is level and a useable aquifer extends down 1,000 feet. The surface area of the section is 27,878,400 square feet, and the volume is 27,878,400 square feet times 1,000 feet which equals 27,878,400,000 cubic feet (27.9 billion cubic feet). If the static water level ("water table" or groundwater surface) is assumed to be at 50 feet below the ground surface, the water saturation is 95 percent (950 feet) of the 1,000 feet deep section.

Porosity of bedrock formation aquifers is widely variable (from 0 to 30+ percent) and with an assumed average 10 percent porosity. Using the average 10 percent porosity value, the acre-feet per square mile can be calculated as follows:

27,878,400,000 ft^3 x 95% saturation x 10% porosity

= 2,648,448,000 ft^3 of water in aquifer storage x 7.48 gallons/ft^3

= 19,810,391,000 gallons (325,851.43 gallons/acre-foot)

= 60,796 acre-feet per square mile in storage

If 60,796 acre-feet per square mile is used for groundwater contained in a 95 percent saturated aquifer (10 percent porosity) down to a depth of 1,000 feet (approximate depth limit for acceptable groundwater quality), and take the Mesozoic and Paleozoic mapped areas of the basin (combined total of approximately 2,000 square miles), the maximum volume of groundwater contained within these two major aquifer groups of the basin can be estimated as follows:

Groundwater of 60,796 acre-feet/square mile x 2,000 square miles

= 121, 592,000 acre-feet of groundwater in maximum aquifer storage

This maximum quantity of 121.6 million acre-feet includes both recoverable and non-recoverable groundwater in the Mesozoic and Paleozoic bedrock aquifers of the basin. Not all water that is contained within a geologic unit (unconsolidated deposit or bedrock formation) can be removed from that unit. The "specific yield" of an aquifer is considered to be the "effective permeability" of an aquifer, or another way of stating it is - the volume of groundwater that can be recovered by pumping a well per unit volume of that aquifer. If we assume an average specific yield for bedrock formations of approximately 18.5 percent [ranges from 12 to 27 percent (Johnson, 1967)], then the amount of water available to pumping wells can be calculated as follows:

121,592,000 acre-feet maximum groundwater volume x 18.5% specific yield

= 22,494,520 acre-feet of groundwater is available to pumping wells

Approximately 22.5 million acre-feet of groundwater is the total amount of groundwater available to wells constructed into Mesozoic and Paleozoic bedrock aquifers within the Snake/Salt River Basin. In addition, Hinckley Consulting (2003) estimated the available groundwater in useful storage in the 400-square mile area of the alluvial aquifer to be approximately 10 million acre-feet (Hinckley Consulting, 2003).

Based on these assumptions and calculations, more than 32.5 million acre-feet of groundwater may be available (recoverable) for development from wells constructed in the saturated alluvial aquifer and the saturated bedrock formations of the Snake/Salt River Basin of Wyoming. This very large estimated quantity of groundwater available in the bedrock formations greatly exceeds the current total use of groundwater within the basin.

An estimate of the total annual water recharge to the unconsolidated and bedrock aquifers of the entire Snake/Salt River Basin may range between one million and 1.5 million acre/feet (Hinckley Consulting, 2003). This is approximately the upper limit of sustainable groundwater development within the Snake/Salt River Basin per year.

4.2.2 GROUNDWATER QUALITY

The available groundwater resources are commonly of acceptable quality on most private land areas of the Snake/Salt River Basin. However, the quality of the groundwater available in the basin is widely variable and may range from very good to very poor. Groundwater quality generally depends on the geochemistry of the soils, sediments, and bedrock that water encounters while traveling to the aquifer and of the geochemistry of the aquifer host rock.

Groundwater tends to increase in total dissolved mineral content the farther distances and deeper depths that the water travels while in contact with soluble chemicals in earth materials (soils and rocks). Time is another factor affecting groundwater quality, because the longer water remains in contact with soluble chemicals, the higher the total dissolved solids within the water.

Generally, in the basin, shallow groundwater tends to be of the calcium-sulfate-type water chemistry and deeper groundwater tends to be sodium-bicarbonate-type or sodium-chloride-type. Groundwater in the Preuss Sandstone (as called the Preuss Redbeds), or other formations that are in close hydrologic connection with this geologic formation, may contain elevated levels of sodium chloride (table salt) because of rock salt (evaporite minerals) deposits contained within parts of the formation. The Wyoming State Engineer's Office Snake River Basin report noted the occurrence of salty springs located in the Gannett Hills associated with groundwater flowing through the Preuss Sandstone (WSEO, 1972).

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