# 4.0 WATER RESOURCES

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## 4.1 SURFACE WATER

As in most Wyoming river basins, surface water is a vital component to the way of life and economy in the Bear River Basin. Snowpack is the primary source of surface water in the Basin, and agriculture is the largest water user, diverting streamflow onto fields where crops consumptively use the water. The remaining unused water eventually returns to the shallow groundwater and streams to be used again.

### 4.1.1 SURFACE WATER MODELING METHODOLOGY

The methodology used to develop the model and water availability in the 2001 Bear River Basin Plan was employed for this update. The only changes to the models were the streamflow and diversion data. The irrigation efficiency data input and model structure and operation all remain unchanged.

The models are made up of nodes that represent gages, diversions, and storage sites. Nodes are organized into reaches defined by tributaries or sections of the main stem of the Bear River. The gage data represent the inflow to the system and the diversions represent water taken from a reach and used for irrigation. Efficiency calculations are applied to each diversion to determine the water consumptively used and the water that returns back to the system. Available water is calculated at the bottom of each reach based on gage data, return flows, and reach gains or losses. The gains and losses are attributed to ungaged tributaries that are not explicitly modeled, and water that may be lost in the system to sub-irrigated riparian areas and/or recharge of aquifers.

### 4.1.2 GAGE DATA

It is through a network of streamflow gages that the quantity of water entering and leaving the basin can be measured. Gage data, obtained from the United States Geological Survey (USGS), were placed in an EXCEL spreadsheet for analysis, and eventually exported to the spreadsheet model as the hydrologic input. Generally, the methodology used in the 2001 Bear River Basin Plan (Forsgren Associates, Inc. 2001) was used for this study. Refer to Task 3A. Surface Water Data Collection and Study Period Selection technical memorandum from the 2001 Bear River Basin Plan for explanation of the methodology used to select the index gages http://waterplan.state.wy.us/plan/bear/techmemos/task3a.html. Index gages are those selected to determine hydrologic input to the model. The following are index gages used for the hydrological analysis, and Figure 4-1 depicts the location of each index gate in the system.

- 10011500 Bear River near Utah-Wyoming State Line
- 10015700 Sulphur Creek above Reservoir below La Chapelle Creek near Evanston, WY
- 10016900 Bear River at Evanston, WY
- 10020100 Bear River above Reservoir near Woodruff, UT
- 10020300 Bear River below Reservoir near Woodruff, UT
- 10026500 Bear River near Randolph, UT
- 10028500 Bear River below Pixley Dam near Cokeville, WY

- 10032000 Smiths Fork near Border, WY
- 10038000 Bear River below Smiths Fork, near Cokeville, WY
- 10039500 Bear River at Border, WY

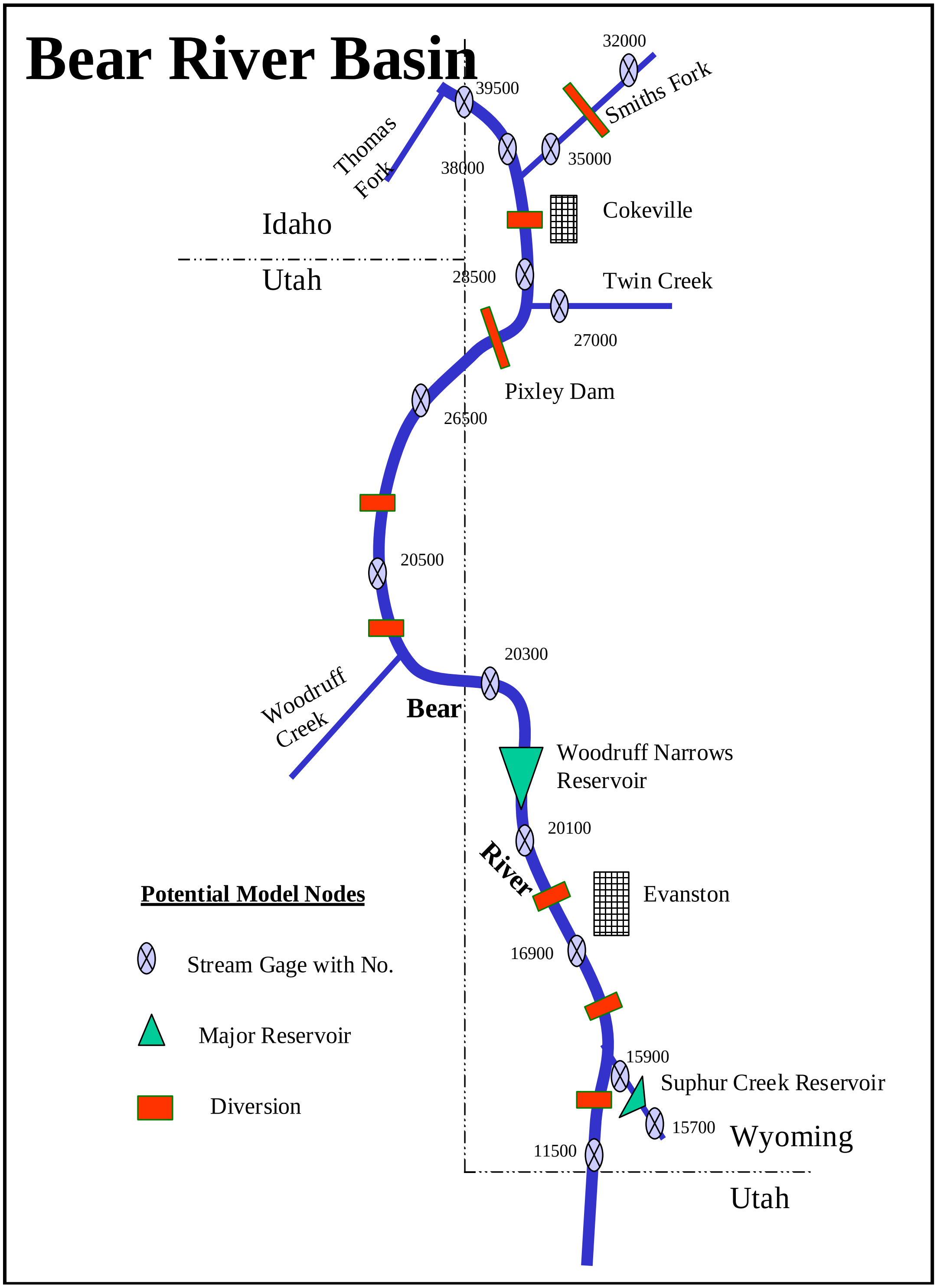


**Figure 4-1: Bear River Basin Schematic (Source: 2001 Bear River Basin Plan)**

### 4.1.3 PERIOD OF RECORD

The period of record used for the 2001 Basin Plan was 1971 to 1998. For this study, the record was extended to the year 2008 for every gage. This period is representative of the Basin hydrology over time because some of the driest years on record occurred after 1998 along with representative wet years.

Regarding streamflow gages with missing monthly data, there was a concern about the total number of missing records for these gages. Gages 10011500, 10020100, 10020300, and 10032000 had complete data sets for the period of record. Gages 10038000 and 10039500 had only a few months that required data filling. The remaining gages (10015700, 10016900, 10026500, & 10028500) had a significant amount of missing data that needed to be filled using the regression methods in EXCEL. For further understanding of the study period selection and the filling of missing data, refer to the Surface Water Data Collection and Study Period Selection Technical Memorandum [Volume 2, Tab: I (2011)]. Future updates to this basin plan should require a more thorough investigation of the available gage data and data filling methodology. It is recommended that gage 10015700 not be used in the future because of the lack of data and the number of monthly records that must be modeled. Gage 10015700 was terminated in 1997 and part of this evaluation was to decide whether or not to eliminate this gage from the study entirely or to try to fill the missing data. WWDC has a concurrent study, Sublette Creek Reservoir Level II Study [States West Water Resources Corporation (States West), 2001], which is looking at the potential for building a reservoir in the Bear River Basin. As part of the study, States West is updating BearMod, another type of water budget model, through 2006. BearMod is a river and diversion simulation model that was built as part of the 2001 Bear River Basin Plan. The BearMod model requires the same data as the spreadsheet model presented here. States West decided to extend the flow data for gage 10015700 through 2006. Because of this decision and to be consistent with other WDC projects, it was decided to use the gage in this analysis.

### 4.1.4 DETERMINATION OF DRY, NORMAL, AND WET YEARS

For this study, three hydrologic scenarios were developed to represent typical dry, wet, and normal hydrology. These conditions are major components of the spreadsheet models. The hydrologic conditions were developed by first obtaining streamflow gage data from the USGS, filling data where missing, and finally ranking the data for analysis. Most of the gages required data filling to develop the hydrologic conditions. The flow scenarios developed in the 2001 Basin Plan differed from how they were calculated in this update. Missing data in the update were filled using both linear and polynomial regression analyses focusing on the regression equation that produced the highest correlation ( $r^2$) value. When the data sets were complete the dry, normal, and wet year conditions were calculated. The driest 20% of the ranked yearly flows were averaged to determine the “average dry” condition; the wettest 20% of the ranked yearly flows were averaged to determine the “average wet” condition; and the remaining years were averaged to determine the “average normal” condition. Each of these conditions was used as the input for their respective model (dry, normal, wet).

In general, hydrologic conditions used for this plan update were drier than those used for the 2001 Plan. This is partly due to a difference in how the modeled hydrologic conditions were developed in the previous plan, and also the fact that some of the driest years on record occurred since the 2001 Plan was completed. In the 2001 Plan, many of the conditions for a specific gage were determined by the locations of "natural breaks" in the ranked flow values. For this study, it was decided to use the 20% dry - 20% wet analysis recommended for basin planning in the Guidelines for Development of Basin Plans (States West Water Resources Corporation, 2001).

Figure 4.2 represents the dry, normal, and wet year classification for each gage and year followed by tables comparing the 2001 Bear River Basin Plan to the update. Table 4-1 presents hydrologic conditions and a comparison of the calculated flows to the 2001 Plan.

*Bear River in Wyoming*

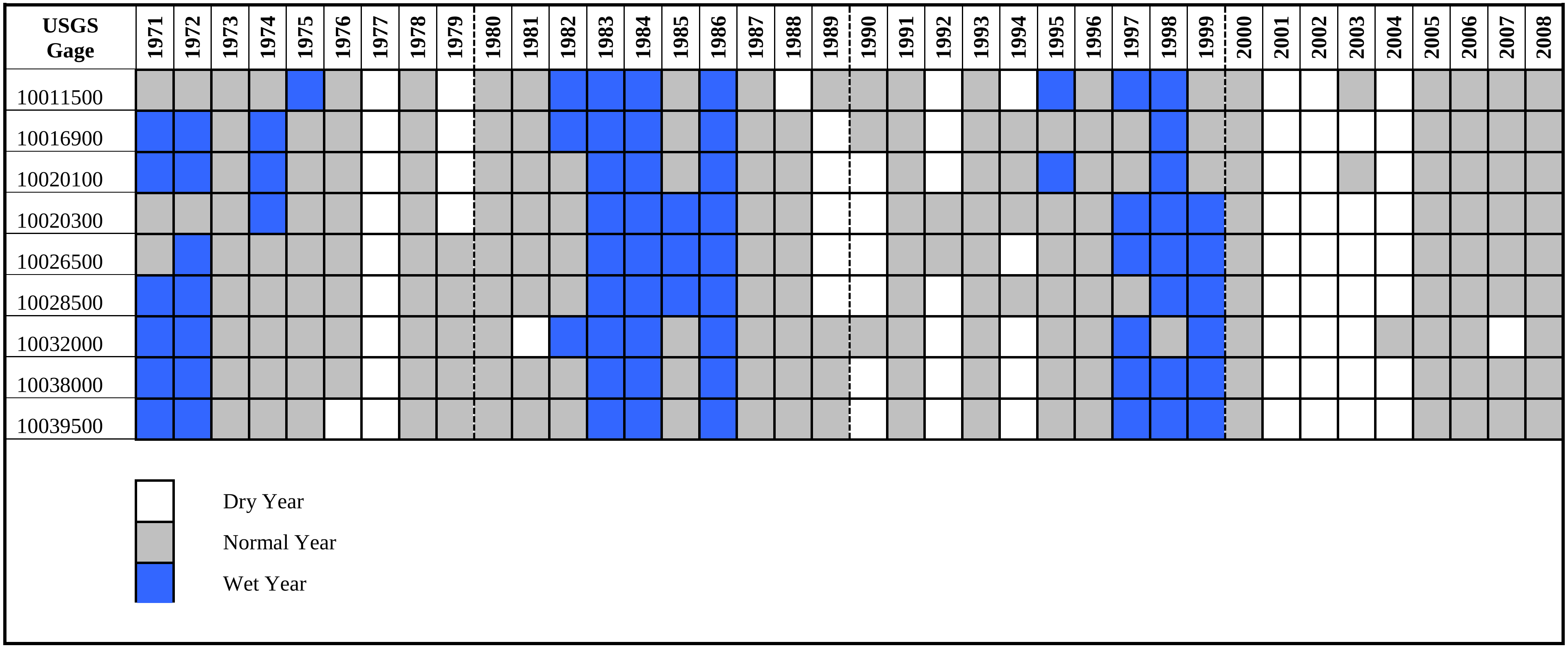


**Figure 4-2: Distribution of Dry, Normal, and Wet Years for Period of Record 1977 to 2008**

**Table 4-1: Comparison of Dry, Normal, and Wet Conditions at USGS Streamflow Gages between the 2001 Plan and the Update**

| USGS Gages | Dry (AFY) | Normal (AFY) | Wet (AFY) |
|---|---|---|---|
| 10011500<br>Bear River near Utah-Wyoming State Line | 85,491 | 136,746 | 202,737 |
| 10015700<br>Sulphur Cr above Res below La Chapelle Cr near Evanston, WY | 5,307 | 24,237 | 12,851 |
| 10016900<br>Bear River at Evanston, WY | 85,336 | 173,201 | 297,149 |
| 10020100<br>Bear River above Reservoir near Woodruff, UT | 61,334 | 146,595 | 293,805 |
| 10020300<br>Bear River below Reservoir near Woodruff, UT | 65,137 | 148,917 | 286,865 |
| 10026500<br>Bear River near Randolph, UT | 27,867 | 125,956 | 315,583 |
| 10028500<br>Bear River below Pixley Dam near Cokeville, WY | 17,170 | 108,316 | 263,711 |
| 10032000<br>Smiths Fork near Border, WY | 75,340 | 130,998 | 207,238 |
| 10038000<br>Bear River below Smiths Fork, near Cokeville, WY | 114,006 | 297,559 | 610,967 |
| 10039500<br>Bear River at Border, WY | 101,937 | 291,128 | 624,727 |

The updated period of record has a four-year dry period with some being the driest on record. 1999 was the last wet year with the most recent four years being in the normal category.

Table 4-2 shows the total annual natural streamflow. These values are derived by summing up the flow at the final stream gage in the Basin and the total consumptive use in the Basin. The final gage in the system is 10039500 and the total consumptive use is the irrigation supply-limited consumptive use, reservoir evaporation, industrial use, and municipal and domestic use. There is no comparison to the 2001 Plan because the analyses for determining dry, normal, and wet conditions were different for the two plans.

**Table 4-2: Total Annual Natural Streamflow**

| Dry Conditions (AFY) | Normal Conditions (AFY) | Wet Conditions (AFY) |
|---|---|---|
| 202,790 | 391,981 | 725,580 |

### 4.1.5 KEY DITCHES

For the purposes of basin modeling, the Wyoming diversion records and other data have been gathered for key diversion structures within the Basin. Key diversions were generally defined as those diversions typically diverting at least 10 cfs, or those structures having other regulatory or operational significance within the Basin. The remaining smaller Wyoming diversions were modeled on a cumulative basis within each reach of the surface water model. Listed below are the key diversion structures; they are the same as those in the 2001 Plan:

**Upper Division Key Ditches**

- Hilliard East Fork
- Lannon and Lone Mountain
- Hilliard West Side
- Bear Canal
- Crown and Pine Grove
- McGraw
- Lewis
- Myers No 2
- Myers No 1
- Myers Irrigation
- Booth
- Anel
- Evanston Water Supply
- Evanston Water Ditch
- Rocky Mountain Blythe
- John Sims
- SP
- Chapman
- Morris Brothers
- Tunnel
- Francis Lee
- Bear River Canal
- Pixley Dam
- BQ Dam

**Central Division Key Ditches**

- Quinn Bourne
- Button Flat
- Emelle
- Cooper
- Covey
- VH Canal
- Goodell
- Whites Water
- S. Branch Irrigating
- Alonzo F. Sights
- Oscar E. Snyder
- Cook Brothers

Diversion data for these structures was obtained from the Bear River Commission and SEO. Similar to the stream gages, the diversion data were organized into the corresponding dry, normal, and wet conditions. The dry, normal, and wet conditions used to define the diversion data corresponds to the hydrologic condition of the gage immediately upstream of each diversion. For example, if "Gage X" has dry year conditions for 1970, 1972, 2006, and 2008, then these years were used to determine the dry year diversion amounts for the diversions downstream of said gage. The results from the surface water models are presented in Chapter 5.

### 4.1.6 SURFACE WATER QUALITY

It is difficult to define water quality for the entire basin. There are a variety of natural conditions and land uses that can affect surface water quality and the Bear River Basin is no exception, even though it is a relatively small basin within Wyoming. The purpose of this section is to summarize information presented in the Bear River Basin Water Plan, Final Report (Forsgren Associates, Inc., 2001) and to present new data and information that has been developed since the completion of that plan.

#### *4.1.6.1 SURFACE WATER QUALITY ISSUES FROM THE 2001 PLAN*

Authors of the 2001 Bear River Basin Plan used Total Dissolved Solids (TDS) as a surrogate measure for determining surface water quality. This measure was selected because it provides an easily calculated parameter and assessment of overall water quality. Forsgren Associates used five USGS gages where water quality data were collected over an extended period of time. The water quality standards set for groundwater by the Wyoming Department of Environmental Quality, Water Quality Division (DEQ) were used to evaluate the data since there are no set standards for TDS in surface water. Using TDS as a standard, surface water quality within the

Bear River Basin of Wyoming was found to be of acceptable quality for the designated uses. Forsgren Associates (2001) specifically note that "surface water in the Bear River and Smiths Fork is of sufficient quality for domestic use" and that "surface water, in Twin Creek, is of sufficient quality for livestock and agricultural use." Water quality standards for TDS are presented in Table 4-3.

**Table 4-3: Water Quality Standards for Total Dissolved Solids (TDS)**

| Water Use | Domestic (mg/l) | Agricultural (mg/l) | Livestock (mg/l) |
|---|---|---|---|
| TDS Standard | 500 | 2,000 | 5,000 |

*Adapted from Wyoming Department of Environmental Quality, Water Quality Division, Chapter 8, Water Quality Rules and Regulations, Quality Standards for Wyoming Groundwaters 2007; and Forsgren Associates, Inc. 2001.*

#### *4.1.6.2 DISCUSSION OF CURRENT WATER QUALITY ISSUES AND CHANGES*

This section discusses current water quality issues in the Bear River Basin compared to the issues discussed in the 2001 Plan.

Current water quality in the Bear River Basin was examined using TDS, the same methodology as was used in the 2001 Plan. The same five gaging stations were used and TDS data were calculated and compiled for the years 1999 to 2008. These data sets were considerably smaller than the data sets used in 2001 but do provide an adequate water quality evaluation when compared directly to, and then combined with the original data sets. Results are presented in Table 4-4; there have not been noticeable water quality changes within the Basin. Bear River and Smiths Fork water quality is suitable for agriculture, livestock, and domestic use while Twin Creek is suitable for agricultural and livestock use. Soils in the Twin Creek watershed are derived primarily from marine and saline lake sediments, which help account for the higher TDS concentrations.

**Table 4-4: Bear River Surface Water Quality – Average Calculated TDS for Five Stations on Bear River**

| Station Name | Station Number | 2001 Plan TDS Data (mg/l) | 2011 TDS Data (mg/l) | Combined TDS Data (mg/l) |
|---|---|---|---|---|
| Bear River near Woodruff | 10020100 | 238 | 247 | 259 |
| Twin Creek | 10027000 | 565 | 536 | 562 |
| Smiths Fork at Cokeville | 10035000 | 222 | 218 | 220 |
| Bear River below Smiths Fork | 10038000 | 340 | 334 | 330 |
| Bear River at Border | 10039500 | 338 | 338 | 341 |

Major surface water quality problems within the Bear River Basin and adjoining states are related to sediment and nutrients loads. High water temperatures and low dissolved oxygen are also problems in some areas. Concern for these water quality problems is centered on the Bonneville cutthroat trout and water quality in Bear Lake (Wyoming Department of Environmental Quality, Water Quality Division [DEQ] 2008). The Bonneville cutthroat trout was petitioned for listing as threatened under the Endangered Species Act in 1998. It was determined by the USFWS in 2001, that listing was not warranted, because self-sustaining populations are well distributed throughout their historic range and are being protected in all currently occupied watersheds.

Water quality assessments of the Bear River were completed by DEQ in 1995, 1996 and 1998, and indicate it is supporting designated use as a cold water fishery above Sulphur Creek. Monitoring was also conducted below Sulphur Creek in 1998 and those data indicate that Bear River between Sulphur Creek and Woodruff Narrows Reservoir is only partially supporting aquatic life uses due to sediment deposition. Much of this reach has channelized, resulting in the loss of trout habitat. This reach was placed on the 303(d) List in 2002 and has remained on the list through 2010 (DEQ 2010).

The Uinta County Conservation District formed the Upper Bear River Water Quality Steering Committee whose mission was to develop a plan to improve and maintain water quality in the Upper Bear River Basin. The Upper Bear River Watershed Management Plan was published in September 2005 with the aim to improve and maintain water quality in the Upper Bear River, to support all designated uses through public education, public awareness, and voluntary application of feasible Best Management Practices. This plan is currently being implemented.

Bridger Creek is the only other stream within the Bear River Basin currently listed on the 303(d) List. Erosion causing increased sediment and phosphorous loading threatens aquatic life. Recent monitoring studies recommend changes in grazing management that could address erosion issues (DEQ, 2010). All 303(d) listed streams are shown on Figure 4-3.

DEQ surface water quality standards were presented in the 2001 Plan, Chapter 4. The stream classification system was subsequently changed after the plan was published and those changes were adopted by DEQ in April 2007. The revised stream classification system is presented in Appendix B. Classification of streams and stream segments in the Bear River Basin can be found in Wyoming Surface Water Classification List, Wyoming Department of Environmental Quality, Water Quality Division, 2001. The Bear River and most of its major tributaries are listed as class 2AB. The definition of class 2AB streams is presented below.

> *<u>Class 2AB</u> waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, and aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses.*

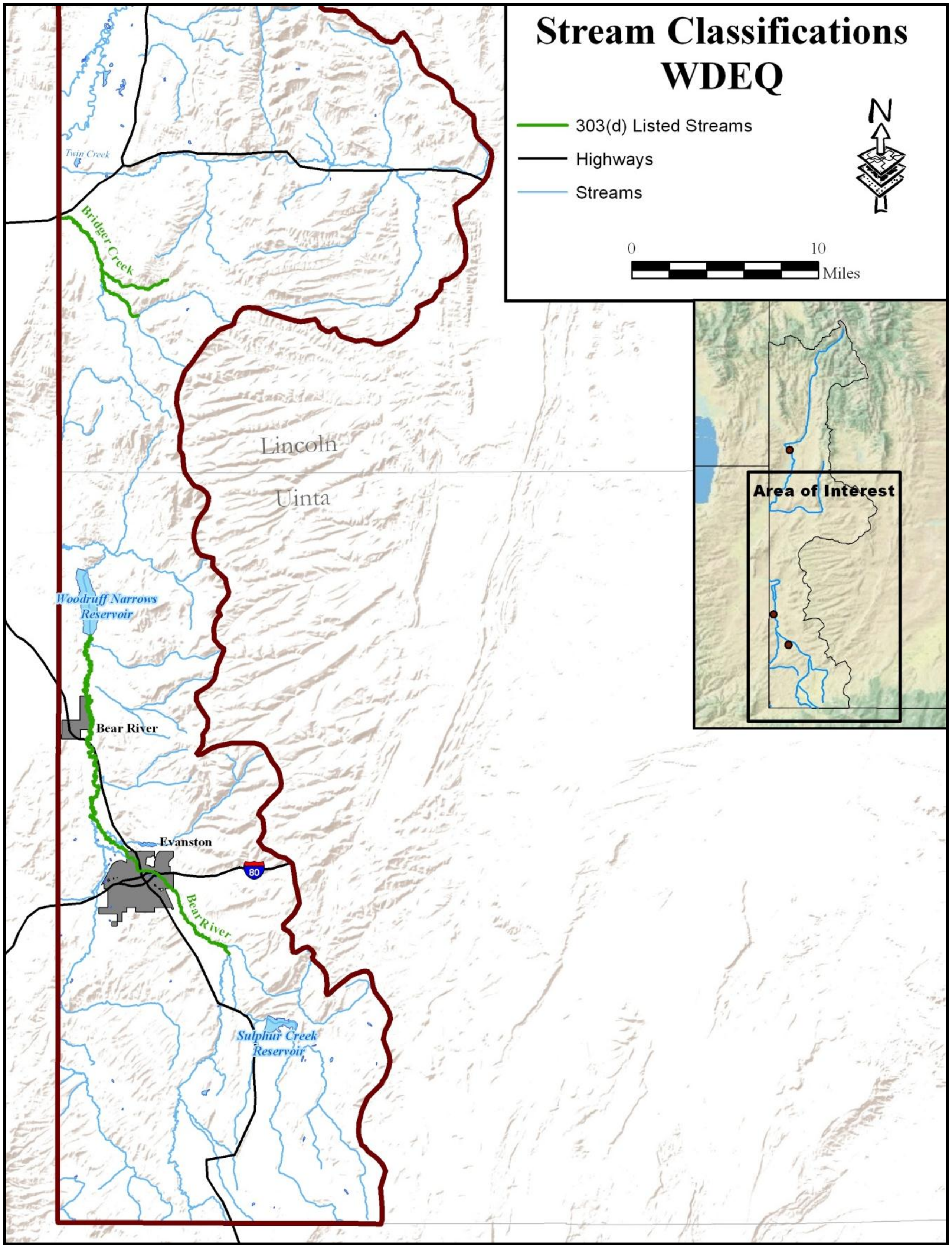


**Figure 4-3: Wyoming Department of Environmental Quality 303(d) Listed Streams**

## 4.2 GROUNDWATER

The Bear River Basin is situated along the southwestern border of the State of Wyoming, with adjacent portions of the drainage basin located in Idaho and Utah. The 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 bedrock formations. The steeper mountain uplifts and ridges are commonly cored by the older Paleozoic and Mesozoic bedrock 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 four major aquifer groups based on geologic time and the stratigraphic columns for the Basin areas.

The large regional aquifer systems discussed in the 2001 Bear River Basin Plan, were reevaluated for this study and redefined, including combining some of the separate units from Appendix O – Ground Water Resource Investigation (Forsgren Associates, Inc., 2000). Major 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. Therefore, four major regional aquifer groups have been identified in the Bear River Basin. The major aquifer groups are shown on Figure 4-4 by hydrogeologic unit, in descending geologic order:

- Cenozoic aquifer group;
- Mesozoic aquifer group;
- Paleozoic aquifer group; and
- Precambrian aquifer group.

The Precambrian aquifer group is not shown on the figure since it does not surface in the Wyoming portion of the Bear River Basin. Precambrian rocks underlie the Basin but at depths that limit its potential as an aquifer.

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. 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 classification of the four major aquifer groups is also applicable to the geologic units of other adjoining states (Idaho and Utah) with adjoining hydrogeology. A geologic map and discussions of the geologic units of the Bear River Basin are included as an appendix to the groundwater technical memorandum (Volume 2, Tab: V (2011)).

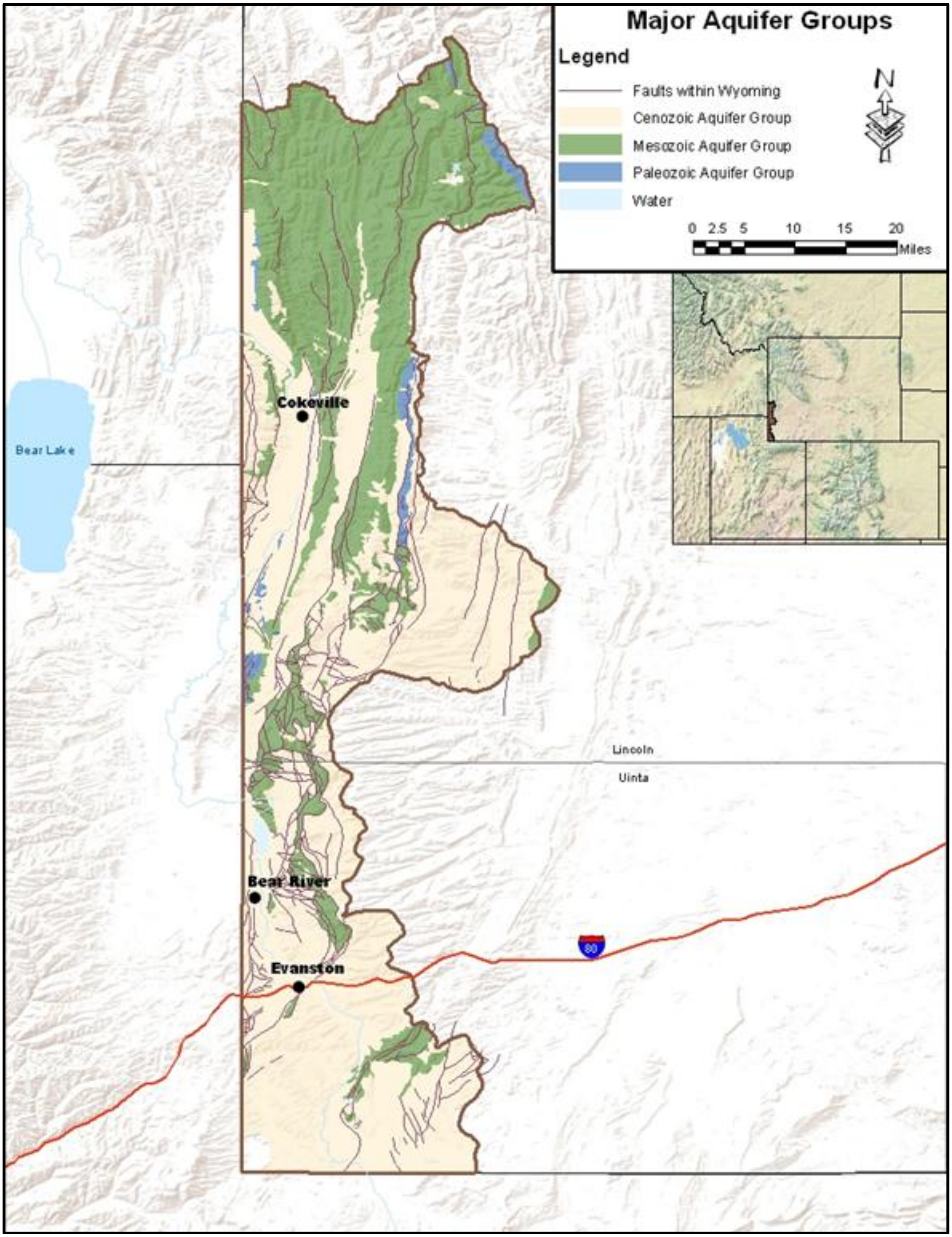


**Figure 4-4: Major Aquifer Groups of the Bear River Basin**

In the Bear River Basin, the Quaternary unconsolidated deposits and most of the Tertiary bedrock formations (Cenozoic aquifer group) are relatively flat-lying and unconformably overlie the older, intensely deformed Mesozoic and Paleozoic bedrock formations. The contact between the relatively flat-lying geologic units with the underlying formations is commonly an erosional and angular unconformity. The 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 in these formations. The most heavily used aquifer within the Bear River Basin consists of the Quaternary alluvial deposits located along the Bear River Valley and the associated unconsolidated deposits. The second most heavily used aquifer includes the Tertiary formations, especially the extensive Wasatch Formation.

Complex recharge-discharge interactions occur between the surface water and groundwater within some areas of the Bear 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 local topographic elevations located along the Bear River Valley and associated tributary streams.

### 4.2.1 GROUNDWATER QUANTITY

The SEO groundwater supply report (1973) calculated the total quantity of groundwater available in the saturated portion (aquifer) of the alluvial deposits of the Bear River Basin to be approximately 4,250,000 acre-feet. If a specific yield is assumed as 18% for these deposits, then the total quantity of groundwater in storage within the alluvial aquifer (Cenozoic aquifer group) is approximately 765,000 acre-feet in the Bear River Basin (4,250,000 acre-feet x 18% = 765,000 acre-feet).

In order to calculate the amount of groundwater available in the bedrock aquifers (Mesozoic and Paleozoic aquifer groups) of the Bear River Basin, start with 1-square mile section in the basin, and assume the ground surface is level and a useable aquifer extends down 1,000 ft deep. The surface area of the section is 27,878,400 square ft, and the volume is 27,878,400 square ft x 1,000 ft = 27,878,400,000 $ft^3$ (27.9 billion $ft^3$). If the static water level ("water table" or groundwater surface) is assumed to be at 50 ft below the ground surface, the water saturation is 95% (950 feet) of the 1,000 ft deep section.

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

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-ft)
= 60,796 acre-ft per square mile in storage

If 60,796 acre-feet per square mile is used for groundwater contained in a 95% saturated aquifer (10% porosity) down to a depth of 1,000 ft deep (approximate depth limit for acceptable groundwater quality), and take the whole mapped area of the Wyoming Bear River Basin (1,500 square miles), the maximum volume of groundwater contained within the aquifers of the Basin can be estimated:

Groundwater of 60,796 acre-ft/square mile x 1,500 square miles
= **92,194,000 acre-feet of groundwater in maximum aquifer storage**.

This maximum quantity of 92.2 million acre-feet includes both recoverable and non-recoverable groundwater. 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 that it is the volume of groundwater that can be recovered by pumping a well per unit volume of that aquifer. Assuming an average specific yield for bedrock formations of approximately 18.5% [ranges from 12 to 27 % (Johnson, 1967)], the amount of water available to pumping wells can be calculated:

91,194,000 acre-feet maximum groundwater volume x 18.5% specific yield
= **16,870,890 acre-feet of groundwater is available to pumping wells**.

If approximately 16.9 million acre-feet of groundwater is the total amount of groundwater available to wells in the Bear River Basin and the amount of groundwater available in the alluvial aquifers is subtracted (765,000 acre-feet; SEO, 1973):

16,870,890 acre-feet (groundwater available) – 765,000 acre-feet (alluvial aquifers)
= **16,105,890 acre-feet of groundwater is available in bedrock aquifers.**

In summary, for this update of the Bear River Basin Plan, these calculations show that there are approximately:

- 91,200,000 acre-feet of maximum volume of groundwater contained within the geologic units of the Bear River Basin (maximum aquifer storage = recoverable and non-recoverable water), but not all of this water is available to be extracted by pumping wells.
- 765,000 acre-feet of groundwater available in alluvial aquifers to wells (SEO, 1973);
- 16,100,000 acre-feet of groundwater available in bedrock aquifers to wells; and
- 16,800,000 acre-feet total groundwater available in aquifers of the Bear River Basin to wells (effective aquifer storage).

Based on these assumptions and calculations, approximately 16.1 million acre-feet of groundwater may be available (recoverable) for development from wells constructed in the saturated bedrock formations of the Bear River Basin of Wyoming. This very large estimated quantity of groundwater available in the bedrock formations greatly exceeds the current use of groundwater within the Basin which is approximately 3,125 acre-feet per year.

As to an estimate of the annual water recharge to the aquifers of the Bear River Basin, WWC Engineering (2007) and Forsgren Associates (2001) estimated the total quantity of annual recharge to the aquifers in the Basin to be 14,000 acre-feet/year. This annual recharge estimate was based on the assumption that aquifer recharge was equal to 2% of the average annual precipitation in the Basin (WWC Engineering, 2007). This 14,000 acre-feet/year quantity is likely a very conservative estimate and it is probably an underestimate or a low-end estimate for river basin planning purposes. Earlier, the amount of annual natural recharge to solely the alluvial aquifer in the Bear River Basin was estimated to be 50,000 acre-feet/year of groundwater during an average year, excluding artificial recharge from irrigation water (SEO, 1973).

These two estimated annual groundwater recharge quantities ranging from 14,000 acre-feet/year for all aquifers (WWC Engineering, 2007) to 50,000 acre-ft/yr to only the alluvial aquifers (SEO, 1973) should conservatively be considered the maximum annual limit of groundwater use that could be safely developed in the Basin for a long-term sustainable yield. With the current annual groundwater use estimated at 3,125 acre-feet/year, there is sufficient room for the future development of additional groundwater resources in the Bear River Basin. This Basin update report recommends that actual field investigations of groundwater recharge in the Bear River Basin be conducted to help determine a realistic and accurate estimate of annual recharge quantities for the Basin aquifers.

### 4.2.2 GROUNDWATER QUALITY

The quality of the groundwater available in the Bear River Basin is widely variable and ranges from very good to very poor. Groundwater quality generally depends on the geochemistry of the soils, sediments, and bedrock that the water encounters while traveling to the aquifer storing the water and also of the geochemistry of the aquifer host. 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 (minerals) as earth materials (soils and rocks). Time is another factor affecting groundwater quality because the longer the water remains in contact with soluble chemicals, the higher the total dissolved solids of the water becomes.

Overall, shallow groundwater tends to be of the calcium-sulfate-type of water chemistry and deeper groundwater tends to be of the sodium-bicarbonate-type. Groundwater in the Preuss Sandstone (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 the rock salt (evaporite minerals) deposits contained within parts of the formation.

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