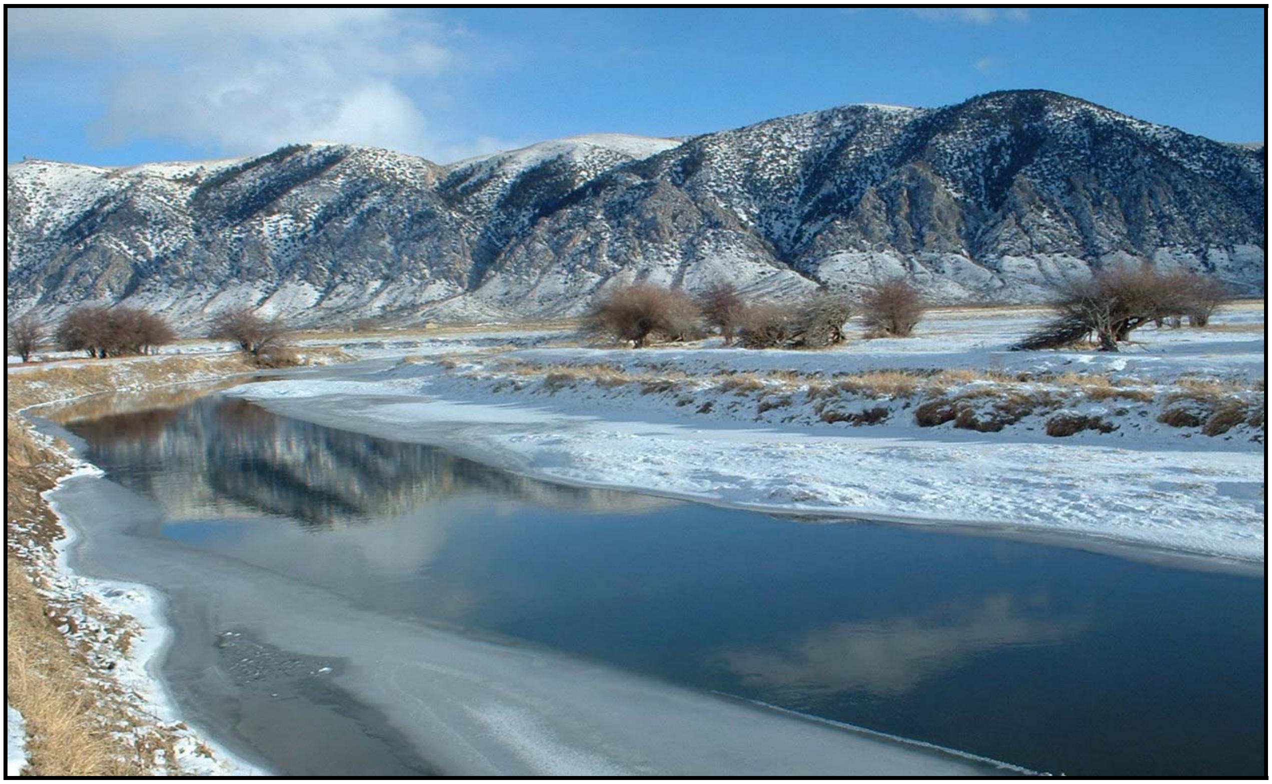

Upper Bear TMDL
Water Quality Study

Prepared for:

Utah Department of Environmental Quality -
Division of Water Quality

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EPA APPROVAL DATE
AUGUST 4, 2006

Utah Department of Environmental Quality
Division of Water Quality
TMDL Section

Upper Bear TMDL

Waterbody ID	16010101-006 and 16010101-009
Location	Rich County, Utah
Pollutants of Concern	Dissolved Oxygen
Impaired Beneficial Uses	Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
Loading Assessment	Up to 25 percent of DO samples < 6.5 mg/l and up to 77 percent exceedance of TP samples > 0.05 mg/l on mainstem Bear River monitoring stations measured during intensive monitoring.
Water Quality Targets/Endpoints	• Annual TP load of 6,073 kg/yr at Station 4908100 Bear River East of Sage Creek Junction. • 0.05 mg/l TP and 5 mg/l BOD for all tributary streams to the Bear River in Rich County. • Macroinvertebrate communities with a Family Biotic Index < 4.25
Implementation Strategy	Implement Nonpoint Source BMPs to reduce organic matter loading to Upper Bear River: • Improve water quality of irrigation return flows through vegetative filtering, land leveling, and conversion from flood to sprinkler irrigation. • CNMPs on all AFO facilities in study area. • Relocate winter feeding areas away from mainstem Bear River • Remove direct livestock access to stream channels, provide offsite watering.

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CHAPTER 1: INTRODUCTION

The Total Maximum Daily Load (TMDL) study for the Upper Bear River in Rich County, Utah has been completed under the direction of the Utah Department of Environmental Quality – Division of Water Quality (DWQ). This report will be submitted to the U.S. Environmental Protection Agency (EPA) as specified by section 303(d) of the Clean Water Act (CWA). The assessment of water quality and flow defines conditions leading to low concentrations of Dissolved Oxygen (DO) in two segments of the Bear River in Rich County as well as Saleratus Creek, located in the southwest portion of Rich County (Figure 1). This assessment relies upon recent and historic monitoring data collected in the study area and as such, provides an accurate picture of existing water quality conditions while incorporating the longer-term climatic influences that influence the greater Bear River Basin.

There are many factors influencing water quality in the Upper Bear River. It is not the intent of this assessment to place blame or criticism on any individual or group, but to try and provide an accurate characterization of **all** conditions that lead to water quality impairment in the study area.

1.1 TMDL PROGRAM DESCRIPTION

The TMDL program was one of several programs established in connection with the 1977 Clean Water Act to maintain and restore water quality to waters of the United States. A specific goal of the TMDL program is to ensure that water quality standards established by states are achieved and maintained. A critical element of the TMDL process identifies the maximum amount of pollutant that a water body can receive and still meet water quality standards. This amount is sometimes called the maximum allowable pollutant load or “permissible load”. If needed, the TMDL can associate the permissible load with a critical time period including months of low stream flow.

The scientific assessment of water quality included as part of a TMDL incorporates the best information available to determine the nature and extent of impairment for a given water body. Pollutant loads are also defined for each significant pollutant source contributing to impairment. Following allocation of pollutant loads, an implementation plan is provided that will reduce existing pollutant loads and allow water quality standards to be achieved.

The TMDL process is a shift from the more generalized approaches employed in the past to implement the CWA. It demands a more local focus on the target watershed, from both a scientific and an applied perspective. Water quality standards that are broadly applied can be carefully evaluated under this process in terms of restoring and maintaining beneficial uses under actual conditions that influence water quality. Successful implementation of this assessment will require cooperation between federal, state, and local entities, including local stakeholders living within the study area.

1.2 PREVIOUS STUDIES

Bear River water quality and flow have been monitored for many years. Scarcity of water in the arid West has resulted in numerous water flow studies and a limited number of reviews of water quality. Segments of the mainstem Bear River and tributaries to these segments have been examined by the Bear Lake Regional Commission (1992), UDWQ (2000) and the Wyoming Department of Environmental Quality (2005).

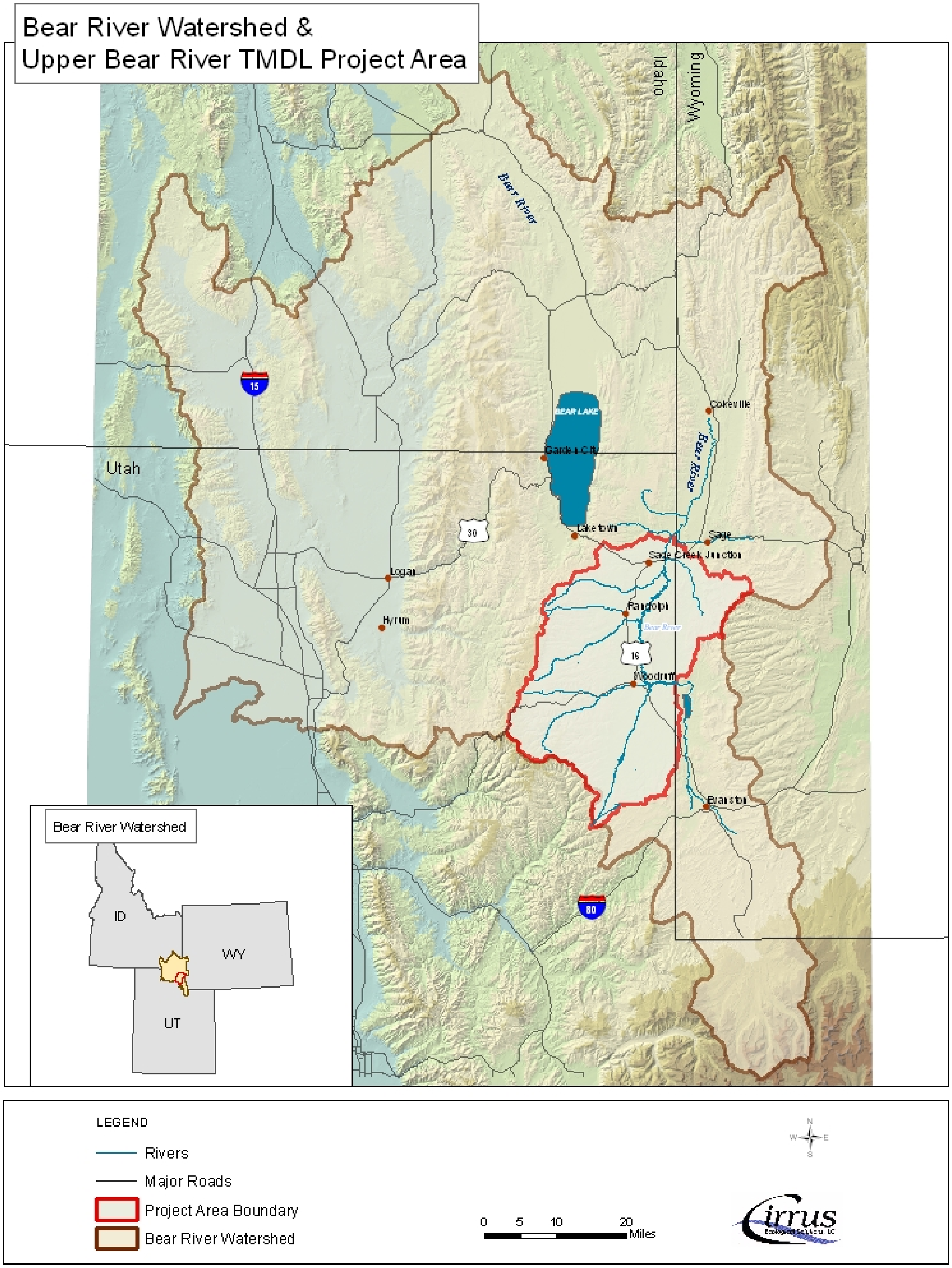

Figure 1.1. Bear River Watershed and Upper Bear River TMDL Project Area.

1.2.1 DRAFT UPPER BEAR RIVER WATERSHED MANAGEMENT PLAN (2005).

The purpose of the 2005 plan is to improve and maintain water quality in the Bear River by identifying potential issues and mitigating impairment sources to realistic and achievable levels, promote the voluntary use of BMPs while respecting private property rights, and maintain local control of the watershed by attaining designated uses established for the Bear River. The steering committee for this management plan focused primarily on impairments identified on the Wyoming 303(d) list. The impaired segments of the Bear River and tributaries in this state are located upstream of Woodruff Narrows Reservoir. Thus the reservoir has a strong influence on the quality of water that flows into Utah. Indeed, the Utah Division of Water Resources (UDWR) has identified this reservoir as the cause of impairment (i.e., low DO concentration) in the Utah portion of the Upper Bear River. The Bear River in Idaho is also listed as impaired due to phosphorus and sediment concentrations. The Wyoming Department of Environmental Quality (WDEQ) identified Bridger Creek as a significant contributor of both sediments and phosphates to the Bear River during the 1980s and 1990s. Historically, phosphate mining has occurred in this watershed. However, recent monitoring indicated that Bridger Creek fully supports aquatic life. Most contributions of phosphorus to the Bear River in Wyoming are most likely non-point sources. Monitoring data from the single waste water treatment facility along the Bear River in Wyoming indicated that phosphorus discharges are minimal.

Watershed concerns addressed in the plan area classified as urban, rural subdivisions and rural areas, recreation, wildlife, agriculture, industry, landscape disturbances, education and information, monitoring, funding, and agency coordination. Objective and future actions include reduce pollution from storm sewers, increase vegetative cover in urban areas, inform the public about the importance of publicly functioning septic systems and hazardous waste collection, design a strategy for river bank stabilization, reduce the amount of sediment and pollutants entering the river from surface runoff, and promote housing development plans that account for natural resource concerns. Objectives and actions for the agriculture sector include maintaining a viable and sustainable agricultural industry while improving livestock management practices and water quality, reduce the amount of sediments and other contaminants reaching stream channels by reducing overland flow through efficient irrigation BMPs and delivery systems, and reduce the amount of agricultural waste and human-caused sediment entering the Bear River.

1.2.2. WATER QUALITY IN THE UPPER BEAR RIVER: PROBLEMS AND MITIGATION (1992)

The main goal of the 1992 study was to develop a water quality management plan for the reduction of total phosphorus, nitrogen and sediment load into the Bear River and Bear Lake. This report stated that previous studies on the Bear River and its tributaries above Bear Lake including the Thomas Fork, Twin Creek, and Bridger Creek indicated mass gains for nitrogen, phosphorus, and total suspended solids. The majority of the lands in the Twin and Bridger creeks are publicly owned. The BLM is the responsible agency for the largest portion of these lands. Thus, these lands are managed for multiple use including livestock grazing, agriculture, wildlife, and recreation. Twin Creek is a perennial stream but may not reach the Bear River during the irrigation season due to diversions. Water flows in Bridger Creek depend mainly on snowmelt and storm runoff. County and private roads provide access to these areas as a result of the extraction and transport of natural gas and oil in these watersheds; many of these roads have caused erosion-related problems.

Surveys in this study found high nutrient concentrations throughout Bridger Creek with substantial increases in the lower sections of the stream. The most drastic increases were observed in TSS, which increased nearly 300 times from an upstream location to another near the confluence with the Bear River.

Surveys in Twin Creek indicated that average nutrient concentrations as well as dissolved and suspended solids were higher that those observed in the mainstem of the Bear River. Further, the surveys indicated that nutrient concentrations in this stream peaked in the spring; and later increases were associated with summer storm events. Low Total Phosphorus (TP) concentrations in samples collected near the Phosphoria Formation located in this area indicated that these outcrops do not result in elevated phosphorus concentrations in downstream reaches.

1.2.3 BEAR RIVER WATERSHED MANAGEMENT UNIT WATER QUALITY ASSESSMENT REPORT (2000).

This 2000 report presents the results of the second intensive monitoring (1998-1999) of the Bear River Watershed Management Unit conducted by the Utah Division of Water Quality. This monitoring survey assessed the beneficial uses of streams based on State water quality standards and pollution indicators. All water bodies in the Upper Bear River watershed were assessed as fully supporting their beneficial uses (i.e., Class 3A-cold water aquatic life and Class 4-agricultural use) with three exceptions. Two mainstem segments of the Bear River were assessed as partially supporting their class 3A beneficial use due to low dissolved oxygen. These two segments of the Bear River are located from the Utah-Wyoming border to the Woodruff Creek confluence (11.84 miles) and from the Woodruff Creek confluence to the Utah-Wyoming border (54.79 miles). Saleratus Creek (23.37 miles) and its tributaries were also assessed as not supporting all of their beneficial uses due to dissolved oxygen, temperature, and total dissolved solids. It is not known what is the potential source, or sources, of impairment for the Bear River. The possible source of total dissolved solids entering Saleratus Creek are agricultural and natural. Sources for temperature and dissolved oxygen for this stream is not known.

In addition to the water bodies assessed as impaired, this study indicated that the lower portion of Big Creek and Woodruff Creek, located within the Upper Bear River TMDL study area, presented elevated levels of total phosphorus. The report stated these water bodies need further examination to determine if the elevated TP concentrations constitute a water quality problem.

1.3 PLAN OBJECTIVES

The goal of this TMDL assessment is to restore the beneficial uses assigned by the State of Utah to the Bear River in Rich County by meeting numeric criteria and narrative standards for water quality parameters that influence DO concentrations. In addition, Saleratus Creek will be assessed to determine if this water body is capable of supporting a Class 3A beneficial use. The Upper Bear River in Rich County was listed on the Utah 303(d) list beginning in 1996 when it was listed for high levels of TP. This listing was removed in 1998 when the state determined that TP data could not be used by itself as a means for determining beneficial use support. The 2000 303(d) list included both the Upper Bear River in Rich County and Saleratus Creek as impaired for low levels of DO. These water bodies have remained on the 303(d) list while additional monitoring data was collected by the State.

A technical assessment of DO concentrations in the Upper Bear River and Saleratus Creek is included in the remainder of this document. The assessment includes a description of seasonal and inter-annual flow and pollutant loading scenarios that typically occur in the study area and how these conditions lead to low DO concentrations. A Use Attainability Analysis (UAA) has also been completed for Saleratus Creek to determine if the proper designated use has been assigned to this water body. In addition, a project implementation plan has been included that will result in meeting the TMDL and provide full support to the recommended beneficial use of the Bear River and Saleratus Creek.

CHAPTER 2: PROJECT AREA DESCRIPTION

The project area associated with this study is in the Bear River Watershed. The Bear River Basin is in northern Utah, southern Idaho, and southwestern Wyoming. Specifically, this project is concerned with the upper portion of the Bear River Basin within the State of Utah. The study area is primarily located within the boundary of Rich County, Utah, with a small portion located in Lincoln County, Wyoming (Figure 2.1). The Bear River originates in the Uinta Maintains in Utah. It enters Wyoming flowing north trough Evanston and into Woodruff Narrows Reservoir. Just downstream of this reservoir it crosses into Utah, where it flows through Woodruff and Randolph. Further north, it returns to Wyoming and flows through Cokeville. It then crosses into Idaho, reenters Utah and flows into the Great Salt Lake through the Bear River Wildlife Refuge.

Throughout the basin, developed and undeveloped agricultural lands are located in the valleys along the main stem of the river and its tributaries. As the Bear River crosses the Utah-Wyoming border it enters a series of mayor valleys including the Upper Bear and Bear Lake valleys, which are partially located within Rich County. Arable lands surround valleys along the mainstem of the river and its tributaries. These valleys are separated by narrow canyons or gorges and bordered by sharply rising mountain ranges (UDWR 2002).

2.1 HISTORY

The first group of Bear Lake Basin settlers were lead by Charles C. Rich in 1863. They first settled in what is now Idaho, but several years later they moved to the southern end of the lake, near the present towns of Meadowville and Laketown. By 1870, Randolph and Woodruff had become the first settlements in the Bear River Valley. The largest community, Randolph, became the county seat in Rich county in 1872. In the study area and throughout Rich County, agriculture has long been an important factor for the economy. Corn, wheat, oats, and barley were planted by early setters, but the short growing season limited the success of most crops. Native and improved grasses grow well in the valleys and surrounding foothills and mountains. The importance of these grasses for livestock production was recognized early in the settlement of Rich County. Livestock production has become an important segment of Rich County's economy (Campbell and Lacey 1982).

The earliest water use of the Bear River Basin was irrigation for the Lower Bear River Valley and Cache Valley. These areas hold the earliest water rights. Given that the delivery of irrigation water is the main objective of the Bear River system of management, management activities are accomplished by means of water diversions. The Bear River is unique in that there has been very little presence of any Federal water agency in any of the developments in the basin. One of the earliest goals of irrigators was to ensure sufficient water for irrigation during the agricultural late-growing season. For this reason, water from the river was diverted to Bear Lake, which works as a storage reservoir (UDWR 2004). The water that flows though the Utah portion of the upper Bear River basin is released from Woodruff Narrows Reservoir. This storage facility was built to provide water for industrial, agricultural, and municipal use in Utah and Wyoming (WWDC 2001).

2.2 SUBWATERSHED DESCRIPTION

The Bear River watershed includes large amounts of private and federal lands (primarily Bureau of Land Management) that serve a range of natural and agricultural functions, which generate unique impacts and demands on water resources. The study area lays within the HUC 16010101 and covers an area of approximately 496,036 acres. Bear River subwatersheds comprise approximately 22 percent of the study area. Saleratus and Big Creek subwatersheds comprise approximately 19 percent and 10 percent of the study area, respectively (Table 2.1). The location of these subwatersheds is shown in Figure 2.1.

TABLE 2.1. SUBWATERSHEDS IN THE UPPER BEAR RIVER TMDL STUDY AREA.

12th Level HUC	States	Subwatershed Name	Area (acres)	Percentage
160101010802	UT,WY	Bear River-Sage Creek	29,112	5.9
160101010801	UT,WY	Bear River-Brazier Canyon	36,160	7.3
160101010604	UT	Bear River-Sage Hollow	35,658	7.2
160101010606	UT,WY	Bear River-Whitney Canyon Creek	7,369	1.5
160101010605	UT	Lower Big Creek	18,860	3.8
160101010305	UT	Upper Big Creek	28,517	5.8
160101010603	UT	Birch Creek-Walton Canyon	26,833	5.4
160101010601	UT,WY	Bridger Creek-Bear River	39,298	7.9
160101010602	UT,WY	Cottonwood Creek-Bear River	32,869	6.6
160101010303	UT	Little Creek	23,896	4.8
160101010704	UT,WY	Neponset Reservoir	47,295	9.5
160101010703	UT	Otter Creek	27,993	5.6
160101010503	UT,WY	Lower Saleratus Creek	24,689	5.0
160101010504	UT	Middle Saleratus Creek	36,940	7.4
160101010702	UT	Upper Saleratus Creek	30,549	6.2
160101010502	UT	Sugar Pine Canyon	10,018	2.0
160101010701	UT	Lower Woodruff Creek	21,350	4.3
160101010501	UT	Upper Woodruff Creek	18,631	3.8
Total			**496,036**	100

2.3 CLIMATE

The climate of the Upper Bear River Basin is typical of the semiarid central and northern mountainous regions of Utah, with wide variations in temperature between summer and winter as well as diel variations. Long cold winters and short cool summers are characteristic of high mountain valleys in the basin. Lower valleys are warmer but experience more variation in temperature. In the agricultural area of the basin in Wyoming, the average annual temperature is approximately 4° C. Average temperatures throughout the basin are -13° C to -1° C in the winter and 3° C to 11° C in the summer. Temperature in agricultural regions allow the typical growing season to extend from mid-May through September, but because of the arid climate, irrigation water is required to grow most crops. As is typical throughout the intermountain west, precipitation is highly seasonal and most falls as snow. Annual precipitation in the basin ranges from 10 to 65 inches depending on the elevations, which vary from 4,200 to 13,000 feet (UDWR 2002) (Figure 2.2). Higher precipitation in the higher elevation mountains generates runoff to the Bear River and its tributaries. Run off in the Bear River Basin is bimodal with the first peak being correlated to the snowmelt from the valley bottoms and the second peak from snowmelt in the higher parts of the basin (UDEQ 2005).

The National Weather Service has 18 climatological stations within the Utah portion of the Bear River Basin; two of these stations are located within the project area. A summary of climatological data for the stations located in the Utah portion of the study area is shown in Table 2.2.

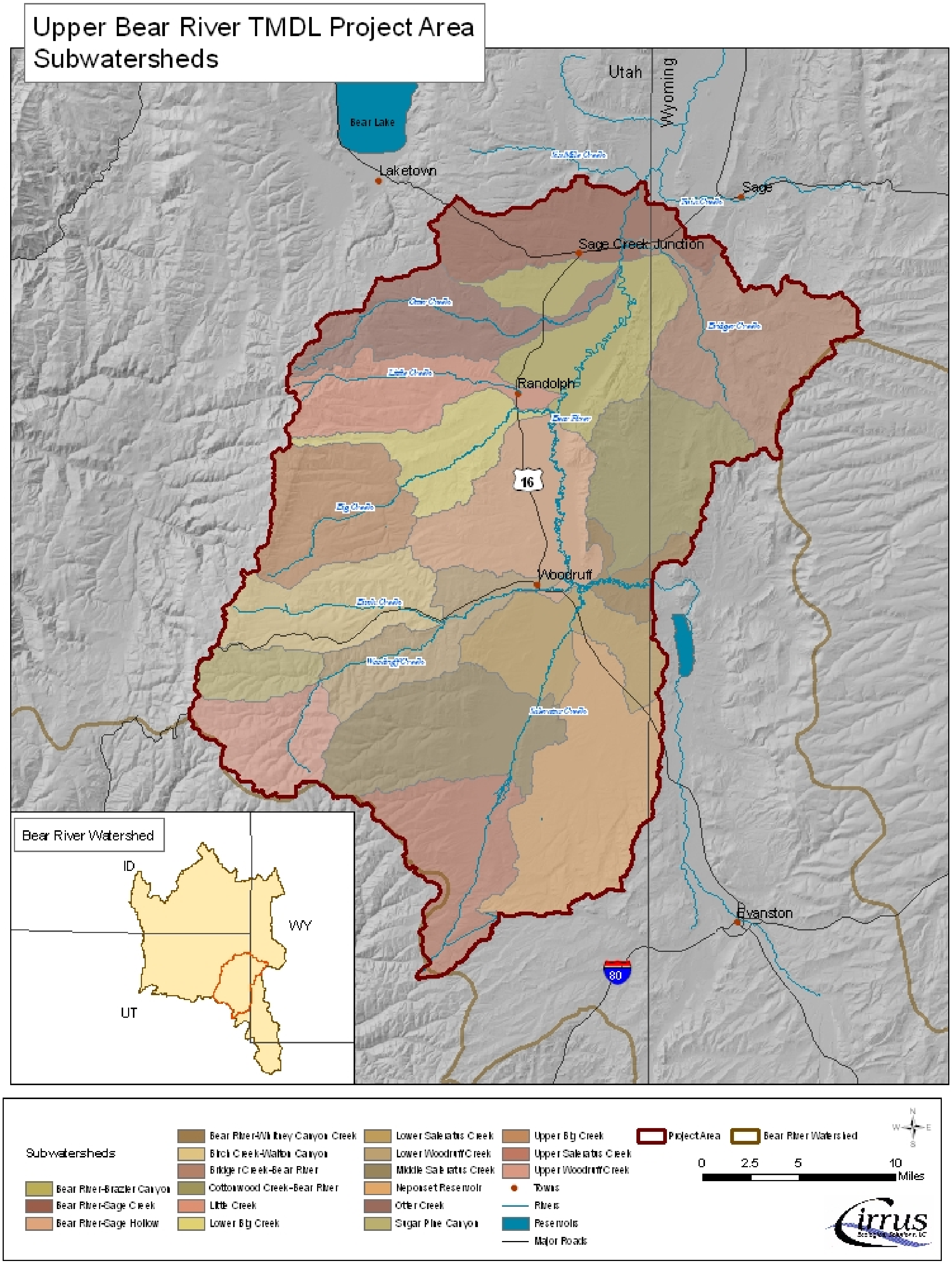

Figure 2.1. TMDL project area and subwatersheds.

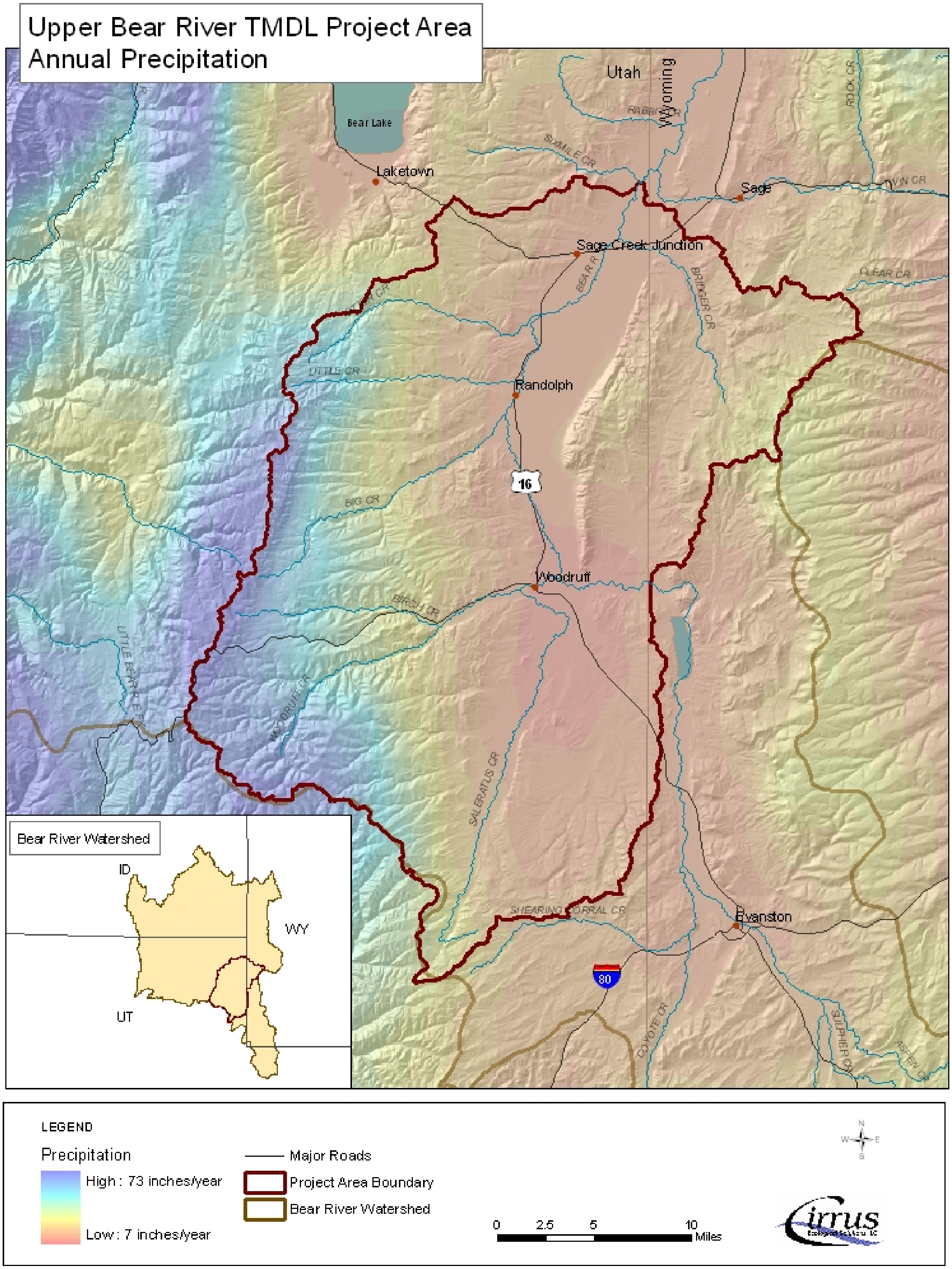

Figure 2.2. Average annual precipitation map of the TMDL project area.

Table 2.2. Climatological data for stations in Rich County, Utah							
Station	**Temperature (° C)**					**Precipitation (inches)**	
	January		**July**		**Mean**	**Snow**	**Mean Annual**
	Max	**Min**	**Max**	**Min**			
Laketown	0.0	-11.8	28.4	8.7	5.7	42.5	12.2
Randolph *	-3.4	-0.2	27.0	6.2	3.6	34.2	11.2
Woodruff *	-1.9	-17.9	27.6	6.7	3.9	42.3	9.0
Bear Lake	-0.2	-11.1	29.2	9.8	7.0	41.1	14.0

* Stations within the Utah portion of the Upper Bear River.
Source: UDWR (2002)

2.4 LAND COVER

The Upper Bear River watershed has a contributing area of approximately 496,036 acres. Table 2.3 shows the land cover distribution for the study area.

The majority of the land in the Upper Bear River watershed is comprised of rangeland (approximately 78 percent) or irrigated agriculture (approximately 12 percent) which account for nearly 90 percent of the total watershed area. Although irrigated agricultural land represents a relatively small percentage of land use within the study area, these areas are likely very important to water quality because they are mainly located adjacent to streams (Figure 2.3).

Table 2.3. Land cover distribution within study area.

Land use/cover	Area (acres)	Percentage
Barren	137	0.03
Forest land	25,847	5.21
Irrigated Agriculture	59,515	12.00
Non-irrigated Agriculture	13,470	2.72
Rangeland	388,183*	78.26
Urban/Residential	1,462	0.29
Water	2,578	0.52
Wetlands	4,844	0.98
TOTAL	**496,705**	**100**

Source: USGS National Land Cover Dataset (NLCD) and State of Utah Department of Water Resources Water Related Land Use GIS coverage (WRLU).
* Rangeland acreage reduced to account for rounding error.

2.5 LAND USE

The Upper Bear River supports a wide range of land uses. Figures 2.3 and 2.4 indicate the distribution of existing land use/land coverage and land ownership within the study area, respectively. Recent land use data for Rich County indicated that a total of 101,938 acres are used for agricultural crop production. Grain accounted for approximately 13 percent of the irrigated cropland, while alfalfa and grass/hay accounted for 3 percent and 42 percent, respectively (UDWR 2004; Table 2.4).

Campbell and Lacey (1982) indicated that approximately 93 percent of the total land area in Rich County is used for some form of agriculture. Approximately 90 percent of all the agricultural land is used by the livestock industry and the remaining 10 percent is used for crops. Currently, the natural resources and mining sector account for approximately 20 percent of the county's total economy (UDWR 2004). Within this sector, livestock raising is the most important enterprise and is responsible for maintaining the economic stability of the county.

Table 2.4. Irrigated and non-irrigated agricultural ground by crop type in Rich County, Utah.

Irrigated cropland	
Crop	**Acres**
Alfalfa	9,019
Grain	1,905
Corn	11
Berries	52
Pasture	14,752
Sub-irrigated pasture	15,038
Grass/hay	29,884
Sub irrigated grass/hay	32
Total irrigated cropland	**70,693**
Non-irrigated cropland	
Alfalfa	641
Grains/beans/seeds	15,408
Pasture	13,491
Fallow	138
Idle	1,567
Total non-irrigated cropland	**31,245**
Total agricultural cropland	**101,938**

Source: UDWR (2004)

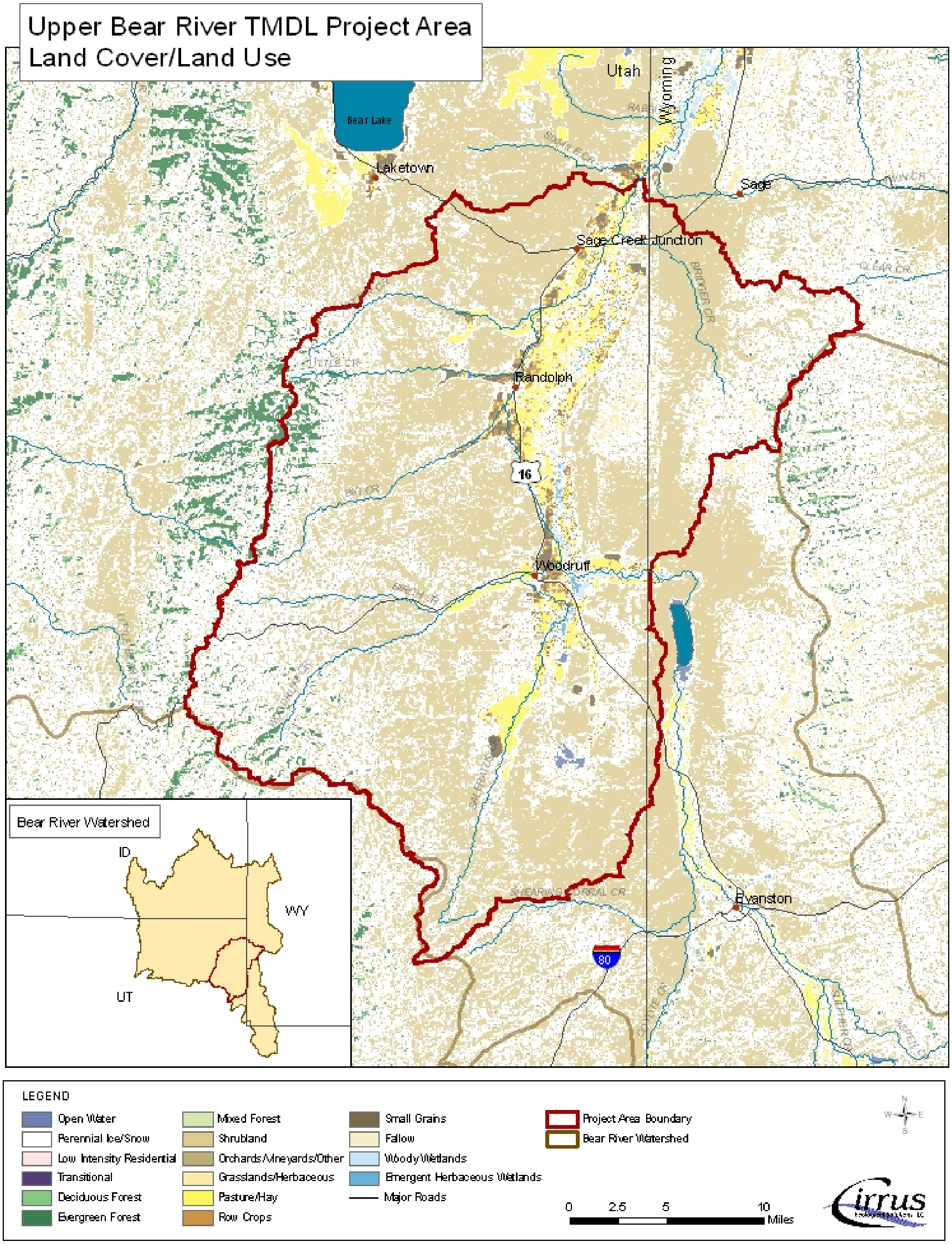

Figure 2.3. Land cover map of the TMDL project area.

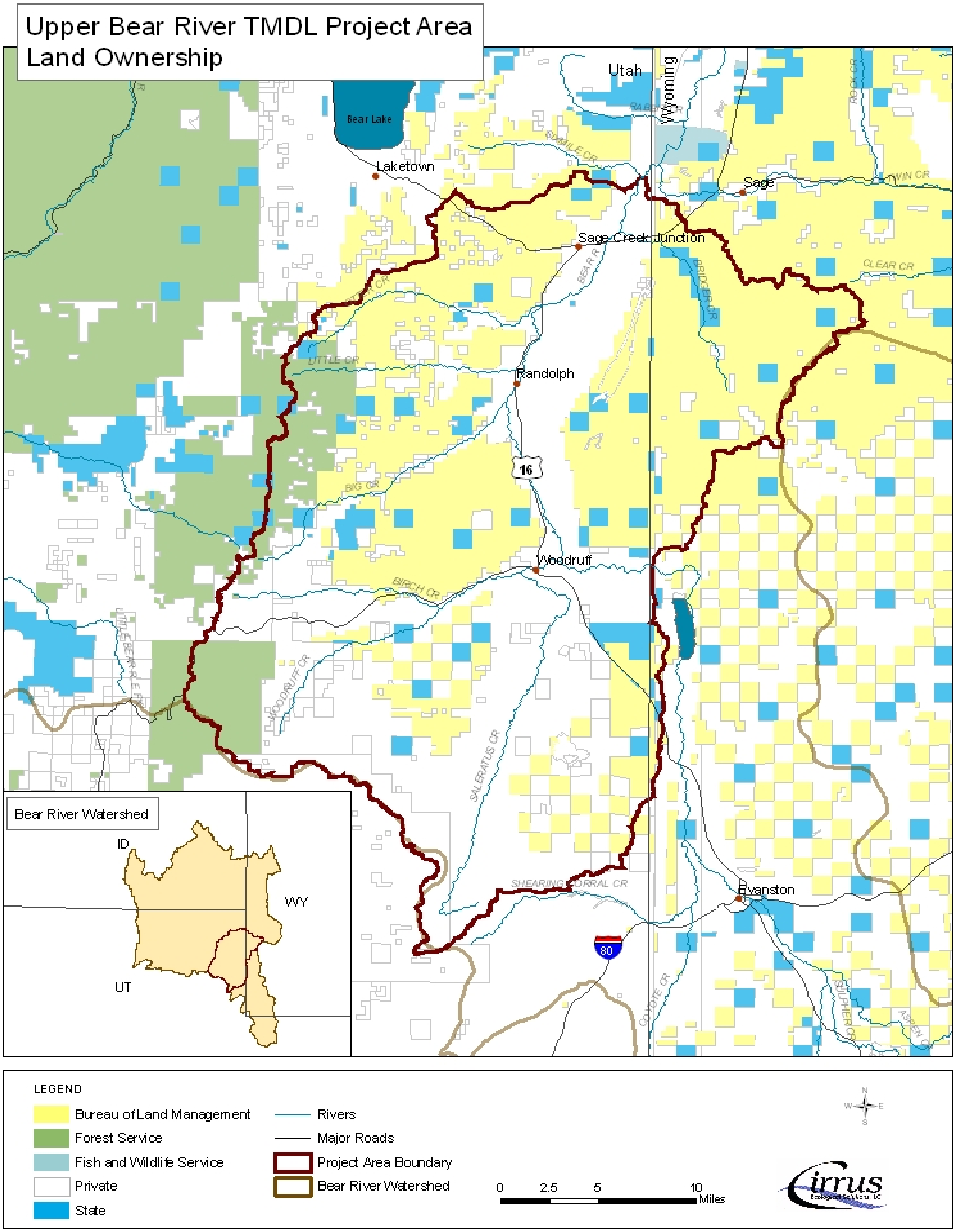

Figure 2.4. Land ownership within the TMDL project area

2.6 PHYSIOGRAPHY/GEOLOGY/SOILS

The Upper Bear River is located in the southern part of the Middle Rocky Mountain physiographic province. Physiographic areas in the Upper Bear River Basin include parts of the Bear River plateau, the Bear River Basin, the Bear River Valley, the Crawford Mountains, and the Bear River Range. The Bear River Plateau, bordered by the Bear Lake Basin on the West and the Bear River Valley on the East, is the largest physiographic area. This area is characterized by nearly level to steep uplands and foothills, dissected by many small drainage ways. The rock outcroppings and underlying bedrock in the Bear River Plateau are mainly sandstone and limestone of the Wasatch formation. The Bear Lake Basin, in the northwestern corner of Rich County, borders the northwesterN boundary of the project area. Steep foothills and mountains in this area resulted from recurrent faulting. The Bear River Valley is along the eastern boundary of Rich County; the major drainage way in the valley is the Bear River. A nearly level flood plain and adjoining terraces and foothills are characteristic of this valley. Most of the flood plain is under irrigation. The Crawford Mountains are located between the Bear River flood plain and the Utah-Wyoming state line. These steep mountains are composed of folded and faulted Paleozoic strata and a limestone formation along the western front. The Bear River Range, located along the western edge of Rich County, is the northern extension of the Wasatch Range. This range in the boundary between Rich and Cache counties and it provides drainage into the Bear River Valley and Bear Lake Basin (Campbell and Lacey 1982).

The geology of the Bear River mountain ranges consist primarily of Paleozoic marine sedimentary rocks overlying a core of Precambrian quartzite. Volcanic rocks are common along the footslopes of ranges in the northern part of the range adjacent to the Snake River Plain. Tertiary deposits overlayed with Quaternary lake sediments are characteristic of the valleys. Mountain ranges are mostly dissected by V-shaped fluvial canyons. U-Shaped glacial valleys are also present in the Bear River Range. Glacial features are most evident along the upper part of the Logan River. In general, major streams that discharge from canyons have dissected into broad alluvial deltas remnant of Lake Bonneville (UDEQ 2005). Most of the range in Rich County is capped by sandstone or conglomerate of the Wasatch formation. Streams flowing through mountainsides in this area have cut through the cap rock exposing tilted layers of sandstone and limestone (Campbell and Lacey 1982).

A map of soil units in the study area is shown in Figure 2.5. Typically, a map unit consists of one or more major soils and some minor soils. The 12 map units in the study area have been grouped in five general kinds of landscapes for interpretive purposes. A description of general characteristics of each landscape and map unit is included in Table 2.5.

2.6.1 PHOSPHATE-BEARING FORMATIONS

Large deposits of phosphate are found in the northern and eastern parts of the of the study area (Figure 2.5). These deposits have been partially mined. Phosphate mining, however, has decreased due to the depressed market price (Campbell and Lacey 1982).

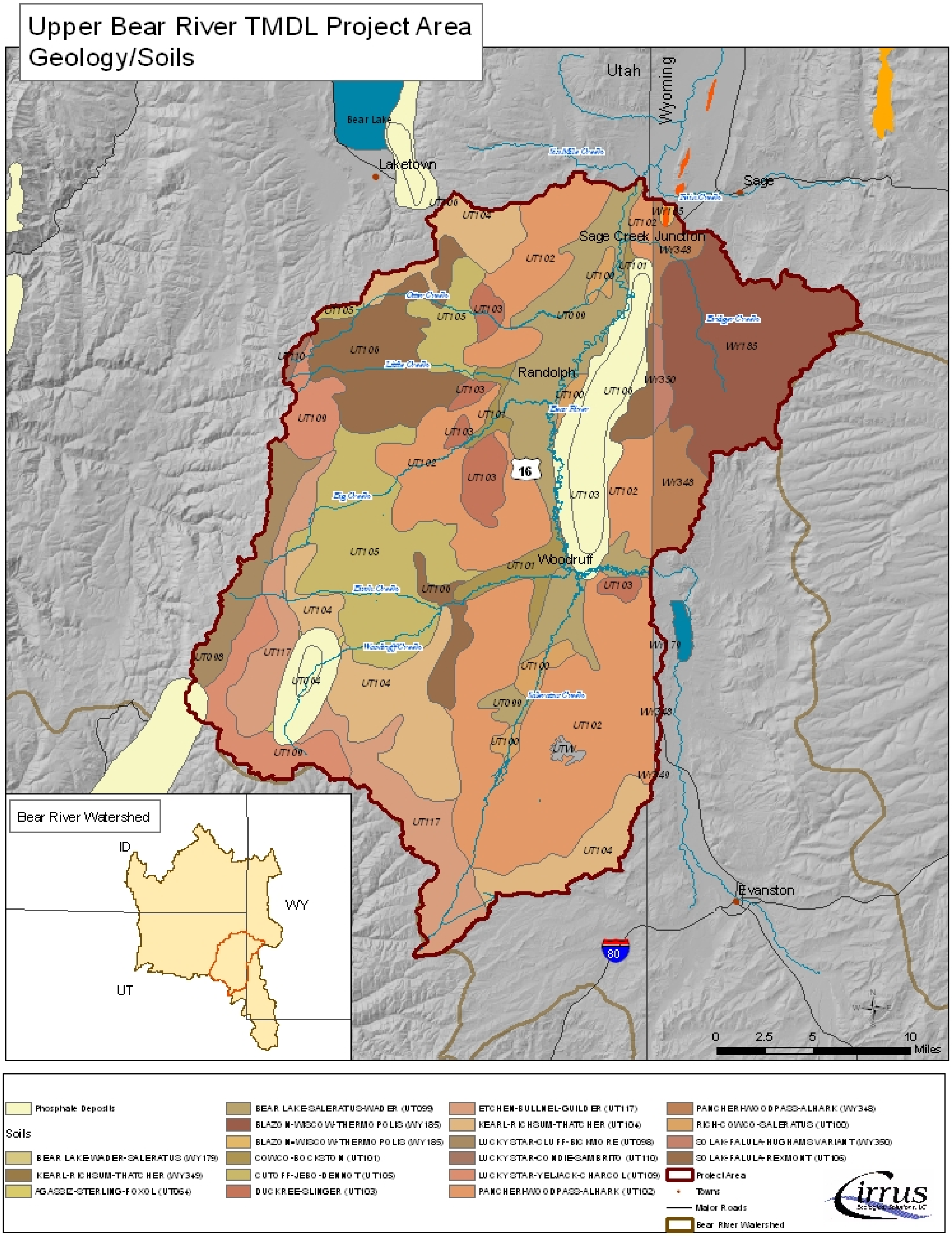

Figure 2.5. STATSGO soil map of the TMDL project area.

Phosphate deposits in the study area are associated with beds of the Phosphoria Formation that consist of deposits of the Permian Sea in the northern Rocky Mountains (Williams 1939). Phosphate-bearing Permian deposits extend from northern Utah through southeastern Idaho, western Wyoming, and central Montana. Phosphate deposits occurring in the study area consist of an upper and lower member. The upper member is comprised of interbedded light gray, cherty limestone and shale ranging from 80 feet to 175 feet in thickness, and can be associated with the Rex Member of the Phosphoria Formation of southeastern Idaho. The lower member is a light gray-green to olive-green phosphatic shale and phosphate rock about 20 feet to 30 feet thick. This lower member can be correlated with the Meade Peak Member of the Phosphoria Formation (Garrand 1985).

Table 2.5. Description of soil characteristics in the Utah portion of the TMDL study area.

Map Unit Name/Number	Landscape kind description	General Map Unit Description
AGASSIZ-STERLING-FOXOL (UT064)	Very shallow to very deep soils on the upper parts of alluvial fans and on plateaus, mountainsides, and the sides of foothills	Very shallow or shallow, somewhat excessively drained, moderately steep to very steep soils, and rock outcrop; on ridges and mountains.
ETCHEN-BULLNEL-GUILDER (UT117)		Moderately deep to very deep, well drained, gently sloping soils on mountain sides, plateaus, and foothills.
BEAR LAKE-SALERATUS-WADER (UT099)	Very deep soils on stream terraces, alluvial fans, and flood plains	Very poorly drained or poorly drained, nearly level to gentle sloping soils; on flood plains.
RICH-COWCO-SALERATUS (UT100)		Very deep, well drained, somewhat poorly drained and poorly drained, nearly level to gently sloping soils; on flood plains and alluvial fans.
COWCO-BOCKSTON (UT101)		Very deep, well drained, nearly level to sloping soils; on alluvial fans, flood plains, and stream terraces.
PANCHERI-WOODPASS-ALHARK (UT102)	Moderately deep to very deep soils on foothills, stream terraces, uplands, and alluvial fans	Deep and very deep, well drained, gently sloping to very steep soils; on alluvial fans, foothills and uplands.
DUCKREE-SLINGER (UT103)		Moderately deep and very deep, somewhat excessively drained, gently sloping to very steep soils; on foothills and extra terraces.
KEARL-RICHSUM-THATCHER (UT104)	Shallow to very deep soils on the lower parts of uplands, plateaus, foothills, mountainsides, and alluvial fans	Moderately deep and very deep, well drained, gently sloping to steep soils; on alluvial fans, uplands, and foothills.
CUTOFF-JEBO-DENNOT (UT105)		Moderately deep and deep, well drained and somewhat excessively drained, gently sloping to very steep soils; on foothills, mountainsides, and alluvial fans.
SOLAK-FALULA-REXMONT (UT106)		Shallow, somewhat excessively drained, gently sloping to very steep soils; on foothills, mountainsides, rides, and plateaus.
LUCKY STAR-YELJACK-CHARCOL (UT109)	Very deep soils on high mountain sides	Very deep, well drained, strongly sloping to steep soils on mountainsides and ridges.
LUCKY STAR-CONDIE-SAMBRITO (UT110)		Very deep, well drained, steep and very steep; on mountain sides.
LUCKY STAR-CLUFF-BICKMORE (UT098)		Very deep, well drained, strongly sloping to steep soils on mountainsides and ridges.

Source: Campbell and Lacey (1982)

2.7 HYDROLOGY

In general, Rich County can be divided into two main surface drainage regions. Approximately 77 percent of the county drains into the Bear River system and the remaining 23 percent drains into the Bear Lake Basin. The project area is located in the larger region. The headwaters of the Bear River are located on the north slope on the Uinta Mountains in Summit County. The River enters Rich County—and the project area —on the east from Wyoming and flows northward through the Bear River Valley (Campbell and Lacey 1982). The length of the Bear River section within the study area is approximately 60 miles. Tributaries of the river within this section include Saleratus, Birch, Little, Bridger, Woodruff, Big, Sage, and Otter creeks. The latter four flow directly into the mainstem of the Bear River. The Bear River flows back into Wyoming approximately 12 miles north of Randolph. The main tributaries of the Bear River in this area are Swan and Big Creeks and North Eden and South Eden Canyons. These tributaries are located outside the project area boundary. Locations of all major water features in the study area are shown in Figure 2.6.

The water that flows into the study area through the Bear River is largely affected by releases from Woodruff Narrows Reservoir located in Wyoming. Annual average flows below the reservoir are 228 cfs while monthly average flows range from 43-46 cfs during winter to 960 cfs during June. Annual average flow in the Bear River near Randolph is 208 cfs with monthly average flows ranging from 52 cfs to 635 cfs.

Table 2.6. Upper Bear River monthly average streamflow.

Month	USGS 10020300 - Bear River Below Woodruff Narrows Reservoir (1961-2004)			USGS 10026500 - Bear River near Randolph (1943 – 1992)		
	Mean (cfs)	Min (cfs)	Max (cfs)	Mean (cfs)	Min (cfs)	Max (cfs)
January	43	1	208	77	14	260
February	46	5	237	96	16	1140
March	93	0	990	206	14	2010
April	267	0	1290	388	8	2470
May	754	0	3390	495	5	2870
June	960	23	3630	635	8	3500
July	277	0	1540	214	3	1650
August	76	0	1080	79	2	630
September	59	0	886	52	4	639
October	56	0	662	75	5	586
November	52	0	627	90	4	700
December	45	0	612	79	6	700
Annual	227.9	0	3390	208.0	2	3500

Source: USGS – NWIS (http://waterdata.usgs.gov/nwis)

Average monthly streamflows for the Bear River in the study area indicate this river segment is a gaining reach during October through April and a losing reach from May through August (Figure 2.7). This is primarily due to consumptive loss from irrigated crops as well as minor amounts of evaporation. Return flows from irrigated lands have been determined to range from 45 percent to 72 percent depending upon annual precipitation levels and total diverted water volumes (UDWR 1994, WWDC 2001, Johnson 2006). It is generally believed that Bear River irrigation diversions in Rich County are dependent upon return flows. As a result, during the irrigation season Bear River water is reused several times before leaving Rich County.

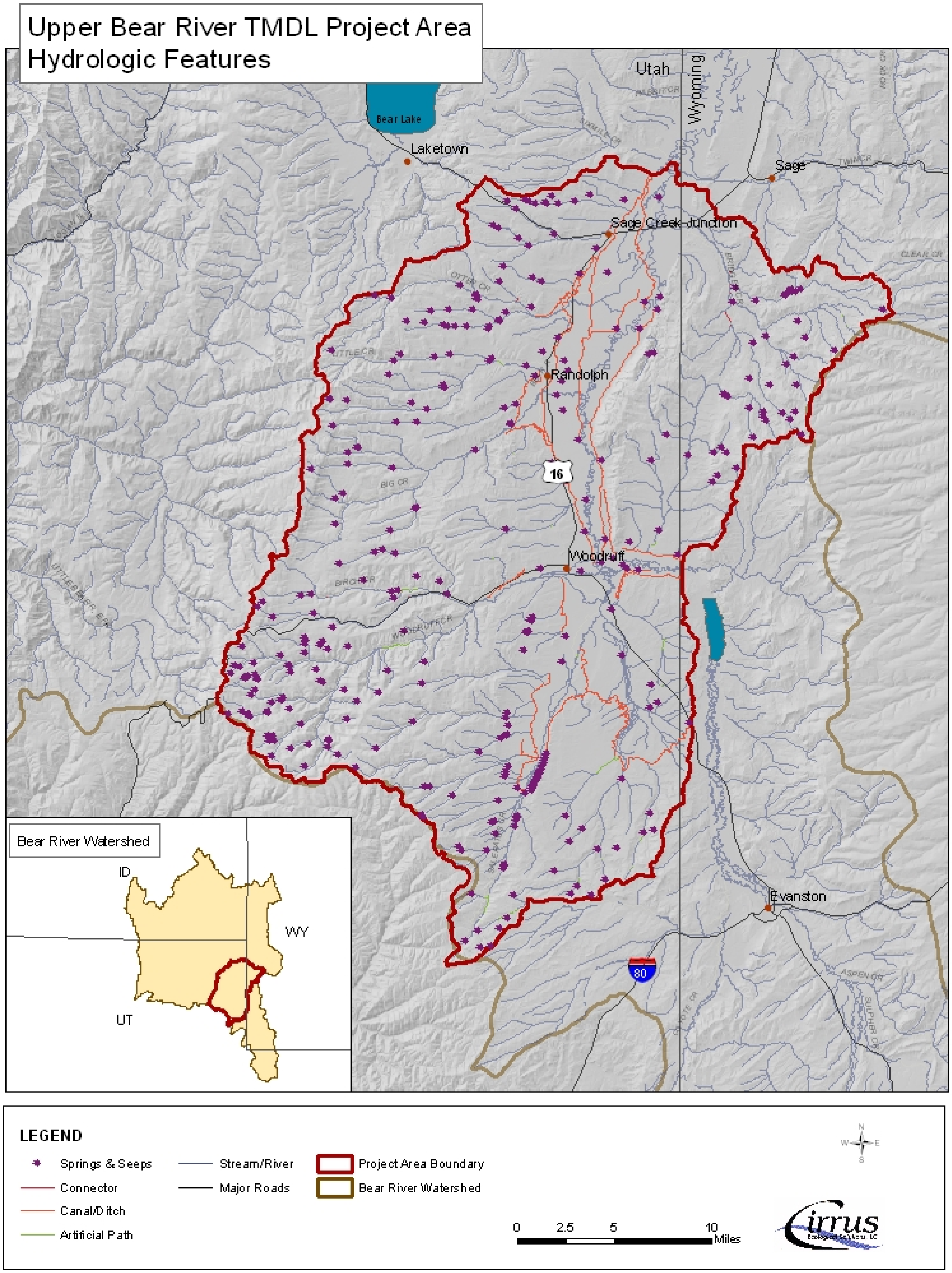

Figure 2.6. Hydrologic features within the TMDL project area.

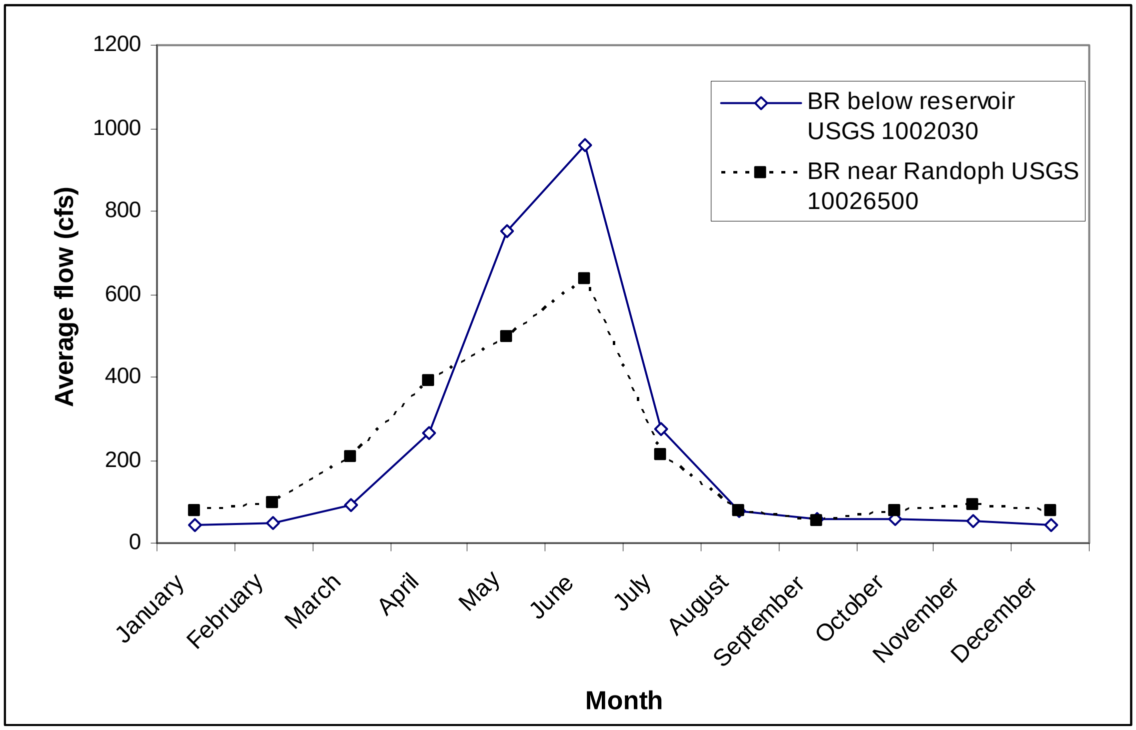

Figure 2.7. Average monthly flow for Bear River stations located below Woodruff Narrows Reservoir (Station 1002030) and near Randolph (Station 10026500).

Flow monitoring stations on Bear River tributaries within the study area are limited to Woodruff Creek (USGS stations 10020900 and 1002100) and Big Creek (USGS station 1002300). Birch Creek and the South Fork of Woodruff Creek flow into Saleratus Creek near the lower end of the Saleratus Creek watershed. All flow from Saleratus Creek is typically diverted into the Randolph-Woodruff Canal before reaching the Bear River (Hoffman 2006). Minimum and maximum flows in Woodruff Creek near Woodruff (USGS station 1002100) range from one cfs during winter to 496 cfs during spring. The average flow at this station is 28 cfs. Similarly, minimum and maximum flows in Big Creek (USGS station 1002300) occur during the winter and spring season, respectively. Flow in this station ranges from zero to 140 cfs and averages 13 cfs. Typically, peak discharge in Woodruff Creek and Big Creek occurs in May.

Nearly all of the perennial and seasonal stream channels that originate on the either side of the Bear River Valley in Rich County are intercepted entirely or partially by canals that parallel the Bear River. A thorough review of hydrographic survey maps, aerial photos, field reconnaissance information, and multiple discussions with state and local officials was completed to obtain information on the Upper Bear River and tributary streams. Based on this information, five tributary streams have been identified that contribute meaningful flows to the Bear River on a seasonal or perennial basis including Woodruff Creek, Big Creek, Otter Creek, Bridger Creek, and Twin Creek.

Based on average monthly flows, it was estimated that approximately 165,086 acre-feet per year of water flow though the Bear River at the station located below Woodruff Narrows Reservoir. Approximately 154,558 acre-feet per year of this amount are diverted through 13 irrigation canals (Table 2.7).

Table 2.7. Diversions associated with the Bear River in the TMDL project area.	
Canal Name	**Withdrawal (acre-feet/year)**
B&Q Westside Canal	21,100
Bear River Canal	9,048
Booth Canal	2,697
Crawford-Thompson Canal	18,953
Francis Lee Canal	6,142
Neville Canal	837
Randolph-Sage Creek Canal	25,271
Randolph-Woodruff Canal	35,091
Rees Canal	6,801
Dykens Canal	3,572
McMinn Canal	3,341
Enberg Canal (Rex Canal)	3,221
Chapman Canal at State Line - Station 10019500	18,484
Total	**154,558**

Water diverted from the Bear River though Randolph-Woodruff Canal accounts for 23 percent of the total. Randolph-Sage Creek Canal and BQ Westside Canal account for 16 percent and 14 percent, respectively (Figure 2.8).

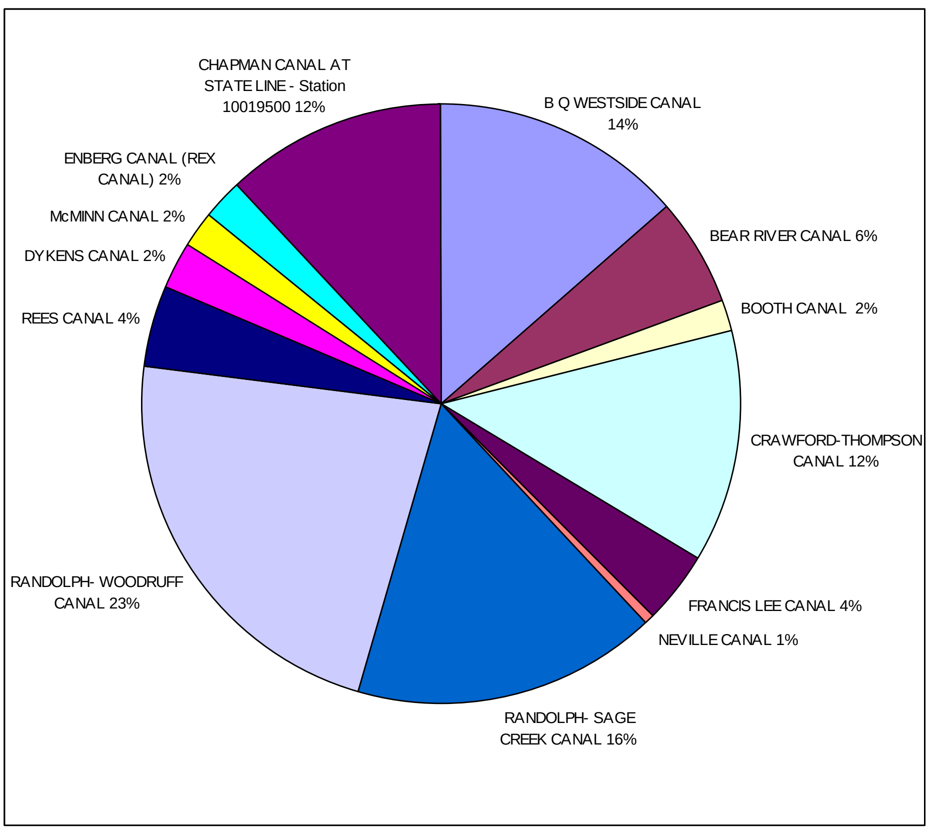

Figure 2.8. Proportion of total water withdrawal allocated to diversions in the TMDL project area.

The Bear River Compact, a document voluntarily written by the states which establishes the rights and obligations of Idaho, Utah, and Wyoming with respect to the waters of the Bear River, became effective on March 17, 1958. The goal of the compact is to minimize the causes of controversy over the distribution and use of water from the Bear River, to provide its efficient use, and to permit additional development of the water resources of the river. The compact reserved a portion of the storage capacity in Bear Lake for primary use by, and protection of, irrigation uses and rights downstream from Bear Lake. This compact-established "irrigation reserve" establishes minimum Bear Lake levels that correspond to upstream storage development, below which the Bear Lake cannot be drawn down for power purposes only. According to the compact (as amended in 1979) additional storage is granted above Bear Lake for 74,500 acre-feet, of which 4,500 acre-feet is granted to Idaho, and 35,000 acre-feet is granted each to Utah and Wyoming. This storage, plus water appropriated including groundwater applied to beneficial use is limited to an annual depletion of 28,000 acre-feet of which Idaho is allocated 2,000 acre-feet and Utah and Wyoming are allowed 13,000 acre-feet each. This additional upstream storage is not allowed when the elevation of Bear Lake is below 5,911 feet (Utah Code 2004) (Ref: Utah Code- Title 73chapter 16- amended bear river compact-Available at *http://www.code-co.com*).

2.8 ANNUAL WATER BUDGET

The overall water budget for the Upper Bear River TMDL study area was estimated under the assumption that inflows to the watershed are equal to outflows and based on available data using the following equation:

$$P + Q_{in} + Q_{c,in} + Q_{g,in} = Q_{out} + Q_{c,out} + Q_{g,out} + CU \qquad (2.1)$$

Inflows = Outflows

Where:
- P = Average annual precipitation
- Q_{in} = Average annual inflow to watershed.
- $Q_{c,in}$ = Average annual canal inflow
- $Q_{g,in}$ = Average annual groundwater inflow
- Q_{out} = Average annual discharge from the watershed
- $Q_{c,out}$ = Average annual canal outflow
- $Q_{g,out}$ = Average annual groundwater outflow
- CU = Average annual consumptive use (includes evapotranspiration)

The following assumptions were made to facilitate the completion of the water balance calculations:

1. The average yearly change in storage in the watershed is equal to 0.
2. Average flows calculated at USGS gage 10026500 near Randolph are characteristic of discharge from the project area above this gage. Twin Creek joins the Bear River stream channel downstream of USGS gage 10026500 and just before it crosses into Wyoming. The Twin Creek stream channel is dewatered for irrigation purposes during the summer and fall seasons. For the purpose of water budget calculations, annual flow contributions from Twin Creek to the project area are considered negligible.
3. Average inflows at USGS gage 10020300 are characteristic of inflow to project area from Woodruff Narrows Reservoir releases. (Q_{in})
4. The Chapman Canal provides the only canal inflow to the watershed.
5. The B&Q Westside Canal provides the only canal outflow from the watershed. Five percent of the annual volume diverted to this canal flows out of the watershed into Wyoming (Hoffman 2006).

6. Net groundwater flux equals zero ($Q_{g,in} = Q_{g,out}$). Furthermore, all groundwater recharge resulting from irrigation returns to the Bear River channel in the project area.
7. The difference between inflows and outflows after all other terms in the water budget have been defined is attributed to consumptive use, which includes evapotranspiration.

Given these assumptions, Equation 2.1 reduces to:

$$P = Q_{out} - Q_{in} - Q_{c,in} + Q_{c,out} + CU \qquad (2.2)$$

The results of the water budget calculations for the Upper Bear River TMDL study area watershed are shown in Table 2.8. The results shown in the table have also been normalized by watershed area and are presented in inches per year.

Table 2.8. Upper Bear River watershed annual water budget results.

	Annual Average Volume (acre-ft)	Watershed Normalized Depth (in./yr)
Inflows		
Precipitation (P)	702,718	17.0
Chapman Canal ($Q_{c,in}$)	18,484	0.45
Watershed Inflow at USGS 10020300 (Q_{in})	165,086	4.0
Total	**886,288**	**21.4**
Outflows		
Watershed Discharge (Q_{out})	150,562	3.64
B&Q Westside Canal ($Q_{c,out}$)	1,065	0.03
Consumptive Use (CU)	734,661	17.8
Total	**886,288**	**21.4**

The greatest inflow volumes shown in Table 2.2 are from precipitation. Consumptive use in the watershed is responsible for a loss of 734,661 acre-feet per year. A more detailed description of how the elements shown equation 2.2 were calculated is included below.

2.8.1 PRECIPITATION (P)

The Upper Bear River is part of a larger river basin that is typical of mountainous areas in the western United States. The climate in these regions is characterized by wide variations of temperature between winter and summer and between day and night. Precipitation in the greater Bear River basin varies from 10 to 65 inches depending on the elevation, which ranges from 4,200 to 13,000 feet.

The annual average precipitation value used in the water budget for the study area was calculated from spatially explicit precipitation data contained in the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset (Daly et al. 1994). PRISM is a modeling system that uses data collected at meteorological stations and a Digital Elevation Model (DEM) to generate grid estimates of precipitation. Based on the PRISM dataset, the average annual precipitation value for the study area is 17 inches/year or 702,718 acre-feet.

Annual average precipitation values for two climate stations within the watershed were calculated using data obtained from the Utah Climate Center. Table 2.2 above lists the annual average precipitation levels for stations located at Randolph and Woodruff as well as two additional stations located near the project area. Average precipitation levels for stations in the project area are less than PRISM values. This is likely due to the fact that all stations shown in Table 2.2 are located in valley areas and do not account for greater precipitation amounts that occur at upper elevations.

Precipitation patterns in the study area are the result of two major storm patterns; a frontal system from the Pacific Northwest during winter and spring, and thunderstorms from the south and southwest during late summer and early fall. The spatial pattern of precipitation in the Upper Bear River watershed is strongly influenced by the mountain ranges which border valley areas.

2.8.2 WATERSHED DISCHARGE (Q_{OUT}) AND INFLOW (Q_{IN})

Watershed discharge from the study area is influenced by upstream releases from Woodruff Narrows Reservoir and the annual amount of water diverted for irrigation purposes. Although a large amount of water is diverted for irrigation purposes, irrigation return flows for Rich County are high and contribute substantial flows to the Bear River upstream of USGS 10026500 Bear River near Randolph and before it leaves Rich County (Hoffman 2006). The period of record for the USGS gage near Randolph is 1943-1992. Watershed inflow to the study area is characterized by flow records at USGS 10020300 Bear River below Woodruff Narrows Reservoir. Figure 2.9 and Figure 2.10 show annual average flows for the period of record at these gages. The flow records for these gages represent the cycle of drought that has been observed in the Upper Bear River watershed. It is anticipated that any shifts in management of Woodruff Narrows Reservoir that may have occurred during the period of record do not affect the average magnitude of watershed discharge calculated from this data set.

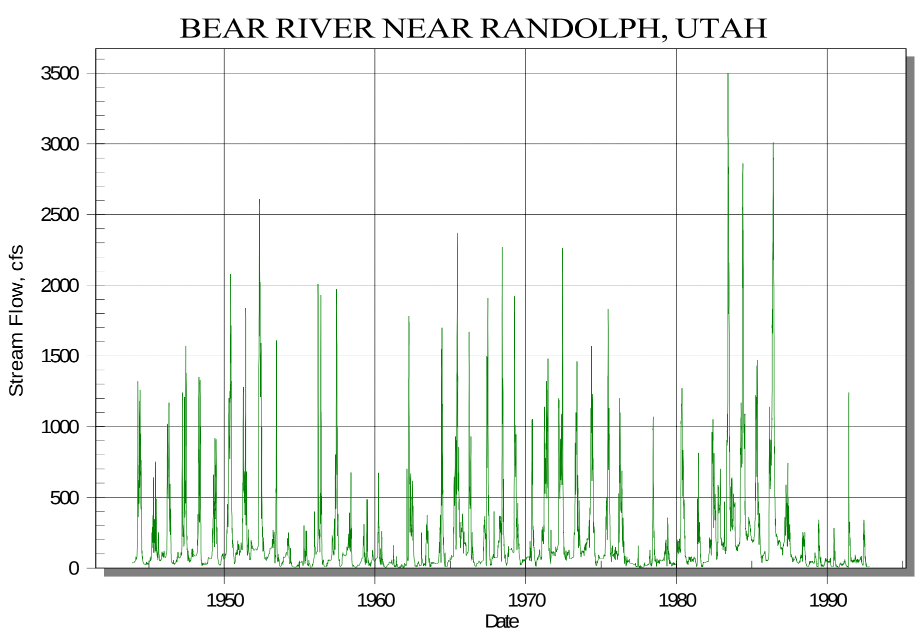

Figure 2.9. Annual average flows for the Bear River near Randolph from 1943-1992 (USGS 10026500).

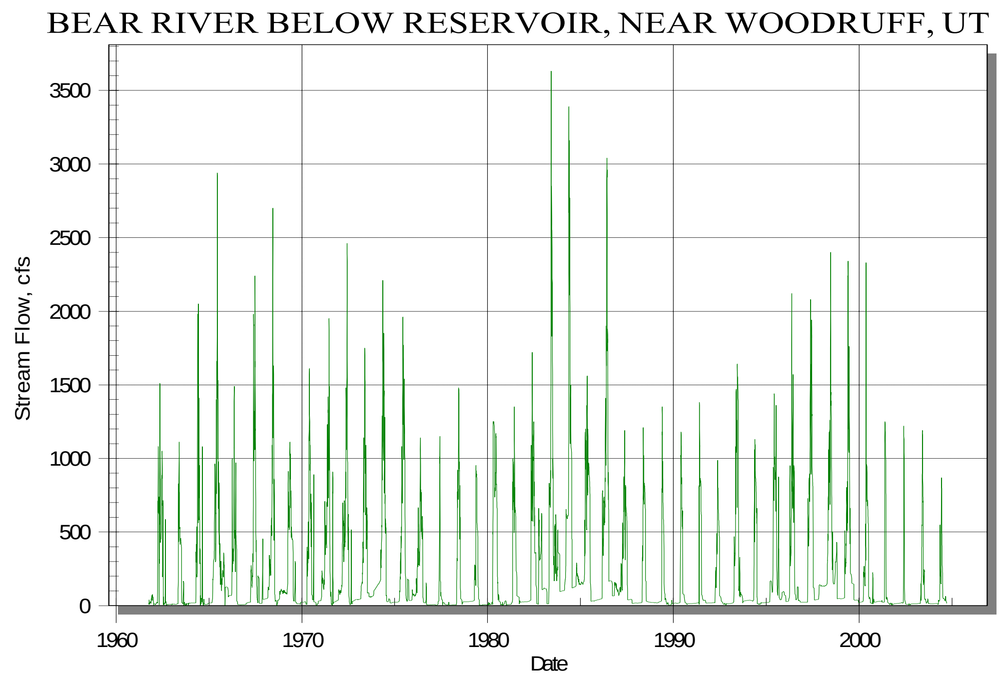

Figure 2.10. Annual average flows for the Bear River below Woodruff Narrows Reservoir from 1961-2004 (USGS 10020300).

Equations 2.3 and 2.4 below were used to calculate the annual average watershed discharge and watershed inflow. In these equations, an average volume is calculated for each day of the year using existing flow records. Average daily values were then summed to get an annual average volume. This method was chosen because it provides a more meaningful distribution of average daily flows that are reflected in the annual average value. For flow records where data is non-continuous, it also provides a means to use each daily flow value rather than discarding years with incomplete data.

$$Q_{i,avg} = \frac{\sum_{j=1}^{m} Q_{i,j}}{m} \tag{2.3}$$

$$Q = \sum_{i=1}^{n} Q_{i,avg} \tag{2.4}$$

Where: $Q_{i,avg}$ = Period of record average volume for day i of the year
$Q_{i,j}$ = Observed flow volume for day i in year j
m = Number of years for which data are available in the period of record
Q = Annual average watershed volume (discharge or inflow)
n = Number of days in the year (365)

Evaluating these equations using the USGS stream flow data leads to an annual average watershed discharge of 150,562 acre-feet. Normalized to the watershed area and converted to inches, the watershed discharge is equal to 3.64 in/yr. Using the same equations, annual average watershed inflow was calculated as 165,086 acre-feet or an equivalent depth of 4.0 inches.

2.8.3 CANAL INFLOWS ($Q_{C,IN}$) AND OUTFLOWS ($Q_{C,OUT}$)

It is assumed that the only canal providing inflow to the study area is the Chapman Canal. This canal diverts water from the Bear River in Wyoming, above Woodruff Narrows Reservoir. The diverted water is then stored in Neponset Reservoir, located in the Saleratus Creek watershed and used for irrigation purposes. The available flow record for the Chapman Canal was obtained from USGS 10019500 Chapman Canal at State Line near Evanston, Wyoming. Flow records were available from 1960 – 1986. Figure 2.11 shows the average daily flows for the period of record at this gage.

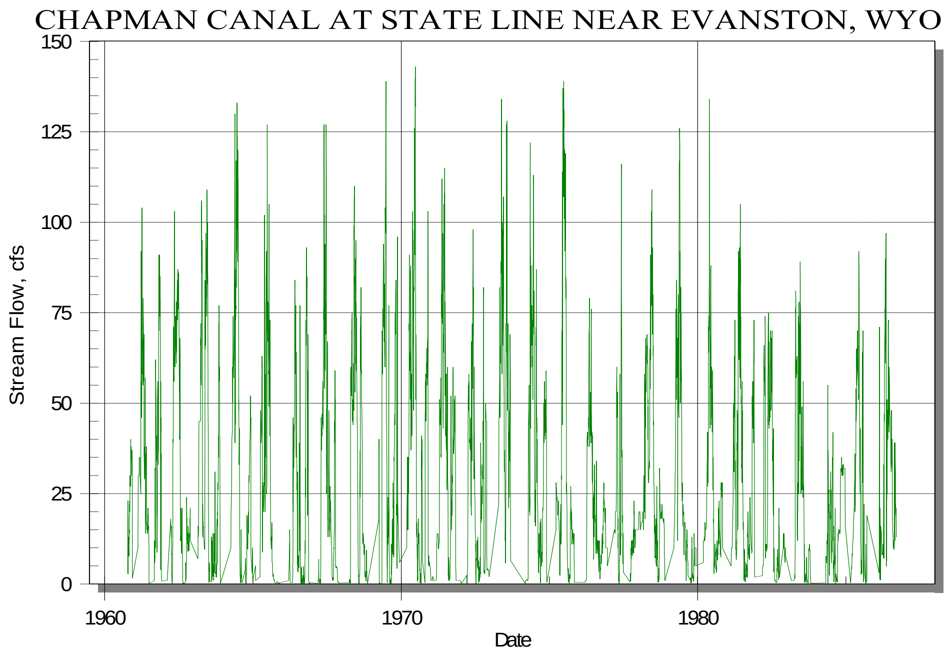

Figure 2.11. Average daily flows for the Chapman Canal at the point of diversion from the Bear River.

The only canal providing outflow from the study area is the B&Q Westside Canal. Discussions with the Bear River commissioner in Rich County provided an estimate of roughly 6 cfs that remained in this canal as it entered Wyoming during the peak irrigation season. This value roughly corresponds to 5 percent of the flow during that period. This percentage was applied to the annual flow value calculated for this site to provide an estimate of canal outflow. All available flow records for this canal were obtained from the Division of Water Rights and cover a period from 1964 – 2004. Flow measurements on the B & Q Westside Canal were collected at a gage near the point of diversion from the Bear River. Figure 2.12 shows the average daily flow measurements at this gage.

Similar to the calculation of the annual average watershed discharge volume, a daily average flow for each day of the year was first calculated for canal inflows and outflows using the available data. The period of record daily average flow values were then summed to determine the annual average canal inflow and outflow volumes. Evaluating Equations 2.3 and 2.4, but substituting the available data for canal inflows and outflows, leads to an annual average canal inflow volume of 18,484 acre-feet and an outflow volume of 1,065 acre-feet. Normalized to the watershed area and converted to inches, canal inflows are 0.45 in/yr and canal outflows are equal to 0.03 in/yr.

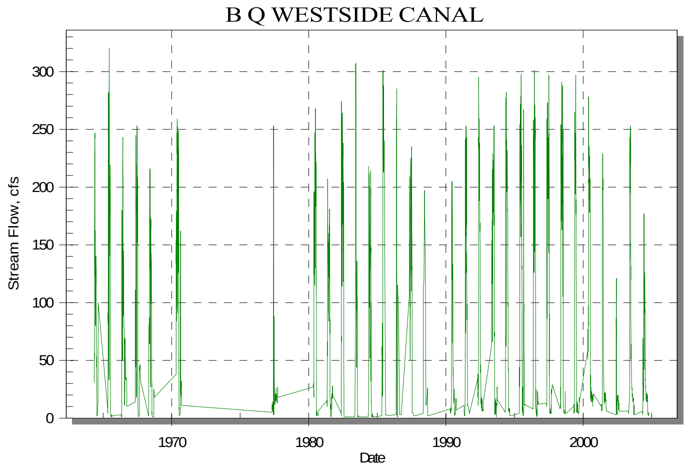

Figure 2.12. Average daily flows for the B & Q Westside Canal at the point of diversion from the Bear River.

2.8.4 CONSUMPTIVE USE (CU)

For the purposes of this water budget, consumptive use has been divided into two components. The first is defined as urban and residential water use, where the water does not return to the system via a septic system or some other pathway and excludes irrigation. The second is water that is consumptively used through evapotranspiration (ET) and includes water used for irrigation. Typically, consumptive use by residents of the watershed is a relatively small fraction of the total urban and residential water use (usually less than 10 percent).

There are two municipal areas in the study area including Woodruff and Ranolph. Water use estimates for these towns with public water supply systems were available from the State of Utah Division of Water Rights website (http://waterrights.utah.gov/cgi-bin/wuseview.exe). A review of these data, however, indicated that the magnitude of the water that is consumptively used via urban and residential use (excluding irrigation) is relatively small and was subsequently grouped with evapotranspiration.

Evapotranspiration (ET) is defined as the total evaporation from all free-water surfaces plus the transpiration of water vapor through plant tissues (Bedient and Huber 1992). In order to estimate ET separately, the land cover distribution in the watershed must be known along with ET rates for each land cover category. Table 2.3 above shows the land cover distribution in the study area according to the existing conditions land use/land cover dataset that was produced to support modeling and analysis in the watershed.

Generally speaking, ET rates are available for most agricultural land cover types due to research on irrigation requirements of agricultural crops. However, little information is available to characterize ET rates from non-agricultural land cover classes (i.e., evergreen forest, shrubland, etc.).

Annual ET estimates are provided at selected National Weather Service stations within Utah by the Utah Division of Water Rights. No information was identified for the Rich County area. Table 2.9 lists average ET estimates for the Upper Weber Basin which is located southwest of the study area. Agricultural areas in the Upper Weber Basin are at a similar elevation to those in Rich County and it is anticipated these values represent good estimates of ET from agricultural crops in the study area.

The values in Table 2.9 are for agricultural land cover classes and are, in general, somewhat higher than would be expected for the average ET rate for the study area as a whole. This is expected since agricultural lands typically transpire more water than rangeland or forestland vegetation, which make up the majority of the area within the watershed.

Table 2.9. Annual ET estimates by crop type obtained from average ET calculations for the Upper Weber Basin, UT.

		Annual Average ET	
Location	**Crop Type**	**mm**	**in**
Average	Alfalfa	635	25.0
	Pasture	502	19.8
	Other Hay	556	21.9
	SP Grain	507	20.0
	Turf	471	18.6

Source: http://waterrights.utah.gov/cgi-bin/libview.exe

Approximately 85 percent of the land in the study area is not agricultural (Table 2.3), and since reasonable ET rates are unavailable for these areas, ET for the watershed was not specifically calculated. Instead, as stated above, ET was lumped with the rest of the consumptive water use in the watershed and was estimated by difference. Under the assumption that inflows to the watershed equal outflows, all of the inflows and outflows (except consumptive use) in Equation 2.5 were evaluated. These include precipitation, canal inflows/outflows, and watershed discharge. Next, the difference between the inflows and outflows was attributed to consumptive use. This was done by solving Equation 2.5 for consumptive use and then evaluating the terms on the right side of Equation 2.5:

$$CU = P - Q_{c,out} - Q_{out} \tag{2.5}$$

Once all of the other terms in Equation 2.5 have been evaluated, the annual average consumptive use volume in the study area equals 734,661 acre-feet. Normalized by area and converted to inches, the annual average consumptive use in the study area is approximately 17.8 in/yr. It is expected that the vast majority of consumptive use within the study area is due to evapotranspiration and that consumptive use by urban and residential water users is relatively minor.

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CHAPTER 3: EXISTING WATER QUALITY CONDITIONS

The Utah Division of Water Quality (UDWQ) and the United States Geological Survey (USGS) have been involved with water quality monitoring in the Upper Bear River basin. The record of water quality monitoring data reviewed in this assessment extends from the mid-1970s through the summer of 2005. The exact length of the data record varies depending on the monitoring site and the agency responsible for data collection. The assessment of water quality conditions indicated that dissolved oxygen (DO) concentrations at various stations within the study area exceeded the water quality criterion for the designated beneficial use. This chapter provides a detailed assessment of the available water quality and streamflow data collected within the TMDL study area.

3.1 WATER QUALITY STANDARDS

The water quality standards and goals are based on the designated use of a body of water adopted by the state to protect public health and welfare, enhance water quality, and protect its assigned beneficial uses (e.g. aquatic life, recreation, and agricultural use). The Utah 2004 303(d) list includes two sections of the Bear River and Saleratus Creek. In total, the beneficial use of 66.6 miles along the Bear River and all 23.4 miles of Saleratus Creek are considered impaired (Table 3.1).

Table 3.1. Beneficial use and associated water quality standards for impaired waterbodies located in the Upper Bear River TMDL study area.

Name	Pollutant of concern	Beneficial Use Class	Beneficial Use Support	Standard / Indicator Value
Bear River-4	Dissolved oxygen	3A – Cold water aquatic life	Partial Support	DO (acute) ≥ 8.0/4.0 [a] DO (chronic) ≥ 6.5 mg/l
Bear River-5	Dissolved oxygen	3A – Cold water aquatic life	Partial Support	DO (acute) ≥ 8.0/4.0 [a] DO (chronic) ≥ 6.5 mg/l
Saleratus Creek	Dissolved oxygen	3A – Cold water aquatic life	Partial Support	DO (acute) ≥ 8.0/4.0 [a] DO (chronic) ≥ 6.5 mg/l

[a] First number indicates acute DO standard applicable to early-life stage aquatic species, second number is applicable to adult-life stage aquatic species.

In general, impairment to waterbodies is based on water quality parameters including temperature, pH, and DO. Measurements of these parameters are collected during routine monitoring by the State of Utah. In most cases, full support status is assigned to the water body if less than 10 percent of measurements for any of these water quality parameters exceed the established criteria. Partial support is assigned when exceedance is between 10 percent and 25 percent, while non-support status is assigned when exceedance is greater than 25 percent.

The TP value used by the State of Utah to determine impairment is used as an indicator value and not numeric criteria. Desired concentrations of TP applied to reservoirs and streams are 0.025 mg/l and 0.05

mg/l, respectively. These values have been determined to represent threshold values that prevent eutrophication and excessive algae growth. Excessive growth and decomposition of algae and many forms of zooplankton can deplete DO concentrations to levels that are harmful to fish. The acute DO criteria for early and adult life stages is 8 mg/L and 4 mg/L, respectively. Chronic DO criteria is 6.5 mg/L. In addition to the DO and TP criteria, other measures of water quality health can be used to support a beneficial use assessment. Some of these measures include a fish surveys, phytoplankton, and macroinvertebrate assessments. A detailed review of existing water quality and flow conditions for all water bodies in the Upper Bear River watershed as well as fisheries and macroinvertebrate assessments are provided below.

3.2 WATER QUALITY AND FLOW MONITORING

Compiling and accurately interpreting water quality and flow data is a critical element of a TMDL assessment. The product of the concentration of a particular pollutant and flow can be used to calculate its load equivalent to a mass per unit time (kg/yr). If paired measurements of flow and water quality are collected at regular intervals and at the appropriate locations, these measurements can be used to validate loads allocated to different pollutant sources.

Members of the Cirrus team obtained the majority of data from publicly accessible repositories including the EPA-STORET database, the UDAIT database, and the USGS data archives. In addition, Cirrus contacted all pertinent agencies and stakeholders within the TMDL study area with the ability to provide water quality, flow, and additional data and information that could be used to characterize pollutant sources.

This water quality assessment reviews all available water quality data for the study area. Some of the assessment relies primarily upon water quality collected by the UDWQ during intensive monitoring cycles and flow data collected by the USGS. As this information was collected on a regular basis, it provides a comprehensive review of water quality and flow conditions in the study area. In general, the most recent data considered in this assessment was collected during 2003-2004.

3.2.1 WATER QUALITY MONITORING STATIONS

A total of 63 water quality monitoring stations have been identified to date measuring water quality parameters from surface and underground sources in the Bear River TMDL project area. Surface water quality measurements have been collected at 34 stream sites and 4 lake/reservoir sites (Table 3.2). The UDWQ has collected the majority of surface water quality samples to date, extending back to the mid-1970s. The oldest USGS water quality records date from the mid 1950s. The USGS has collected all groundwater and spring water quality monitoring data in the project area; 25 groundwater or spring sources were identified. No facility sources were identified in the project area. The geographic location of water quality monitoring stations in the study area is shown in Figure 3.1.

Table 3.2. Water quality monitoring stations identified within the Upper Bear River TMDL project area.

Agency	Stream/ River	Groundwater/ Spring	Lake/ Reservoir	Facility	Total
Utah Division of Water Quality	18	0	4	0	22
USGS	16	25	0	0	41

Figure 3.1. Upper Bear River TMDL project area water quality monitoring stations - DWQ.

3.2.2. FLOW MONITORING STATIONS

The USGS monitors continuous flow at six stations located within the Upper Bear River Watershed. The longest record of continuous flow dates from 1942 through 2003 at a gauging station located at the Bear River near the Utah-Wyoming state line (USGS 10011500). Of the flow monitoring stations identified within the study area, two have a data record that extends through 2003 and one though 2004. Continuous flow monitoring stations located within the project area are shown in Table 3.3 and Figure 3.1.

Table 3.3. USGS flow monitoring stations located in the Upper Bear River TMDL project area.

Station	Station Name	Range of dates	Average flow (cfs)	No. of Obs.
10011500	Bear River near Utah-Wyoming state line	1942-2003	192	22,372
10020900	Woodruff Creek below Reservoir near Woodruff, Utah	1970-1986	31	5,844
10021000	Woodruff Creek near Woodruff, Utah	1937-1975	28	11,595
10023000	Big Creek near Randolph, Utah	1939-2003	13	15,639
10026500	Bear River near Randolph, Utah	1943-1992	207	17,850
10020300	Bear River below Reservoir near Woodruff, Utah	1961-2004	227	15,706

In addition to these continuous flow-gauging stations, instantaneous flow is typically recorded at UDWQ monitoring sites at the time when water quality samples are collected, thus providing additional records of stream discharge.

3.2.3. WATER QUALITY SAMPLING FREQUENCY

The frequency of sampling events is not homogeneous across the monitoring stations identified in the project area. While the UDWQ has monitored water quality parameters since the mid-1970s at some of stations, data collection at a number of stations started with the intensive monitoring efforts of 1998-1999. During the monitoring sampling periods of 1998-1999 and 2003-2004, samples were collected twice a month during the spring runoff period and on monthly intervals during the remaining survey. Physical, chemical, and biological measurements and samples were generally collected, however, at several stations only field parameters and nutrient data were recorded. Nutrient data collected at various monitoring sites is used to quantify nutrient loads and determine potential sources of nutrients. Water quality data collected by the USGS is limited. A few observations were recorded at USGS stations monitored within the last decade. No USGS stations were sampled during intensive monitoring periods. A list of the water quality monitoring stations identified in the project area, including those that were surveyed during intensive monitoring rounds, is shown in Table 3.4.

Table 3.4. UDWQ and USGS stream water quality monitoring stations identified within the Upper Bear River TMDL study area.

UDWQ Stations			
Station	**Station name/Site description**	**Intensive monitoring**	
		1998-1999	**2003-2004**
4906630	Otter Creek near Randolph, Utah		
4908100	Bear River east of Sage Creek Junction at U30 crossing above confluence with Bridger Creek	X	X
4908110	Bridger Creek above confluence with Bear River at Sage Creek Junction		X
4908150	Sage Creek 2 miles west of Sage Creek Junction	X	
4908180	Big Creek at U16 crossing	X	X
4908200	Genes Creek at U16 crossing	X	X
4908240*	Six Mile Creek above Johnson Reservoir	X	X
4908280	Bear River at Randolph/Crawford Mountain Road crossing	X	X
4908350	Bear River 5 road mile north of Woodruff at crossing		
4908500	Bear River east of Woodruff	X	X
4908600	Saleratus Creek at U16 crossing	X	X
4908610*	Chapman Canal at U16 crossing at USGS		X
4908620	Saleratus Canal above confluence at Negro Dan Hollow at road crossing		
4908630	Saleratus Creek at County Road crossing to Deseret Ranch		
4909100*	Yellow Creek 2 miles south of state line		X
4909500*	Bear River at Utah/Wyoming state line	X	
4909850*	Bear River below confluence with East Fork of Bear River		
5906500	Little Creek below Little Creek Reservoir		X
5906520	Little Creek above Little Creek Reservoir		
5906850	Woodruff Creek below Woodruff Creek Reservoir		
5906890	Stream above Woodruff Creek Reservoir		
5906900	Woodruff Creek above Woodruff Creek Reservoir		
5907120	Birch Creek above Birch Creek Reservoir #1 and below #2		
5907150	Birch Creek above Birch Creek Reservoir		

* Stations located on or outside the project area boundary that were considered in the analysis.

3.3 EXISTING WATER QUALITY AND FLOW

The assessment of water quality conditions in the Upper Bear River watershed indicated that concentrations of DO and TP in the study area generally do not meet the criteria for aquatic wildlife use (Class 3A). Both DO and TP drive important chemical and biological reactions that support viable aquatic habitat. Oxygen, mostly imported to aquatic systems from the atmosphere, is consumed in respiration by plants and animals but it is only produced by plants under appropriate light and nutrient conditions. In the water column, the depletion of oxygen due to respiration and decomposition is continually balanced by its replenishment from the atmosphere. Oxygen depletion causes changes in the solubility of many metals and some nutrients. Organic matter from natural, domestic, and industrial sources can also contribute to the depletion of oxygen concentrations. Under low oxygen, or anoxic conditions, most aquatic organisms die and are replaced by few specialized organisms capable to tolerate such low oxygen concentrations.

Dissolved oxygen is regulated primarily by temperature, but photosynthesis, respiration, aeration of the water, the presence of other gases, and nutrient concentrations can also affect its concentrations. In general, the concentration of DO is inversely proportional to the water temperature. Organic pollution of rivers and streams in inhabited areas can lead to high fluctuations of DO concentrations. Modern sewage treatment plants reduce the biological oxygen demand of the effluent but where only primary treatment is provided permanent oxygen depletion can occur. Further, the oxygen demand generated by non-point source pollution also reduces oxygen concentrations in streams (Horne and Goldman 1984).

In a watershed, phosphate is rapidly immobilized in the soil and becomes unavailable for plant growth. Groundwater does not easily transport phosphate during recharge to surface streams. Inflows of TP to streams and lakes results primarily from erosion of soil particles from steep slopes and disturbed areas. Most of the phosphorous detached from rocks during surface erosion is transported to the sea or deep lakes in an inert form. Only a portion of the TP in streams is present in soluble form. Domestic, agricultural, and industrial wastes are sources of soluble phosphate and have led to eutrophication in many water bodies.

3.3.1 SURFACE WATER QUALITY

The assessment of current water quality conditions in the Upper Bear River watershed included the compilation and summary of available data. The stations included in this assessment were selected based on their location with respect to impaired water bodies and length of data record. It should be noted that mainstem sites considered for this analysis of existing water quality condition included the Bear River site at Sage Creek Junction (Station 4908100), Bear River at Randolph (Station 4908280), Bear River at Woodruff (Station 4908500), Bear River below Woodruff Reservoir (Station 4908900), Bear River at Utah border (Station 4909500), and Bear River at East Fork (Station 4909850). However, the later three sites are located outside the project area boundary and were only used for comparative purposes. Additionally, the following tributary stations were considered in the analysis: Sage Creek (Station 4908150), Big Creek (Station 4908180), Genes Creek (Station 4908200), and Saleratus Creek (Station 4908600).

Summary statistics for dissolved oxygen (DO), total phosphorus (TP), Dissolved phosphorus (DP), Nitrogen-ammonia (N), total suspended solids (TSS), pH, and temperature for selected stream monitoring sites are shown in Tables 3.5 through 3.15. These tables provide a summary of current data collected at each site within the last decade and during the 1998-1999 and 2003-2004 intensive monitoring rounds. A complete statistical summary of water quality parameters is provided in Appendix - Data. Attachment A shows time series and seasonal box-and-whisker plots for the selected parameters on monitoring sites located along the mainstream of the Upper Bear River and Saleratus Creek.

Table 3.5. Summary Statistics for Sage Creek Junction (Station 4908100 - Bear River East of Sage Creek Junction at U30 Crossing above Confluence with Bridger Creek).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	25	24	1998 - 2004	0.06	-	-	0.06	<BDL>	0.06	0
	11	11	1998 - 1999	-	-	-	-	<BDL>	<BDL>	0
	11	10	2003 - 2004	0.06	-	-	0.06	<BDL>	0.06	0
DO (mg/L)	27	0	1998 - 2005	9.14	9.83	1.78	8.95	5.3	11.51	25.9/0/11.1
	12	0	1998 - 1999	8.54	8.7	2.01	8.30	5.3	11.02	33.3/0/25
	14	0	2003 - 2004	9.80	10.26	1.34	9.71	7.11	11.51	14.3/0/0
% DO (saturation)	15	0	1998 - 2005	103	101.3	15.26	101.9	79.4	136.6	33.3
	0	0	1998-1999	-	-	-	-	-	-	-
	14	0	2003 - 2004	104	103.8	15.45	102.8	79.4	136.6	35.7
pH	58	0	1998 - 2005	8.23	8.24	0.19	8.23	7.67	8.81	0
	26	0	1998 - 1999	8.24	8.23	0.15	8.24	7.9	8.6	0
	28	0	2003 - 2004	8.21	8.265	0.20	8.21	7.67	8.56	0
DP (mg/L)	26	17	1998 - 2004	0.02	0.01275	0.02	0.01	<BDL>	0.091	7.7
	11	5	1998 - 1999	0.02	0.02	0.02	0.02	<BDL>	0.073	9.1
	14	11	2003 - 2004	0.02	0.007971	0.02	0.01	<BDL>	0.091	7.1
TP (mg/L)	30	4	1998 - 2004	0.07	0.0575	0.08	0.06	<BDL>	0.458	66.7
	13	2	1998 - 1999	0.07	0.068	0.03	0.06	<BDL>	0.127	69.2
	14	2	2003 - 2004	0.08	0.0555	0.11	0.05	<BDL>	0.458	57.1
Temperature (°C)	28	2	1998 - 2005	10.90	10.96	7.28	6.19	<BDL>	23.23	10.7
	13	2	1998 - 1999	10.25	9.91	6.82	7.61	<BDL>	20.6	7.7
	14	0	2003 - 2004	11.03	11.47	7.40	5.62	0.09	23.23	7.1
TSS (mg/L)	30	2	1998 - 2004	47.17	33.6	56.61	31.02	<BDL>	316	50
	13	1	1998 - 1999	49.44	57.2	30.27	36.40	<BDL>	97.3	69.2
	14	1	2003 - 2004	50.58	31.65	78.27	29.48	<BDL>	316	42.9

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.6. Summary Statistics for Sage Creek (Station 4908150 - Sage Creek 2 miles west of Sage Creek Junction).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	16	13	1998 - 2004	0.03	0.02709	0.02	0.03	<BDL>	0.084	0
	11	8	1998 - 1999	0.04	0.03342	0.02	0.03	<BDL>	0.084	0
	5	5	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
DO (mg/L)	18	0	1998 - 2004	9.31	9.12	1.42	9.21	7.01	12.09	22.2/0/0
	12	0	1998 - 1999	9.67	9.42	1.40	9.57	7.6	12.09	16.7/0/0
	6	0	2003 - 2004	8.60	8.83	1.30	8.52	7.01	10.5	33.3/0/0
% DO (saturation)	6	0	1998 - 2004	89.7	85.15	17.5	88.34	73.1	115.5	16.7
	0	0	1998-1999	-	-	-	-	-	-	-
	6	0	2003 - 2004	89.7	85.15	17.5	88.34	73.1	115.5	16.7
pH	37	0	1998 - 2004	8.33	8.29	0.25	8.33	7.85	8.93	0
	25	0	1998 - 1999	8.39	8.36	0.20	8.38	7.98	8.93	0
	12	0	2003 - 2004	8.22	8.18	0.32	8.21	7.85	8.9	0
DP (mg/L)	17	10	1998 - 2004	0.02	0.0199	0.00	0.02	<BDL>	0.029	0
	11	4	1998 - 1999	0.02	0.022	0.00	0.02	<BDL>	0.029	0
	6	6	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
TP (mg/L)	19	1	1998 - 2004	0.16	0.112	0.12	0.11	<BDL>	0.388	78.9
	13	0	1998 - 1999	0.22	0.198	0.11	0.19	0.057	0.388	100
	6	1	2003 - 2004	0.04	0.0285	0.03	0.03	<BDL>	0.094	33.3
Temperature (°C)	19	1	1998 - 2004	9.12	8.85	6.36	5.12	<BDL>	20.77	5.3
	13	1	1998 - 1999	8.30	8.79	5.72	4.66	<BDL>	20.77	7.7
	6	0	2003 - 2004	10.89	13.28	7.83	6.44	0.69	19.35	0
TSS (mg/L)	18	2	1998 - 2004	143.10	118.9	122.60	84.88	<BDL>	376	72.2
	12	0	1998 - 1999	196.30	181.4	114.00	160.60	39.2	376	100
	6	2	2003 - 2004	33.80	17.95	48.18	16.37	<BDL>	130.4	16.7

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.7. Summary Statistics for Randolph (Station 4908280 - Bear River at Randolph/Crawford Mountain Road crossing).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	24	23	1998 - 2004	0.07	-	-	0.07	<BDL>	0.07	0
	12	11	1998 - 1999	0.07	-	-	0.07	<BDL>	0.07	0
	11	11	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
DO (mg/L)	28	0	1998 - 2005	7.99	8.095	2.12	7.59	2.09	11.28	46.4/7.1/17.7
	12	0	1998 - 1999	8.64	8.745	1.55	8.51	6.4	10.8	33.3/0/8.3
	15	0	2003 - 2004	7.55	7.58	2.47	6.98	2.09	11.28	53.3/13.3/13.3
% DO (saturation)	16	0	2003 - 2005	81	84.1	25.37	75.43	22.6	123.7	12.5
	0	0	1998-1999	-	-	-	-	-	-	-
	15	0	2003 - 2004	80.8	84.7	26.26	74.92	22.6	123.7	13.3
pH	56	0	1998 - 2005	8.16	8.195	0.21	8.16	7.33	8.58	0
	25	0	1998 - 1999	8.25	8.24	0.12	8.25	8	8.52	0
	29	0	2003 - 2004	8.09	8.11	0.25	8.09	7.33	8.58	0
DP (mg/L)	25	17	1998 - 2004	0.02	0.006594	0.04	0.01	<BDL>	0.226	8
	11	3	1998 - 1999	0.04	0.023	0.06	0.02	<BDL>	0.226	18.2
	14	14	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
TP (mg/L)	28	5	1998 - 2004	0.07	0.049	0.10	0.05	<BDL>	0.554	50
	13	0	1998 - 1999	0.07	0.071	0.02	0.06	0.024	0.11	76.9
	14	5	2003 - 2004	0.04	0.028	0.04	0.03	<BDL>	0.165	21.4
Temperature (°C)	29	0	1998 - 2005	11.15	12.7	6.54	6.71	0.04	20.1	3.4
	13	0	1998 - 1999	9.96	9.4	6.68	5.23	0.04	19.6	0
	15	0	2003 - 2004	11.66	13.78	6.43	7.77	0.27	20.1	6.7
TSS (mg/L)	28	1	1998 - 2004	35.30	22.4	41.48	19.57	<BDL>	174	39.3
	13	0	1998 - 1999	49.17	40.8	36.19	37.51	6	150.8	69.2
	14	1	2003 - 2004	24.34	10.2	44.57	11.23	<BDL>	174	14.3

[1] Number of samples below detection limit (BDL).

[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.8. Summary Statistics for Big Creek (Station 4908180 - Big Creek at U16 crossing).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	23	21	1998 - 2004	0.02	0.01059	0.02	0.01	<BDL>	0.09	0
	11	10	1998 - 1999	0.05	-	-	0.05	<BDL>	0.05	0
	10	9	2003 - 2004	0.09	-	-	0.09	<BDL>	0.09	0
DO (mg/L)	25	0	1998 - 2004	10.53	10.43	1.81	10.38	7	14.13	22.2/0/0
	12	0	1998 - 1999	9.78	9.7	1.77	9.64	7	14.13	16.7/0/0
	13	0	2003 - 2004	11.23	10.98	1.60	11.12	7.84	14.1	7.7/0/09
% DO (saturation)	13	0	1998 - 2004	127	119.6	29.96	123.9	83.1	192.6	76.9
	0	0	1998- 1999	-	-	-	-	-	-	-
	13	0	2003 - 2004	127	119.6	29.96	123.9	83.1	192.6	76.9
pH	54	0	1998 - 2004	8.45	8.31	0.43	8.44	7.49	9.75	13
	26	0	1998 - 1999	8.28	8.26	0.15	8.28	8.04	8.63	0
	26	0	2003 - 2004	8.60	8.645	0.49	8.59	7.49	9.57	23.1
DP (mg/L)	25	9	1998 - 2004	0.03	0.022	0.03	0.02	<BDL>	0.137	8
	11	3	1998 - 1999	0.02	0.021	0.00	0.02	<BDL>	0.031	0
	13	6	2003 - 2004	0.03	0.022	0.03	0.02	<BDL>	0.137	7.7
TP (mg/L)	28	1	1998 - 2004	0.08	0.0702	0.04	0.07	<BDL>	0.183	71.4
	13	0	1998 - 1999	0.08	0.073	0.04	0.08	0.044	0.151	76.9
	13	1	2003 - 2004	0.07	0.057	0.05	0.05	<BDL>	0.183	61.5
Temperature (°C)	26	2	1998 - 2004	11.00	11.8	7.43	6.49	<BDL>	26.61	7.7
	13	2	1998 - 1999	8.70	7.53	6.00	6.48	<BDL>	18.9	0
	13	0	2003 - 2004	13.48	16.18	7.94	7.51	0.13	26.61	15.4
TSS (mg/L)	28	3	1998 - 2004	42.08	24.2	56.29	23.29	<BDL>	278.4	32.1
	13	0	1998 - 1999	50.82	34	37.09	41.61	19.2	147	46.2
	13	3	2003 - 2004	36.94	11.2	74.61	11.19	<BDL>	278.4	23.1

[1]Number of samples below detection limit (BDL).

[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.9. Summary Statistics for Woodruff (Station 4908500 - Bear River East of Woodruff).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	22	22	1998 - 2004	-	-	-	-	<BDL>	<BDL>	0
	12	12	1998 - 1999	-	-	-	-	<BDL>	<BDL>	0
	10	10	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
DO (mg/L)	26	0	1998 - 2005	9.09	9.22	1.52	8.96	6.1	11.59	23.1/0/7.7
	11	0	1998 - 1999	8.85	8.87	1.66	8.70	6.1	11.2	18.2/0/18.2
	14	0	2003 - 2004	9.22	9.46	1.48	9.11	6.56	11.59	28.6/0/0
% DO (saturation)	15	0	1998 - 2005	98.1	105.4	20.68	95.87	54.8	127.1	33.3
	0	0	1998-1999	-	-	-	-	-	-	-
	14	0	2003 - 2004	96.1	100.6	19.78	93.96	54.8	124.5	28.6
pH	55	0	1998 - 2005	8.19	8.19	0.25	8.18	7.33	8.95	0
	26	0	1998 - 1999	8.23	8.215	0.13	8.23	8	8.53	0
	28	0	2003 - 2004	8.13	8.125	0.32	8.12	7.33	8.95	0
DP (mg/L)	25	13	1998 - 2004	0.02	0.01569	0.02	0.02	<BDL>	0.117	4
	11	3	1998 - 1999	0.02	0.021	0.00	0.02	<BDL>	0.031	0
	14	10	2003 - 2004	0.02	0.007374	0.03	0.01	<BDL>	0.117	7.1
TP (mg/L)	27	6	1998 - 2004	0.05	0.0345	0.04	0.04	<BDL>	0.166	29.6
	13	0	1998 - 1999	0.07	0.056	0.04	0.06	0.022	0.132	53.8
	14	6	2003 - 2004	0.03	0.021	0.04	0.02	<BDL>	0.166	7.1
Temperature (°C)	28	1	1998 - 2005	10.03	10.58	6.22	6.63	<BDL>	20.26	0
	13	1	1998 - 1999	9.43	7.23	6.21	6.84	<BDL>	18.1	0
	14	0	2003 - 2004	9.91	10.58	5.94	6.23	0.2	17.31	0
TSS (mg/L)	27	5	1998 - 2004	17.80	8.8	21.71	10.33	<BDL>	90	14.8
	13	1	1998 - 1999	29.54	21.6	26.58	20.84	<BDL>	90	30.8
	14	4	2003 - 2004	7.26	6.4	4.60	6.19	<BDL>	20	0

[1]Number of samples below detection limit (BDL).

[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.10. Summary Statistics for Genes Creek (Station 4908200 - Genes Creek at U16 Crossing).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	19	17	1998 - 2004	0.06	0.05726	0.01	0.06	<BDL>	0.075	0
	11	10	1998 - 1999	0.075	-	-	0.075	<BDL>	0.075	0
	6	5	2003 - 2004	0.07	-	-	0.07	<BDL>	0.07	0
DO (mg/L)	21	0	1998 - 2004	9.46	9.4	1.12	9.40	7.58	11.47	14.3/0/0
	12	0	1998 - 1999	9.61	9.805	1.16	9.54	7.58	11.21	16.7/0/0
	9	0	2003 - 2004	9.27	9.24	1.10	9.21	7.82	11.47	11.1/0/0
% DO (saturation)	9	0	1998 - 2004	98.6	98.4	6.813	98.41	89.8	108.6	0
	0	0	1998-1999	-	-	-	-	-	-	-
	9	0	2003 - 2004	98.6	98.4	6.813	98.41	89.8	108.6	0
pH	46	0	1998 - 2004	8.31	8.365	0.26	8.30	7.59	8.9	0
	26	0	1998 - 1999	8.36	8.37	0.20	8.35	8	8.77	0
	18	0	2003 - 2004	8.23	8.3	0.27	8.23	7.59	8.56	0
DP (mg/L)	21	17	1998 - 2004	0.02	0.01548	0.01	0.02	<BDL>	0.044	0
	11	7	1998 - 1999	0.02	0.02154	0.01	0.02	<BDL>	0.044	0
	9	9	2003 - 2004	-	-	-	-	<BDL>	<BDL>	0
TP (mg/L)	24	9	1998 - 2004	0.06	0.0275	0.08	0.03	<BDL>	0.347	33.3
	13	2	1998 - 1999	0.06	0.034	0.06	0.04	<BDL>	0.188	38.5
	9	6	2003 - 2004	0.02	0.01458	0.02	0.01	<BDL>	0.065	22.2
Temperature (°C)	22	2	1998 - 2004	10.29	12.33	6.46	6.85	<BDL>	22.9	4.5
	13	2	1998 - 1999	9.37	7.4	6.91	6.78	<BDL>	22.9	7.7
	9	0	2003 - 2004	11.75	12.9	5.60	7.65	0.14	18.1	0
TSS (mg/L)	24	8	1998 - 2004	24.69	8	44.68	7.84	<BDL>	202	20.8
	13	1	1998 - 1999	38.43	12.4	56.33	17.33	<BDL>	202	30.8
	9	6	2003 - 2004	9.35	2.241	17.55	2.24	<BDL>	54.8	11.1

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.11. Summary Statistics for Saleratus Creek (Station 4908600 - Saleratus Creek at U16 crossing).										
Parameter	**n**	**BDL[1]**	**Date**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance (%)[2]**
Ammonia (mgN/L)	15	6	1998 - 2004	0.16	0.067	0.15	0.10	<BDL>	0.483	0
	12	3	1998 - 1999	0.19	0.195	0.15	0.14	<BDL>	0.483	0
	2	2	2004 - 2004	-	-	-	-	<BDL>	<BDL>	0
DO (mg/L)	19	0	1998 - 2004	7.32	7.78	2.48	6.83	2.84	10.69	63.2/15.8/31.6
	12	0	1998 - 1999	8.03	8.385	2.41	7.57	2.84	10.69	50/8.3/16.7
	7	0	2004 - 2004	6.10	5.78	2.23	5.71	3	9.26	85.7/28.6/57.1
% DO (saturation)	7	0	2004 - 2004	68.7	71.4	24.67	64.1	30	94.3	0
	0	0	1998-1999	-	-	-	-	-	-	-
	7	0	2004 - 2004	68.7	71.4	24.67	64.1	30	94.3	0
pH	41	0	1998 - 2004	8.13	8.12	0.35	8.12	7.12	8.92	0
	26	0	1998 - 1999	8.15	8.115	0.29	8.14	7.32	8.92	0
	14	0	2004 - 2004	8.16	8.24	0.38	8.15	7.19	8.64	0
DP (mg/L)	18	0	1998 - 2004	0.18	0.131	0.19	0.13	0.024	0.791	88.9
	11	0	1998 - 1999	0.16	0.095	0.22	0.10	0.024	0.791	81.8
	7	0	2004 - 2004	0.22	0.157	0.16	0.18	0.062	0.527	100
TP (mg/L)	21	0	1998 - 2004	0.28	0.23	0.19	0.23	0.077	0.912	100
	13	0	1998 - 1999	0.29	0.235	0.22	0.24	0.077	0.912	100
	7	0	2004 - 2004	0.25	0.169	0.17	0.21	0.108	0.579	100
Temperature (°C)	20	3	1998 - 2004	11.51	11.84	6.05	9.73	<BDL>	21.4	10
	13	3	1998 - 1999	10.22	8.66	7.14	7.72	<BDL>	21.4	15.4
	7	0	2004 - 2004	13.42	14.02	3.89	12.86	7.52	17.86	0
TSS (mg/L)	21	5	1998 - 2004	48.77	12	67.11	13.45	<BDL>	201	33.3
	13	3	1998 - 1999	61.19	19.6	65.02	27.50	<BDL>	189.3	46.2
	7	2	2004 - 2004	32.08	5.8	74.52	4.85	<BDL>	201	14.3

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.12. Summary Statistics for Saleratus Creek at County Road (Station 4908630 - Saleratus Creek at County Road Crossing to Deseret Ranch).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	5	4	2003 - 2004	0.08	-	-	0.08	<BDL>	0.08	0
DO (mg/L)	9	0	2003 - 2004	7.62	7.77	2.26	7.22	2.89	10.99	55.6/11.1/22.2
% DO (saturation)	9	0	2003 - 2004	94.7	96.2	29.92	89.69	38.7	144.3	22.2
pH	18	0	2003 - 2004	8.46	8.395	0.44	8.45	7.95	9.58	11.1
DP (mg/L)	9	2	2003 - 2004	0.09	0.0291	0.20	0.03	<BDL>	0.614	11.1
TP (mg/L)	9	0	2003 - 2004	0.15	0.067	0.22	0.08	0.022	0.732	66.7
Temperature (°C)	9	0	2003 - 2004	17.79	15.62	4.65	17.29	12.38	26.67	33.3
TSS (mg/L)	9	2	2003 - 2004	51.50	14	72.15	17.86	<BDL>	182.7	33.3

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.13. Summary Statistics for Woodruff Reservoir (Station 4908900 - Bear River below Woodruff Narrows Reservoir).										
Parameter	**n**	**BDL[1]**	**Date**	**Mean**	**Median**	**SD**	**Geo. Mean**	**Min**	**Max**	**Exceedance (%)[2]**
Ammonia (mgN/L)	11	8	1998 - 2001	0.04	0.02928	0.04	0.03	<BDL>	0.12	0
	9	6	1998 - 1999	0.05	0.03475	0.04	0.03	<BDL>	0.12	0
DO (mg/L)	8	0	1998 - 1999	9.06	9.585	1.46	8.95	6.3	10.49	25/0/12.5
	8	0	1998 - 1999	9.06	9.585	1.46	8.95	6.3	10.49	25/0/12.5
pH	20	0	1998 - 2001	8.33	8.37	0.22	8.33	7.9	8.78	0
	18	0	1998 - 1999	8.33	8.37	0.17	8.33	7.96	8.62	0
DP (mg/L)	8	2	1998 - 2001	0.04	0.0255	0.04	0.03	<BDL>	0.127	12.5
	7	2	1998 - 1999	0.03	0.025	0.01	0.03	<BDL>	0.042	0
TP (mg/L)	11	0	1998 - 2001	0.07	0.048	0.05	0.05	0.026	0.182	45.5
	9	0	1998 - 1999	0.05	0.034	0.04	0.05	0.026	0.158	33.3
Temperature (°C)	9	0	1998 - 1999	10.42	11.61	5.31	8.75	1.99	18.3	0
	9	0	1998 - 1999	10.42	11.61	5.31	8.75	1.99	18.3	0
TSS (mg/L)	11	2	1998 - 2001	7.28	6	4.58	6.08	<BDL>	17.2	0
	9	1	1998 - 1999	7.38	6	4.67	6.26	<BDL>	17.2	0

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.14. Summary Statistics for Utah Border (Station 4909500 - Bear River at Utah/Wyoming State Line).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
Ammonia (mgN/L)	14	13	1995 - 2001	0.05	-	-	0.05	<BDL>	0.05	0
	11	10	1998 - 1999	0.05	-	-	0.05	<BDL>	0.05	0
DO (mg/L)	14	0	1995 - 2001	9.75	10.31	1.18	9.67	7	10.9	7.1/0/0
	12	0	1998 - 1999	9.80	10.36	1.27	9.72	7	10.9	8.3/0/0
% DO (saturation)	1	0	1995 - 2001	96	96	0	96	96	96	0
	1	0	2001 - 2001	96	96	0	96	96	96	0
pH	31	0	1995 - 2001	7.81	7.81	0.41	7.80	6.86	8.6	0
	26	0	1998 - 1999	7.81	7.805	0.42	7.80	6.86	8.6	0
DP (mg/L)	11	7	1995 - 1999	0.02	0.0156	0.01	0.02	<BDL>	0.044	0
	10	6	1998 - 1999	0.02	0.01653	0.01	0.02	<BDL>	0.044	0
TP (mg/L)	16	9	1995 - 2001	0.02	0.01341	0.03	0.01	<BDL>	0.133	6.2
	13	7	1998 - 1999	0.02	0.02001	0.01	0.02	<BDL>	0.034	0
Temperature (°C)	15	0	1995 - 2001	4.73	2.3	5.05	1.90	0.01	14.9	0
	13	0	1998 - 1999	4.77	2.3	5.37	1.71	0.01	14.9	0
TSS (mg/L)	16	13	1995 - 2001	3.58	0.71	7.00	0.70	<BDL>	24	0
	13	11	1998 - 1999	1.95	0.1342	4.95	0.13	<BDL>	18	0

[1] Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Ammonia: pH dependent criteria calculated for individual data points as per Utah Code R317-2; **Dissolved Oxygen (DO)**: 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**: > 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

Table 3.15. Summary Statistics for East Fork (Station 4909850 - Bear River below confluence with East Fork of Bear River).

Parameter	n	BDL[1]	Date	Mean	Median	SD	Geo. Mean	Min	Max	Exceedance (%)[2]
DO (mg/L)	26	0	2002 - 2005	9.49	9.8	1.97	9.31	6.2	15.8	23.1/0/3.8
	15	0	2003 - 2004	10.06	9.9	2.18	9.86	7.4	15.8	20/0/0
% DO (saturation)	4	0	2002 - 2005	76.2	77.85	7.68	75.9	66	83.1	0
	4	0	2002 - 2005	76.2	77.85	7.68	75.9	66	83.1	0
pH	59	0	2002 - 2005	7.75	7.74	0.62	7.73	6.27	9.9	4.2
	39	0	2003 - 2004	7.62	7.7	0.66	7.59	6.27	9.9	5.1
DP (mg/L)	9	8	2002 - 2004	0.03	-	-	0.03	<BDL>	0.03	0
	8	7	2003 - 2004	0.03	-	-	0.03	<BDL>	0.03	0
TP (mg/L)	27	23	2002 - 2005	0.01	0.003428	0.01	0.00	<BDL>	0.04	0
	22	20	2003 - 2004	0.00	0.002234	0.00	0.00	<BDL>	0.0204	0
Temperature (°C)	29	8	2002 - 2005	5.16	3	5.45	2.30	<BDL>	17	0
	17	4	2003 - 2004	4.24	3	4.42	2.00	<BDL>	14	0
TSS (mg/L)	28	22	2002 - 2005	2.87	2.142	2.36	2.14	<BDL>	10	0
	22	17	2003 - 2004	2.68	1.888	2.44	1.89	<BDL>	10	0

[1]Number of samples below detection limit (BDL).
[2] Percent exceedance values calculated using the following numeric criteria and narrative standards associated with 3A streams:
Dissolved Oxygen (DO): 8.0 mg/L / 4.0 mg/L / 6.5 mg/L; **% DO (saturation)**: <110%; **pH**: <6.5 to >9.0; **Dissolved Phosphorus (DP)**: >0.05 mg/L; **Total Phosphorus (TP)**: >0.05 mg/L; **Water Temperature**:> 20 °C; **Total Suspended Solids (TSS)**: >35 mg/L.

3.3.1.1 Dissolved Oxygen

During the past decade, minimum DO concentrations on the mainstem of the Upper Bear River have ranged from 2.1 mg/L in the Bear River near Randolph (Station 4908280; Table 3.7) to 6.1 mg/L in the station located near Woodruff (Station 4908500;Table 3.9). Mainstem stations upstream of the project area boundary (i.e., 4908900, 4909500, and 4909850) presented higher minimum DO concentrations (min DO>6.2 mg/L). The lowest DO concentration among tributaries of the Bear River in the study area was observed in Saleratus Creek (min DO=2.8 mg/L; Station 4908600; Table 3.11). Maximum DO concentrations in the mainstem were very similar, ranging from 11.3 to 11.6 mg/L. The highest maximum DO concentration among tributaries was observed in Big Creek (Max. DO= 14 mg/L; Station 4908180; Table 3.8).

Average DO concentrations on the mainstem of the Upper Bear River ranged from 7.99 mg/l in the Bear River near Randolph (Station 4908280; Table 3.7) to 9.14 mg/l at the station located on the Bear River east of Sage Creek Junction (Station 4908100;Table 3.5). Higher concentrations were observed upstream outside the project area in the station located at the Utah border (Station 4909500; 9.75 mg/L; Table 3.14). Similar average concentrations were observed at the stations located in Saleratus Creek, 7.32 mg/L and 7.62 mg/l, for stations 4908600 (Table 3.11) and 4908630 (Table 3.12), respectively.

The proportion of DO measurements exceeding the acute standard for early life stages (DO> 8 mg/L) along the mainstem of the Bear River within the project area ranged from 23 percent near Woodruff (Station 4908500; Table 3.9) to 46 percent near Randolph (Station 4908280; Table 3.7). Exceedance of the chronic criteria (DO >6.5 mg/L) at these stations was 8 percent and 18 percent, respectively (Tables 3.9 and 3.7, respectively). Over 63 percent of the DO measurements from Saleratus Creek (Station 4908600; Table 3.11) exceeded the acute criteria for early life stages while 32 percent exceeded the chronic criteria. Dissolved oxygen concentrations generally meet the criteria for adult life stages (DO > 4mg/L).

A consistent pattern of increasing or decreasing DO concentrations from downstream to upstream sites as well as consistent differences across sampling periods (i.e., intensive monitoring rounds and last 10 years), were not observed (Figure 3.2). The DO monthly box and whisker plots indicated that concentrations are generally higher in winter months decreasing from January through July or August to its lowest levels. Concentrations of DO then increase from August through December (Attachment A). A similar pattern of seasonal changes in DO concentrations was observed in Saleratus Creek (Attachment A).

Further, time series plots of DO during the 1998-1999 intensive monitoring cycle showed a unimodal distribution where concentration reached its peak during winter, typically between December and March, and decreased to its lowest levels during summer (Figure 3.3). In general, lower DO concentrations during summer corresponded to the highest percent exceedance recorded for individual stations (Table 3.16). However, the unimodal pattern of DO concentration observed during 1998-1999 was not observed in 2003-2004. Time series plots of DO during this intensive monitoring cycle show scatter concentrations throughout the year (Figure 3.3). This temporal difference may be associated to the drought conditions experienced during the latest monitoring cycle period. Water releases from Woodruff Creek Reservoir, as well as water withdrawals from the mainstem of the Upper Bear River, were lower during 2003-2004 than during 1998-1999 (Table 3.17).

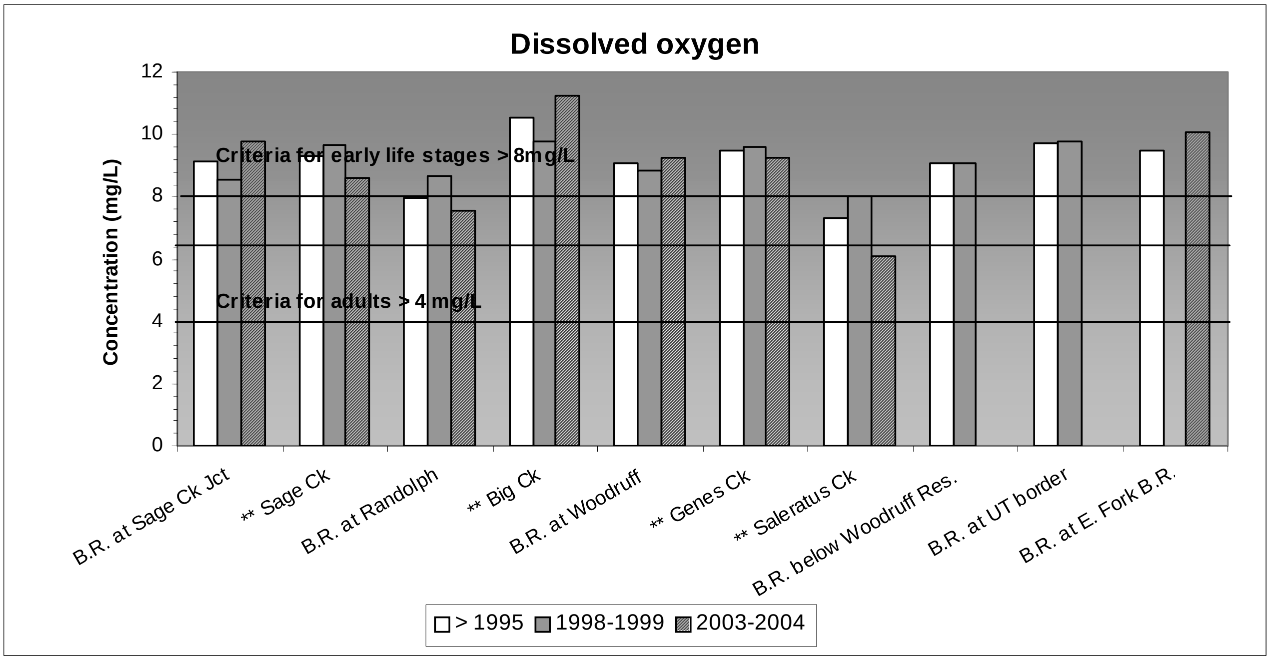

Figure 3.2. Mean DO concentration at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). Lines show the Class 3A DO acute criteria for adult (>4mg/L) and early life stages (>8 mg/L), and the chronic criteria (> 6.5 mg/L).

Table 3.16. Seasonal assessment of Dissolved Oxygen at selected DWQ monitoring stations associated with the Upper Bear TMDL project area. Bold text indicates seasonal maximum percent exceedance for individual monitoring stations.

	Jan-Mar			Apr-Jun			Jul-Sep			Oct-Dec		
Station	**Samples**	**Samples < 6.5 mg/l**	**Percent exceedance**	**Samples**	**Samples < 6.5 mg/l**	**Percent exceedance**	**Samples**	**Samples < 6.5 mg/l**	**Percent exceedance**	**Samples**	**Samples < 6.5 mg/l**	**Percent exceedance**
4908900 – Bear River below Woodruff Narrows Reservoir	20	0	0.0	30	1	3.3	24	6	**25.0**	23	1	4.3
4908500 – Bear River East of Woodruff	6	0	0.0	10	0	0.0	6	2	**33.3**	4	0	0.0
4908280 – Bear River at Randolph/ Crawford Mountain Road crossing	6	0	0.0	12	2	**16.7**	6	1	**16.7**	4	0	0.0
4908100 – Bear River east of Sage Creek Junction at U30 Crossing above confluence with Bridger Creek	28	0	0.0	39	6	15.4	29	11	**37.9**	25	1	4.0
4908600 – Saleratus Creek at U-16 crossing	4	1	25.0	11	3	27.3	2	2	**100.0**	2	0	0.0
4908630 – Saleratus Creek at County Road crossing to Deseret Ranch	0	0	0.0	6	1	16.7	3	1	**33.3**	0	0	0.0

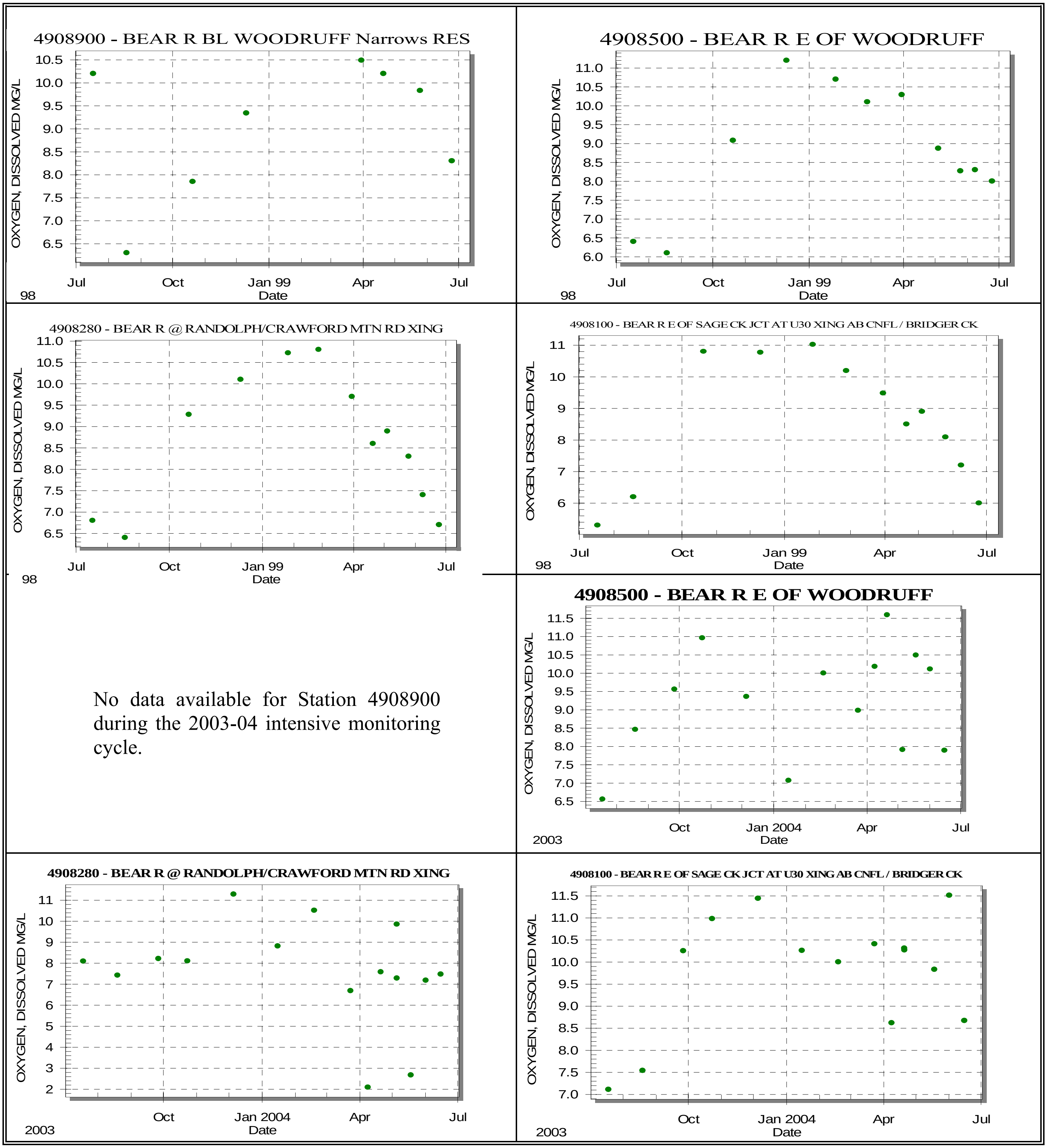

Figure 3.3. DO concentration at selected monitoring stations during the 1998-99 and 2003-04 intensive monitoring cycles.

Table 3.17. Annual water volume released from Woodruff Narrows Reservoir and canal withdrawals during the 1998-99 and 2003-04 intensive monitoring cycles.		
Year	**1998-1999 [3]**	**2003-2004 [3]**
Annual canal water withdrawals[1] (acre-feet/year)	3,661,724	2,083,824
Annual water volume released from Woodruff Narrows Reservoir [2] (acre-feet/year)	5,768,399	1,578,796

[1] Based on flow records from diversion canals located from the Utah/Wyoming state border to Woodruff Narrows Reservoir.
[2] Based on flow records from station 10020300.
[3]Volumes based on flow records collected from January through December.

3.3.1.2 Dissolved Oxygen Percent Saturation

Minimum DO saturation on mainstem stations along the Upper Bear River ranged from 23 percent to 79 percent at stations located near Randolph (Station 4908280; Table 3.7) and Sage Creek Junction (Station 4908100; Table 3.5). The highest maximum levels of DO saturation on the mainstem were observed in these stations; 124 percent and 137 percent, respectively. Minimum DO saturation on tributaries ranged from 30 percent to 90 percent on Saleratus Creek (Station 4908600; Table 3.11) and Genes Creek (Station 4908200; Table 3.10), respectively. The average DO saturation ranged, across mainstem stations, from 98 percent to 103 percent near Woodruff (Station 4908500; Table 3.9) and Sage Creek (Station 4908100; Table 3.5).

The proportion of DO saturation measurements exceeding the water quality criteria for aquatic life (DO percent saturation <110 percent) along the mainstem of the Bear River within the project area ranged from 12.5 percent near Randolph (Station 4908280; Table 3.7) to 33 percent near Woodruff (Station 4908500; Table 3.9) and Sage Creek (Station 4908100; Table 3.5). Seventy-seven percent of the observations from Big Creek (Station 4908180; Table 3.8) exceeded the water quality criteria for DO saturation. Exceedance on mainstem stations located upstream of the project area boundary was zero percent.

A consistent pattern of increasing or decreasing DO saturation from downstream to upstream sites as well as consistent differences across sampling periods (i.e., intensive monitoring rounds and last 10 years), was not observed (Figure 3.4). Monthly box and whisker plots did not show a regular pattern of seasonal DO saturation variation. (Attachment A).

3.3.1.2.1 Diel Variation in DO Concentration and Saturation

Diel DO concentration plots based on data recorded during a 24 hour period during a summer day (9 August, 2005) in selected sites along the Bear River and Saleratus Creek showed a unimodal distribution where concentration reached its peak during day hours. The highest DO concentrations were typically observed between 1:00 pm and 7:00pm at most sites. The lowest concentrations were observed during night and early morning hours; typically between 10:00 pm and 9:00am (Figure 3.5). The pattern of diel DO Saturation corresponds to the variation in DO concentration throughout the day.

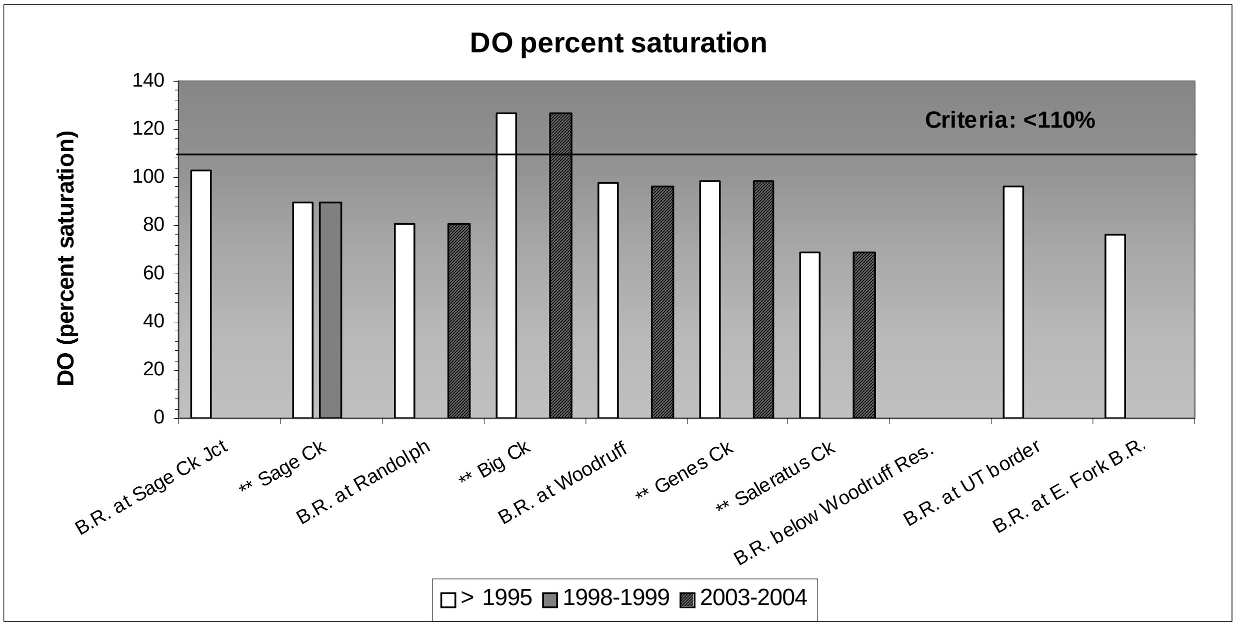

Figure 3.4. Mean DO percent saturation at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). The line shows the Class 3A DO percent saturation criteria (<110 percent).

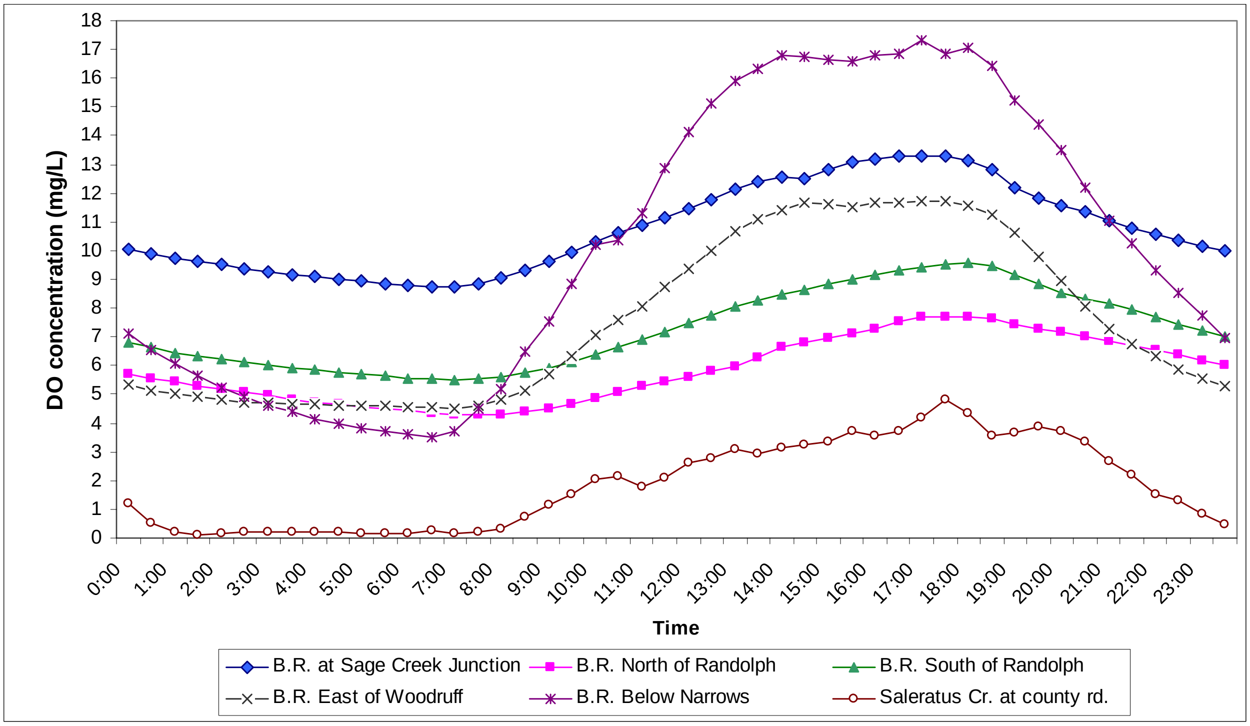

Figure 3.5. Typical diel DO concentration in selected sites along the Bear River and Saleratus Creek. Based on data recorded at 0.5 hour intervals within a 24 hour period on August 9, 2005.

Table 3.18 shows the minimum and maximum DO concentrations and percent saturation within the same 24 hour period mentioned above. The only site where minimum DO concentrations do not drop below the acute criteria for early life stated (DO>8 mg/L), or the chronic criteria for aquatic life (DO> 6.5 mg/L) is the Bear River at Sage Creek Junction (Table 3.18, Figure 3.5). Minimum concentrations at the remaining sites along the Bear River ranged from 3.5 mg/L to 5.6 mg/L below the Narrows and east of Randolph, respectively. Maximum concentrations ranged from 7.7-7.8 mg/L north and east of Randolph to 17.3 below the Narrows. Minimum and maximum DO concentrations in Saleratus Creek are 0.1 mg/L and 4.8 mg/L, respectively (Table 3.18).

The minimum DO saturation during the 24 hour period across Bear River sites ranged from 47 percent and 117 percent the site located north of Randolph and at Sage Creek Junction, respectively. The maximum DO saturation typically exceeded the criteria for aquatic life (DO saturation <110 percent). Maximum DO saturation ranged from 110 percent at Sage Creek Junction to 259 percent below the Narrows (Table 3.18).

Table 3.18. Typical diel minimum and maximum DO concentration and saturation *.

Location	DO range	Dissolved Oxygen		
		Concentration (mg/L)	Saturation (%)	Time **
Bear River at Sage Creek Junction	min	8.7	117	6 am -7 am
	max	13.3	202	3:30 pm -6 pm
Bear River north of Randolph	min	4.3	57	7 am -8am
	max	7.7	110	5 pm -6pm
Bear River east of Randolph	min	5.6	73	5:30 am -7 am
	max	7.8	112	3:30 pm -5:30 pm
Bear River south of Randolph	min	5.5	71	6:30 am -7:30 am
	max	9.6	139	5:30 pm -6 pm
Bear River east of Woodruff	min	4.5	58	6:30 am -7:am
	max	11.7	166	4:00 pm -5:30pm
Bear River below Narrows	min	3.5	47	6 am -6:30 am
	max	17.3	259	5:00 pm -6pm
Saleratus Creek at county road	min	0.1	2	1:30 am -6 am
	max	4.8	67	5:00 pm - 6 pm

*Based on data recorded at 0.5 hour intervals during a 24 hour period on 9 August 2005.
** Approximate time period when minimum or maximum DO concentrations and saturation occurred.

3.3.1.3 Total Phosphorous

Within the last ten years, minimum TP concentrations on mainstem sites have been below the detection limit. A record of minimum TP concentration on the mainstem of the Upper Bear River was available for a station located upstream of the project area boundary. The minimum TP concentration on the site located below Woodruff Reservoir (Station 4908900) was 0.026 mg/L (Table 3.13). The minimum TP concentration in Saleratus Creek was 0.08 mg/L (Table 3.11). Maximum TP concentrations on the mainstem ranged from 0.17 mg/L to 0.55 mg/L at the stations located near Woodruff (Station 4908500) and Randolph (Station 4908280), respectively. The only station were maximum TP concentration did not exceed the 0.05 mg/L criteria was located upstream of the project area boundary near the East Fork Bear River (max DO=0.04mg/L; Station 4909850). Average TP concentrations at mainstem sites within the project area ranged from 0.05 mg/L east of Woodruff (Station 4908500; Table 3.9) to 0.07 mg/L east of

Sage Creek Junction (Station 4908100; Table 3.5) and Randolph (Station 4908280; Table 3.7). The average concentration of TP at the Utah border, upstream of the project area, was 0.02 mg/L (Station 4909500; Table 3.14). The average TP concentrations in Saleratus Creek were 0.28 mg/L and 0.15 mg/L at stations 4908600 (Table 3.11) and 4908630 (Table 3.12), respectively.

Although the beneficial use of the Upper Bear River and Saleratus Creek is not considered impaired due to TP, our assessment indicated that average concentrations in these water bodies generally exceed the State's water quality standard. The percent exceedance of samples collected on mainstem sites ranged from 30 to 67 percent near Woodruff and Sage Creek (Tables 3.9 and 3.5), respectively. Percent exceedance at Saleratus Creek was 100 percent (Table 3.11).

A longitudinal trend for TP concentrations between upstream and downstream stations along the mainstem of the Upper Bear River was not observed. In general, TP concentrations along mainstem sites and tributaries were slightly lower in 2003-2004 than in 1998-1999 (Figure 3.6). No distinct trend of seasonal TP variation was observed. Average TP concentrations in the mainstem station located near Sage Creek increased slightly in March and April from the lower concentration observed from October through February (Attachment A).

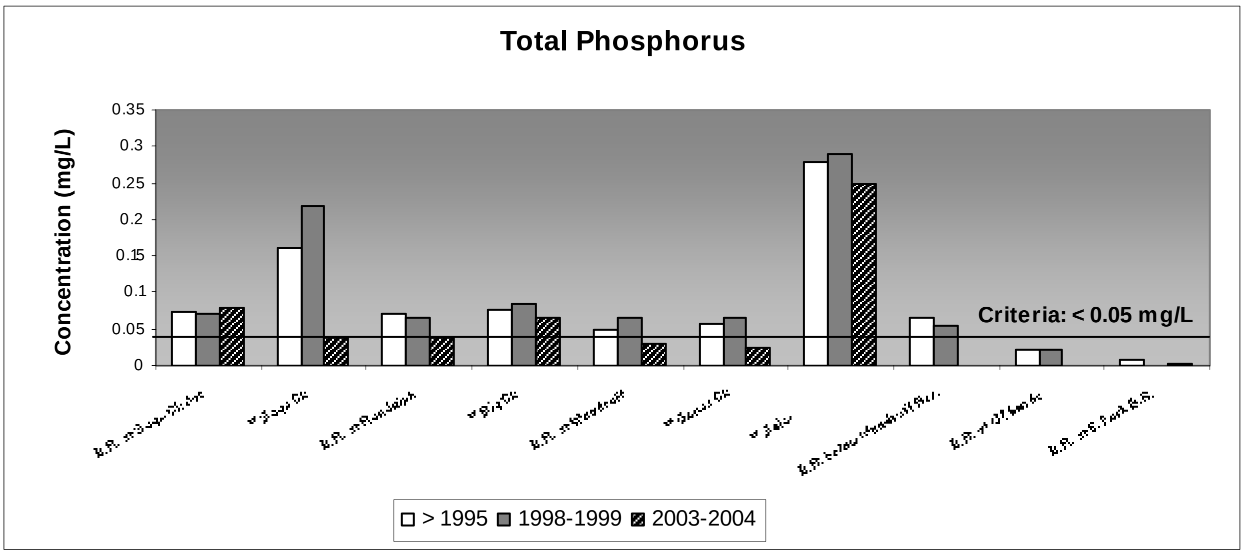

Figure 3.6. Mean TP concentration at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). The line show the Class 3A TP criteria (< 0.05mg/L).

3.3.1.4 Dissolved Phosphorus

As with TP, minimum DP concentrations during the last ten years were below detection limits on mainstem sites along the Upper Bear River and most tributaries. The minimum DP concentration on Saleratus Creek (Station 4908600) was 0.02 mg/L. Maximum DP concentrations on the mainstem ranged from 0.09 mg/L at the Bear River near Sage Creek Junctions (Station 4908100; Table 3.5) to 0.23 mg/L at the station located near Randolph (Station 4908280; Table 3.7). Average DP concentrations across mainstem sites within the project area were approximately 0.02 mg/L. A slightly higher average DP (0.04 mg/l) concentration was observed upstream from the project area boundary at the station located below Woodruff Reservoir (Station 4908900; Table 3.13).

Only a small percentage of the samples collected along the mainstem exceeded the DP standard (DP criteria: <0.05mg/l). Exceedance ranged from 4 percent to 8 percent at the stations located near Woodruff and Sage Creek Junction (Tables 3.9 and 3.5), respectively. Conversely, high DP concentrations were observed in Saleratus Creek (Station 4908600; Average DP=0.2). Exceedance in this site was approximately 90 percent (Table 3.11). No upstream to downstream pattern of increasing or decreasing average DP concentrations was observed (Figure 3.7). No distinct trend of seasonal TP variation was observed; however, maximum DP often occurred during spring or summer months (Attachment A).

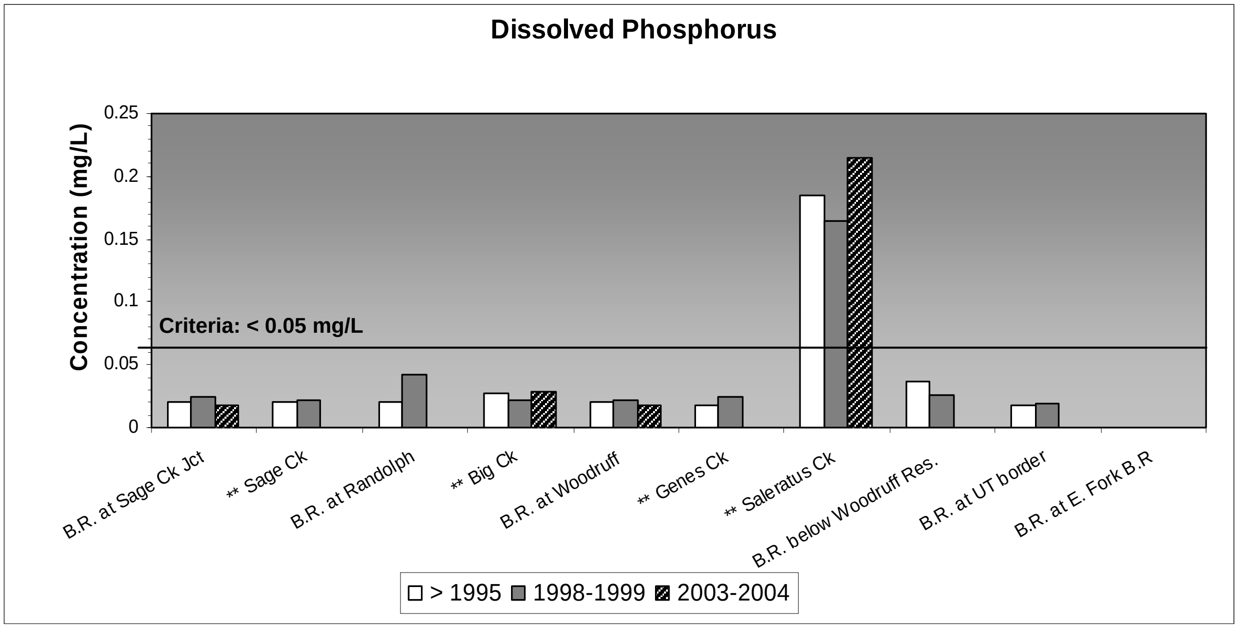

Figure 3.7. Mean DP concentration at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). The line shows the Class 3A DP criteria (< 0.05mg/L).

3.3.1.5 pH

Measurements of pH across all mainstem and tributary stations in the Upper Bear River Watershed indicated that minimum and maximum values tend to be neutral. Minimum pH ranged from 7.3 at the stations located near Woodruff (Station 4908500) and Randolph (Station 4908280). Maximum pH values (i.e., Max pH= 8.9) were observed at the Bear River station near Woodruff (Station 4908500). Average pH values did not vary much across mainstem sites. Generally, neutral values of approximately 8.2 were observed at these sites.

Measurements of pH along mainstem sites and most tributary sites meet the established standard for aquatic life use (i.e., pH between 6 and 9). Only 4 percent of the pH observations at the station located near the East Fork of the Bear River (upstream of the project area boundary) exceeded this criteria (Station 4909850; Table 3.15). Similarly, average pH values in Saleratus Creek (Station 4908600; Table 3.11) remain neutral (approximately 8), and did not exceed the established criteria. However, pH values exceeded the established criteria in 11 percent of the samples on Saleratus Creek at the County Road crossing to Deseret Ranch (Table 3.12). Differences in average pH values between intensive monitoring periods (i.e., 1998-1999 and 2003-2004) were not observed (Figure 3.8).

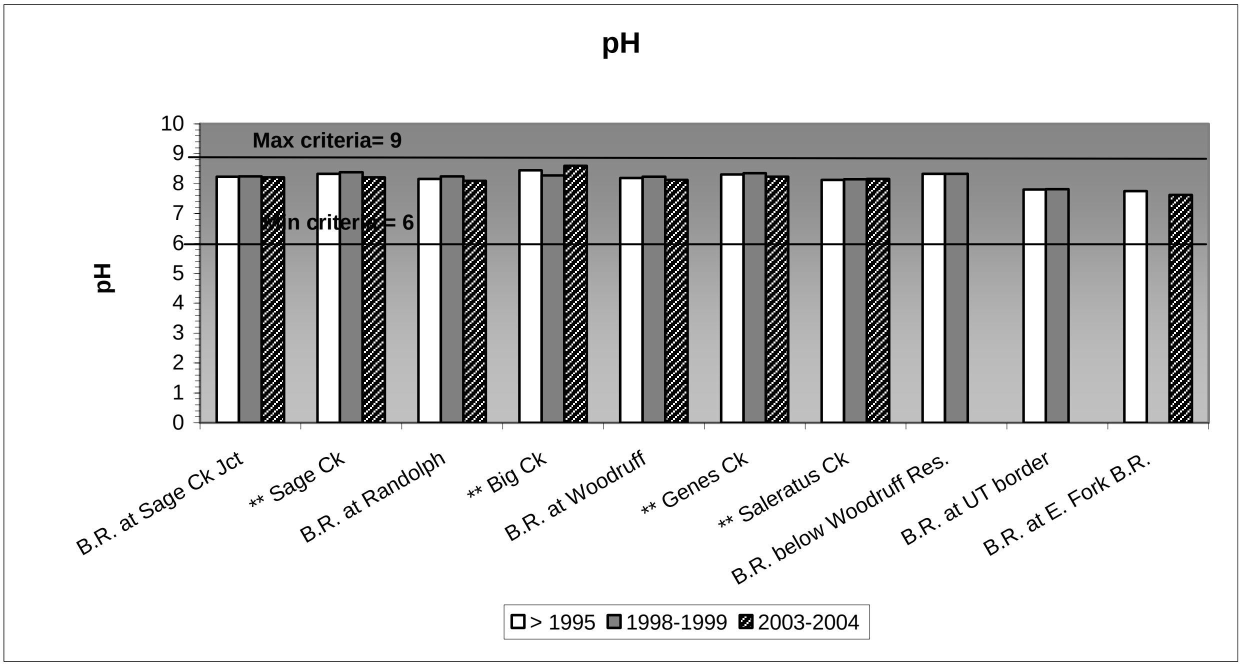

Figure 3.8. Mean pH at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). The lines show the Class 3A pH criteria (between 6.5 and 9).

In general, a seasonal pattern of pH variation was not observed across mainstem and tributaries sites. Average pH values in these sites appeared to be slightly higher during summer and fall months (Attachment A). At Big Creek (Station 4908180), however, average pH values start to increase noticeably in May and reach their highest level in August (Attachment A).

3.3.1.6 Total Suspended Solids (TSS)

Minimum TSS concentrations across all mainstem and tributary stations in the Upper Bear River watershed were below detection limits. Maximum TSS concentrations on mainstem stations ranged from 90 mg/L near Woodruff (Station 4908500; Table 3.9) to 316 mg/L near Sage Creek Junction (Station 4908100; Table 3.5). Maximum TSS concentrations were drastically lower at stations located upstream of the project area boundary (Max TSS=17 mg/L, 24 mg/L. and 10 mg/L on stations 4908900, 4909500, and 4909850, respectively). Maximum TSS concentrations on tributary sites, which were higher than those recorded on mainstem sites upstream of the project area, suggested that the input of suspended solids from these tributary streams may cause the increase of TSS on mainstem stations in the project area. Average TSS concentrations across mainstem sites within the project area boundary ranged from 18 mg/L near Woodruff (Station 4908500; Table 3.9) to 47 mg/L near Sage Creek Junction (Station 4908100; Table 3.5). The percentage of samples exceeding the TSS criteria of 35 mg/l on these stations was 15 percent and 50 percent, respectively. Lower average TSS concentrations in the mainstem were observed upstream of the project area boundary. The average TSS concentration in the station located at the Utah border (Station 4909500; Table 3.14) was approximately 3.6 mg/L.

All samples collected along upstream mainstem stations outside of the project area (Stations 4908900, 4909500, and 4909850) presented concentrations of TSS below the 35 mg/L criteria (Tables 3.13, 3.14, and 3.15). Among tributary sites, the highest average TSS concentration was observed in Sage Creek (Station 4908150; Table 3.6; 10 year-average TSS = 143). Over 72 percent of the samples collected in this site exceeded the 35 mg/l criteria. In Saleratus Creek (Station 4908600; Table 3.11), average TSS concentration was 49 mg/L. Thirty-three percent of the samples collected at this site exceeded the 35 mg/L criteria.

In general TSS concentrations in the mainstem and tributaries were lower in 2003-2004 than in 1998-1999. The concentration of TSS in the Bear River near Sage Creek Junction was slightly higher in the most recent intensive sampling round. A pattern of decreasing TSS concentrations from downstream to upstream mainstem sites within the project area was observed. Average TSS concentrations upstream of the project areas boundary were noticeably lower (Figure 3.9). In general, higher average TSS concentrations across mainstem sites were observed during spring and late summer (Attachment A).

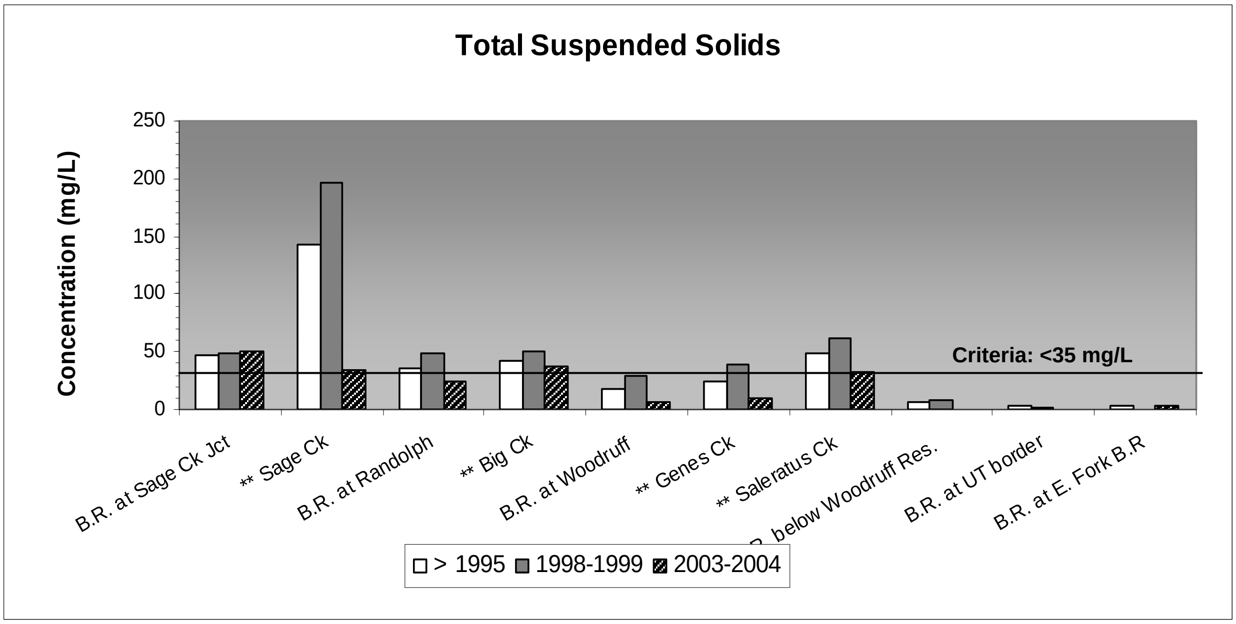

Figure 3.9. Mean TSS concentration at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005).

3.3.1.7 Nitrogen- Ammonia

In general, ammonia concentrations in samples collected in mainstem sites were below the detection limit. For this reason, ammonia averages and other summary statistics for some stations were not calculated. Maximum ammonia concentrations on tributary sites in the Upper Bear River watershed ranged from 0.075 mg/L at Genes Creek (Station 4908200; Table 3.10) to 0.48 mg/L at Saleratus Creek (Station 4908600; Table 3.11).

The percentage of samples that exceeded the ammonia criteria, which is dependent on pH values at each site, was zero percent at all mainstem and tributary sites (Tables 3.5 through 3.14). The average ammonia concentration at the Bear River station located upstream of the project area boundary below Woodruff Reservoir (Station 4908900; Table 3.13) was 0.04 mg/L. Across tributaries, average ammonia concentrations ranged from 0.02 mg/L to 0.16 mg/L at Big Creek (Station 4908180; Table 3.8) and Saleratus Creek (Station 4908600; Table 3.11), respectively.

A pattern of increasing or decreasing ammonia concentrations from downstream to upstream sites was not observed. Average ammonia concentrations appeared to be slightly lower during the 2003-2004 survey than in 1998-1999 (Figure 3.10). No distinct pattern of seasonal ammonia variations was observed (Attachment A).

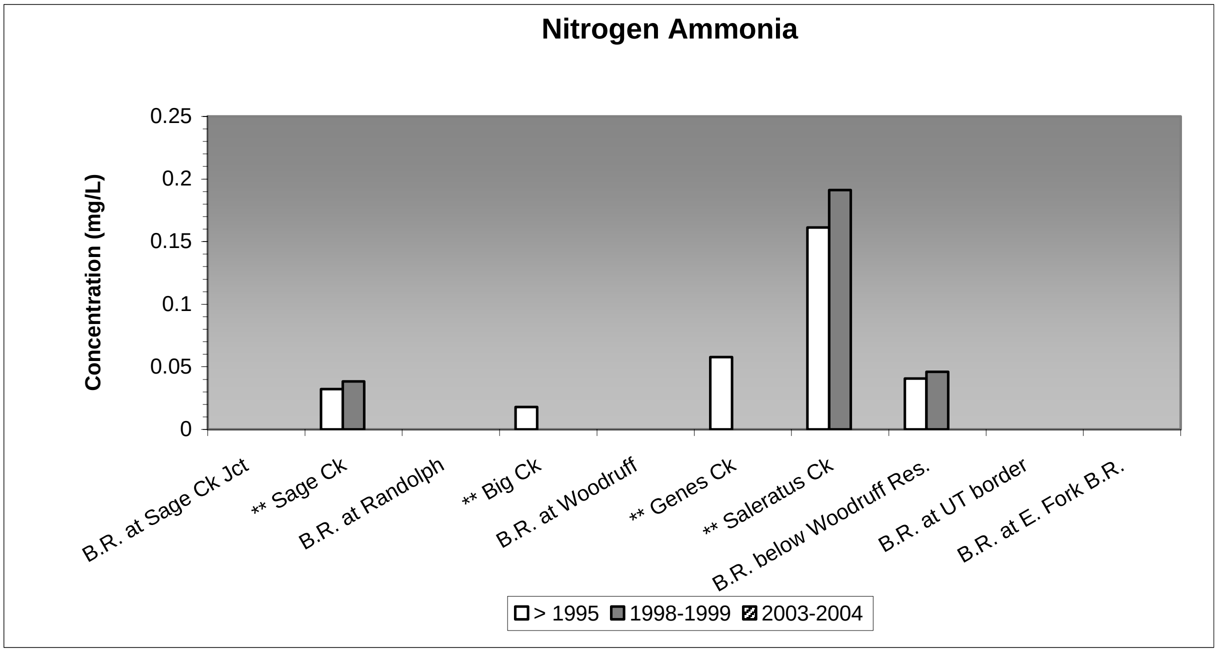

Figure 3.10. Mean Nitrogen- Ammonia concentration at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005).

3.3.1.8 Temperature

Based on observations recorded during the last 10 years, maximum water temperatures along Upper Bear River mainstem stations ranged from 20° C near Randolph (Station 4908280; Table 3.7) to 23° C near Sage Creek Junction (Station 4908100, Table 3.5). Average water temperature across mainstem sites within the project area boundary did not vary noticeably ranging from 10° C to 11° C. In mainstem sites, the percentage of temperature measurements exceeding the criteria for aquatic life use (i.e., < 20° C) ranged from zero percent near Woodruff (Station 4908500; Table 3.9) to 11 percent near Sage Creek Junction (Station 4908100; Table 3.5). Lower average temperatures (approximately 5° C) were observed upstream of the project area boundary at stations located on the Utah border (Station 4909500; Table 3.14) and near the East Fork (Station 4909850; Table 3.15). The percent exceedance at these sites was zero percent. In tributary sites, temperature ranged from 9° C at Sage Creek (Station 4908150; Table 3.6) to 11.5° C at Saleratus Creek (Station 4908600; Table 3.11). Exceedance at these sites was five percent and ten percent, respectively.

Average temperature increased drastically downstream of the stations located below Woodruff Reservoir. However, average temperature across stations within the project area remained relatively stable. A slight increase in average temperature was observed from the 1998-1999 survey to 2003-2004 (Figure 3.11). Higher temperatures could be explained by the drought conditions experienced in those years. As expected, average temperatures were higher during summer months. Average temperatures start increasing in March and peak in July. The lowest average temperatures were observed from November through February (Attachment A).

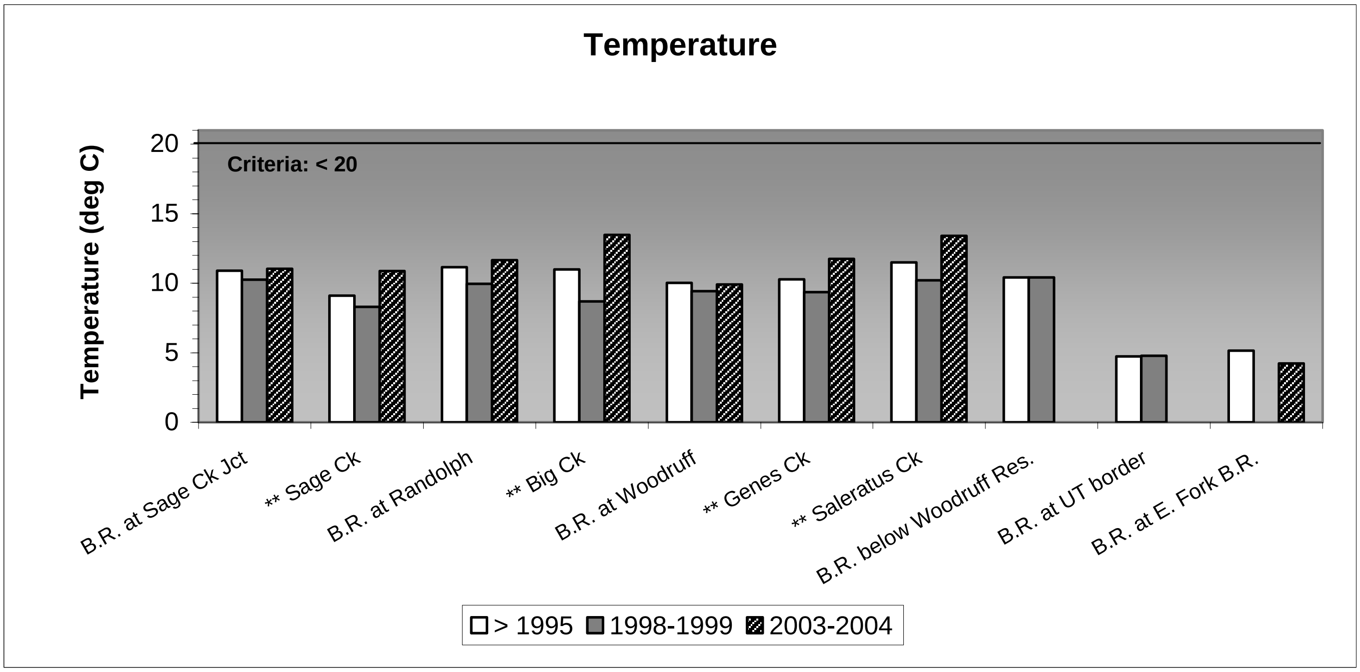

Figure 3.11. Mean temperature at selected monitoring locations on the Upper Bear River. Tributary stations are preceded by an asterisk (**). Different color/pattern in bars indicates three sampling periods (1998-1999, 2003-2004, and 1995-2005). The line shows the Class 3A criteria for temperature (< 20° C).

3.3.2 GROUNDWATER QUALITY

Measurements of groundwater quality parameters relevant for this analysis were not observed across wells and springs within the project area. Therefore, our assessment of current groundwater quality conditions in the Upper Bear River was based on literature review of reports or groundwater studies conducted in the project area.

Groundwater in the Bear River Basin is an important source of water for municipal, industrial, and agricultural uses. With varying amounts, groundwater developments occur in all valleys of the basin. The State Water Plan (UDWR 1992) stated that in 1970 there were over 3,400 wells in the Utah portion of the Bear River Basin according with the Bear River Investigations Status Report. Groundwater reservoirs in the Bear River Basin are typically full. These reservoirs, defined as an aquifer that functions as a surface reservoir because it spills and stores water as its level rises and lowers, are fed from precipitation and surface (river) flows at higher elevation. They release water at lower elevations though wells, springs, and seeps. Surface water quality can be affected by increasing water withdrawals from groundwater reservoirs. Effects could be observed in reductions of water supply to wetlands, and lower base flows in streams.

Estimates from groundwater use in Rich County, which covers a large portion the Upper Bear River basin in Utah, indicated that the average annual residential/commercial, irrigation, and industrial groundwater use was 3,340 acre-feet (AF), 3,000 AF, and 20 AF, respectively (UDWR 1992). These figures correspond to water withdrawals but not necessarily consumed. The amount of groundwater use in the upper basin is small compared to the middle and lower sections of the basin. Public water systems in Randolph, Woodruff, Garden City, Laketown, and Bridgerland Village (west of Bear Lake) use groundwater.

The main groundwater aquifers in the Upper Bear River are limited to the flood plain area along the Bear River and adjacent to the southern part of Bear Lake. In general, these aquifers are deep, alluvial deposits that consist of alternating layers of gravel, silt, and clay. Wells located in the adjacent mountain range have typically low water yields due to the underlying geology of these areas (i.e., clastic sedimentary rocks, predominantly sandstone, quartzite, or shale with interbedded limestone or dolomite).

Water quality of groundwater reservoirs in the Upper Bear River Basin remain good and should continue to satisfy future high water quality needs (UDWQ 1992). Groundwater from the Bear Lake valley is assumed to be generally fresh. Groundwater samples collected in this area from 1964 to 1981indicated that dissolved solids concentrations ranged from 250 mg/L to 260 mg/L. This small variation indicated that groundwater in this area has not changed significantly since monitoring started in 1964 (Price and Arnow 1986).

3.3.3. SURFACE FLOW CONDITIONS

A statistical summary of flow data collected at USGS monitoring stations is shown below in Table 3.19. The monthly distributions of stream flow at these stations indicated that at the Upper Bear River, Woodruff Creek, and Big Creek median monthly flows generally peak from April through June. The highest average flow in the study area occurs near Woodruff (Station 10020300). A typical hydrograph and monthly box and whisker plot for the Upper Bear River is shown below (Figure 3.12). Time series as well as monthly box and whisker plots of all stream flow stations are presented in the Appendix – Data.

Table 3.19. Statistical summary for stream flow gages.

Station	No. of observations	Range of dates	Average flow (cfs)	SD	Median	Min	Max
10011500	22,372	1942-2003	192	320.3	59	13	2,680
10020900	5,844	1970-1986	31	64.35	7	0	694
10021000	11,595	1937-1975	28	49.13	11	1	496
10023000	15,639	1939-2003	13	13.14	10	0	140
10026500	17,850	1943-1992	207	338.7	81	2	3,500
10020300	15,706	1961-2004	227	397.1	40	0	3,630

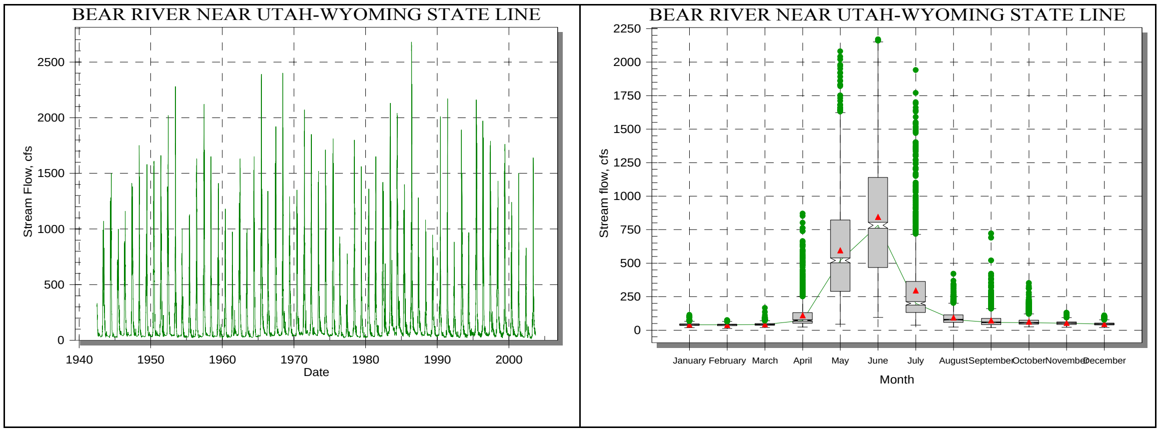

Figure 3.12. Flow time series and monthly box and whisker plot for station 10011500.

3.4 FISHERIES

Streams located in Rich County provide habitat for fish as well as fishing opportunities for the public. Approximately 134 stream miles in the county are classified as Class III cold water fisheries. Class III streams are the most common and support the bulk of stream fishing pressure in the area. These streams not only provide habitat for game fish but also for non-game fish species and amphibians that provide genetic and species diversity. In addition, Bear Lake and Woodruff Reservoir are considered important blue ribbon fisheries within Rich County. Bear Lake is classified as a Class II lake with excellent lake trout, Bear Lake cutthroat trout and numerous endemic species. Woodruff is a Class III-reservoir, which unique attraction is the presence of native Bonneville cutthroat trout.

Water bodies in Rich County support populations of native fishes including Bonneville cutthroat trout, Bonneville whitefish, Bonneville cisco, Bear Lake whitefish, Bear Lake sculpin, mountain sucker, and Mottled sculpin. Exotic species present in the county include brown trout, brook trout, and stocked rainbow trout. The status of these species is shown in Table 3.20. A summary of historic and current fish population abundance is included in Tables 3.21 and 3.22.

Table 3.20. Fish Species in Rich County, origin and status.

Common name	**Scientific name**	**Origin**	**Status**
Bonneville cutthroat trout	*Oncorhynchus clarki utah*	Native	Game, Special management under Conservation Agreement
Bonneville whitefish	*Prosopium spilonotus*	Native	Game, Species of Concern
Bonneville cisco	*Prosopium gemmifer*	Native	Game, Species of Concern
Bear lake whitefish	*Prosopium abyssicola*	Native	Game, Species of Concern
Bear lake sculpin	*Cottus extensus*	Native	Non-game, Species of Concern
Mountain sucker	*Catostomus platyrhynchus*	Native	Non-game
Brown trout	*Salmo trutta*	Exotic	Game
Rainbow trout	*Oncorhynchus mykiss*	Exotic	Game
Mottled sculpin	*Cottus bairdi*	Native	Non-game
Brook trout	*Salvelinus fontinalis*	Exotic	Game

Table 3.21. Fish abundance data for reservoirs located in Rich County.												
Reservoir	**Species***	**Number/net day****										
		1971	**1973**	**1974**	**1975**	**1978**	**1979**	**1980**	**1981**	**1986**	**1997**	**1998**
Woodruff Creek Reservoir	BCT	9.7	18.5	19.2	60.7	5.5	5.5	1.5	55.7	24	10.5	NA
	MWF	5.1	1.2	4.8	2.1	3.7	6.5	1.5	12.5	5.5	15.5	NA
	MTS	1.7	NA	0.8	0.7	1.8	3.7	1.5	7.7	0.9	2	NA
Birch Creek Reservoir	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.2
	RBT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.9
	MTS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4.1

* Species: BCT: Bonneville cutthroat trout; MWF: mountain white fish; MTS: mountain sucker; RBT: rainbow trout.
** NA indicates that no data is available (i.e., no surveys have been conducted).

Of particular interest is the population of Bonneville cutthroat trout *(BCT, Oncorhynchus clarki utah)*. Declines of native cutthroat trout populations have been evident throughout the intermountain west with only a few populations remaining. Factors that lead these declines include habitat degradation, hybridization, and competition with non-native species (Behnke 1992). The American Fisheries Society (AFS) designated the native Bonneville cutthroat trout as “threatened” throughout its range in 1979. This species was reclassified in 1989 as “endangered”. The U.S. Forest Service has designated BCT as a sensitive species, and is considered a species of special concern by the State of Utah. Current management practices are aimed towards meeting the goals and objectives of the wide-range conservation agreement and strategy for BCT (Lentsch et al. 1997).

The primary goal of the conservation agreement and strategy for BCT is to ensure the long-term existence of this species within its historic range by coordinating conservation efforts among government agencies and interested parties. This strategy is organized so that jurisdictional and ecological boundaries can be recognized. Five Geographic Management Units (GMU) have been designated for BCT conservation. Rich County is located within the Bear River GMU and covers part of the Bear Lake GMU (Lentsch et al 1997).

Threats to BCT populations include present or potential destruction or modification of habitat; disease, predation, competition, and hybridization; over-harvesting; and the socio-political pressure associated with the management of a species listed as sensitive by state and federal agencies that can block conservation efforts at state or local levels. Water development and livestock grazing are among the threats related to habitat modification. Water development and diversions have altered flow patterns while diversions have fragmented habitats. Poor grazing practices can alter sediment transport regimes, stream bank stability, water quality, substrate composition, and affect channel structure.

Table 3.22. Fish abundance data for streams located in Rich County.

Stream	Section	Species*	Abundance (#/mile) **										
			1954	1965	1968	1971	1974	1977	1980	1981	1993	2000	2003
Woodruff Creek	Section 2	BCT	NA	140	190	NA	NA	NA	NA	NA	NA	179	NA
		MWF	NA	310	20	NA	NA	NA	NA	NA	NA	sparse	NA
		RBT	NA	NA	50	NA	NA	NA	NA	NA	NA	48	NA
		MSC	NA	NA	abundant	NA	NA	NA	NA	NA	NA	abundant	NA
		BNT	NA	NA	NA	NA	NA	NA	NA	NA	NA	775	NA
	Section 3	BCT	NA	NA	NA	NA	390	NA	NA	NA	NA	1653	NA
		MWF	NA	NA	NA	NA	270	NA	NA	NA	NA	sparse	NA
		MSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	abundant	NA
		MTS	NA	NA	NA	NA	NA	NA	NA	NA	NA	1288	NA
	Headwaters	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	2073	NA
		MSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	abundant	NA
Birch Creek	Section 1	BCT	NA	NA	NA	170	NA	NA	NA	NA	NA	91	NA
		RBT	NA	NA	NA	NA	NA	NA	NA	NA	NA	15	NA
		MSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	sparse	NA
		MTS	NA	NA	NA	NA	NA	NA	NA	NA	NA	sparse	NA
	Section 2	BCT	250	NA	NA	290	NA	NA	NA	NA	NA	Low: 225 High: 1377	NA
		MTS	NA	NA	NA	NA	NA	NA	NA	NA	NA	268	NA
		MSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	abundant	NA
	Below Headwaters	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	1377	NA
Walton Canyon	Section 1	BCT	NP	90	NA	NA	NA	NA	NA	NA	NA	NP	NA
		MCS	NA	sparse	NA	NA	NA	NA	NA	NA	NA	NA	NA
Big Mahogany Creek	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	present	NA
Sugar Pine Creek	Section 1	BCT	NA	NA	NA	NA	570	NA	NA	NA	366	1174	NA
		MSC	NA	NA	NA	NA	NA	NA	NA	NA	NA	abundant	NA

Stream	Section	Species*	Abundance (#/mile)										
			1954	1965	1968	1971	1974	1977	1980	1981	1993	2000	2003
Zeke Hollow	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	present	NA
Dip Hollow		BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NP	NA
Wheeler Creek	Section 1	BCT	NA	760	NA	NA	210	NA	NA	NA	NA	1023	NA
		MSC	NA	abundant	NA	NA	abundant	NA	NA	NA	NA	abundant	NA
Silvia Hollow	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	193	NA
Road Hollow		BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NP	NA
Big Spring Fork	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	60	NA	1080	NA
Fence Creek	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	present	NA
Girl Hollow	Section 1	BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	present	NA
Otter Creek		BKT	40	NA	NA	NA	NA	NA	NA	NA	NA	NA	present
		MSC	abundant	NA	NA	NA	NA	NA	NA	NA	NA	NA	present
		BCT	90	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
South Branch of Otter Creek		BNT	NA	NA	90	NA	NA	NA	NA	NA	NA	NA	present
		BKT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	present
		MSC	abundant	NA	abundant	NA	NA	NA	NA	NA	NA	NA	present
Middle Branch of Otter Creek		BKT	110	NA	NA	NA	NA	NA	NA	NA	NA	NA	657
		MSC	abundant	NA	NA	NA	NA	NA	NA	NA	NA	NA	abundant
		BNT	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
New Canyon			NA	NA	NA	NA	NA	NA	NA	no fish	NA	NA	no fish
Big Creek	Section 2	BCT	NA	NA	NA	NA	NA	present	present	NA	NA	NA	48
		BKT	NA	NA	NA	NA	NA	present	NA	NA	NA	NA	211
		BNT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	32
		MTS	NA	NA	NA	NA	NA	sparse	common	NA	NA	NA	common
		MSC	NA	NA	NA	NA	NA	common	common	NA	NA	NA	abundant
		RBT	NA	NA	NA	NA	NA	present	present	NA	NA	NA	NA
Meachum Canyon		BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	113
Laketown Canyon Creek		BCT	NA	NA	NA	NA	NA	NA	NA	NA	NA	Present	NA
		BKT	NA	NA	NA	NA	NA	NA	NA	NA	NA	Present	NA

* Species: BCT: Bonneville cutthroat trout; MWF: mountain white fish; MTS: mountain sucker; RBT: rainbow trout; MSC: mottled sculpin; BNT: brown trout; BKT: Brook trout.
** NA indicates that no data is available (i.e., no surveys have been conducted). NP indicates no-presence.

Streams that support Bonneville cutthroat trout (BCT) populations within Rich County include Woodruff Creek, Birch Creek, Big Mahogany Creek, Sugar Pine Creek, Zeke Hollow, Wheeler Creek, Silvia Hollow, Big Spring Fork, Fence Creek, Girl Hollow, Big Creek, Laketown Canyon Creek and Meachum Canyon. Historically, BCT has been observed in Otter Creek and Walton Canyon. Previous reports have recommended that streams containing pure BCT should be considered for conservation status, these include Woodruff Creek above Woodruff Creek Reservoir, Birch Creek from Birch Creek Reservoir to the headwaters, Sugar Pine Creek, Wheeler Creek, Silvia Hollow, and Big Spring Fork (Thompson and Smith 2001, Thompson 2003). In addition, the BCT population in Woodruff Creek Reservoir is considered a conservation population, and Birch Creek Reservoir has been recommended for conservation status. Recommendations for the conservation status of most of these waterbodies are dependent on pending genetic analyses (Thompson and Smith 2001). Among the streams that have supported BCT in Rich County, Big Creek, Laketown Canyon Creek, and Otter Creek are the only streams where quantitative aquatic invertebrate studies have been conducted (See below under Aquatic Invertebrates). Stream health assessments have been conducted at Big Creek and the south and middle forks of Otter Creek (See below under Stream Health Assessments).

The Utah Division of Wildlife Resources (UDWR) manages most of the fisheries in Rich County as wild fisheries. However, stocking of exotic species has occurred historically and continues to be used in some waterbodies. The section of Woodruff Creek from the Bear River confluence to Woodruff Creek Reservoir (i.e., Sections 1 and 2) has been stocked historically with catchable rainbow trout and fingerling brown trout. Woodruff Creek Reservoir was stocked with cutthroat trout (likely Yellowstone cutthroat trout, *Oncorhynchus clarki bouvieri*) in the early 1970s. Rainbow trout has been historically stocked in Birch Creek, Birch Creek Reservoir, and Walton Canyon. The stocking of rainbow trout in Birch Creek Reservoir was replaced by tiger trout in 2000 (Thompson and Smith 2001).

3.5 AQUATIC INVERTEBRATES

The use of macroinvertebrates as a surrogate measure of water quality is based on the relationship between the biological health of a water body and the composition of the macroinvertebrate community it supports. Community structure of macroinvertebrate organisms is related to habitat and water quality. While some species of macroinvertebrates are very sensitive to water quality and will only exist in streams and lakes where water quality is high, other species are somewhat tolerant or highly tolerant to pollution and can exist under a wide range of water quality conditions. The Utah DWQ has collected macroinvertebrate data from 1985 to 2001. Within the study area, samples have been collected at monitoring stations located in the Bear River near Sage Creek Junction and at the Utah Wyoming State Line.

The Family Level Biotic Index (FBI) (Hilsenhoff 1988) was calculated using the most current macroinvertebrate data available (i.e., 1999-2001). This index represents the average weighted pollution tolerance value for all arthropods present in a sample, with the exemption of organisms that are too immature or damaged to be identified, as well as organisms that have not yet been assigned a pollution tolerance value. The FBI is an index of organic pollution and is based on the response of a community to the combination of high organic loading and decreased dissolved oxygen levels. Pollution tolerance values were assigned to the family level of each one of the organisms identified. Lower values represent pollution intolerant families. The dominant taxa, abundance, tolerance values of organisms identified, and FBI values are shown in Table 3.23.

Table 3.23. Macroinvertebrate assessment summary for the Upper Bear TMDL study area.						
Station	Date	Family	Tolerance	Abundance #/m²	Abundance (%)	FBI
Station 4908100 Bear River East of Sage Creek Junction at U30 crossing above confluence with Bridger Creek	May-99	Caenidae	7	128	0.54	4.6
		Chironomidae	6	5747	24.86	
		Elmidae	4	341	1.45	
		Ephemerellidae	1	85	0.36	
		Heptageniidae	4	2774	11.80	
		Hydropsychidae	4	13186	56.07	
		Hydroptilidae	4	43	0.18	
		Isopoda	8	259	1.10	
		Leptoceridae	4	43	0.18	
		Leptohyphidae	4	683	2.90	
		Simuliidae	6	128	0.54	
Station 4909500 Bear River at Utah/Wyoming State Line	Oct-00	Baetidae	4	17	1.15	3.1
		Brachycentridae	1	303	20.97	
		Ceratopoginidae	6	3	0.23	
		Chironomidae	6	493	34.10	
		Chloroperlidae	1	17	1.15	
		Elmidae	4	37	2.53	
		Ephemerellidae	1	93	6.45	
		Helicopsychidae	3	3	0.23	
		Heptageniidae	4	73	5.07	
		Hydropsychidae	4	27	1.84	
		Isopoda	8	3	0.23	
		Lepidostomatidae	1	343	23.73	
		Perlidae	1	7	0.46	
		Perlodidae	2	3	0.23	
		Psychodidae	10	7	0.46	
		Tipulidae	3	17	1.15	
	Oct-01	Athericidae	2	18	2.13	2.9
		Baetidae	4	129	15.32	
		Brachycentridae	1	65	7.66	
		Chironomidae	6	93	11.06	
		Chloroperlidae	1	4	0.43	
		Elmidae	4	36	4.25	
		Ephemerellidae	1	93	11.06	
		Heptageniidae	4	29	3.41	
		Hydropsychidae	4	72	8.51	
		Hydroptilidae	4	4	0.43	
		Lepidostomatidae	1	219	25.96	
		Leptohyphidae	4	4	0.43	
		Perlidae	1	7	0.85	
		Philopotamidae	3	4	0.43	
		Psychodidae	10	4	0.43	
		Rhyacophilidae	0	11	1.28	
		Simuliidae	6	54	6.38	

The evaluation of water quality was based on the ratings formulated by Hilsenhoff (1988). This rating system is shown in Table 3.24. The FBI is seasonally dependent; higher values may occur during the summer because the organisms present during this season, characterized by lower water flows and higher water temperatures, generally tend to be more tolerant to pollution than the organisms that are present during spring.

In general, water quality at the stations surveyed ranged from good to excellent. The FBI value calculated for the station in the Bear River near Sage Creek Junction (Station 4908100) was 4.6 suggesting that some organic pollution was probable. Based on the FBI, organic pollution was unlikely at the station located at the Utah border (Station 4909500).

Table 3.24. Water quality ratings for the Family Level Biotic Index.

FBI Value	Water Quality Rating	Degree of Organic Pollution
≤ 3.75	Excellent	Unlikely
3.76-4.25	Very good	Possible - slight
4.26-5.00	Good	Some - probable
5.01-5.75	Fair	Fairly substantial
5.76-6.50	Fairly poor	Substantial - likely
6.51-7.25	Poor	Very substantial
7.26-10.00	Very poor	Severe

Source: Hilsenhoff 1988.

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CHAPTER 4: POLLUTANT SOURCE ASSESSMENT

4.1 SOURCES

The concentration of DO in the Upper Bear River is influenced by physical and chemical factors, each of which can vary by season or from year to year. Long-term drought cycles influence precipitation which in turn influences the rate and volume of water flowing in the Bear River. Water quality parameters such as temperature, nutrients, sediment and organic matter can influence the solubility of DO in water as well as rates of oxygen production and consumption. This section describes the pollutant loading process in the study area and is focused primarily on TP. TP is a nutrient that can influence algal and periphyton growth in river systems. Other pollutants such as sediment, Biochemical Oxygen Demand (BOD), nitrate and ammonia are likely delivered through the same loading process that delivers TP to the Bear River. However, the methods used to control and reduce TP loads from nonpoint sources will also reduce loads from other constituents in the study area.

Based on field observations, discussions with the Natural Resources Conservation Service (NRCS), Utah Association of Conservation Districts (UACD), Utah Department of Water Quality (Utah DWQ), and Utah State University (USU) extension, the following pollutant categories contributing to water quality impairment in the Upper Bear River watershed have been identified:

1. Animal Feeding Operations
2. Livestock Grazing
3. Irrigation Return Flows
4. Diffuse Loads from Runoff

The following sections describe each of these pollutant sources in more detail. Inflowing TP loads carried by the Bear River into Utah from Wyoming are also a pollutant source. This load is defined below in Section 4.2 Pollutant Load Calculation From Existing Data.

4.1.1 ANIMAL FEEDING OPERATIONS

Recognition of animal feeding operations (AFO) as a contributor to water quality impairment has been recently addressed by the Utah AFO/CAFO Advisory Committee (2001). The strategy proposed by the State reflects a desire to implement responsible management techniques while maintaining a local decision making process. A voluntary incentive-based approach is emphasized that reverts to a regulatory approach only for larger facilities or situations where voluntary methods have failed. A critical element of this program is to maintain open communication between stakeholders and agencies. An effort has been made throughout this assessment to maintain the level of confidence previously established between these two groups in the TMDL study area. No site-specific information is provided in this assessment that will violate this confidence.

Discussions with the NRCS have indicated that animal feeding operations (AFOs) are characterized by valley pastures where livestock are confined and fed during the winter season only (Hoskins 2006). Some of these pastures are located adjacent to the mainstem Bear River or tributary streams and can produce direct runoff to these receiving waters. Livestock herds are removed from these pastures during the spring season of each year and moved to public grazing allotments in the study area or transported to other locations outside of the study area.

The official definition of AFOs is included in the Code of Federal Regulations 40 CFR 122.23(b)(1) as an area where animals "have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12 month period and crops, vegetation forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." Furthermore, an AFO is considered to be a concentrated animal feeding operation (CAFO) if it meets the regulatory definition of a CAFO or is designated as such by the regulating agency. CAFOs are defined in 40 CFR 122.23 Appendix B based on the following parameters:

- Any AFO with more than 1,000 animal units.
- A facility with more than 300 animal units where discharge occurs to navigable waters through a man-made conveyance system (e.g., ditch, pipe or other flushing system).
- A facility with more than 300 animal units where discharge occurs directly to waters of the United States.
- An AFO of any size that is determined to be a significant contributor or pollution to waters of the United States, following a site visit. Such facilities must be discharging to a man-made conveyance or directly to waters of the United States.

In general, there are two components of loading from animal wastes generated at animal feeding operations. The first is direct runoff of animal waste that enters adjacent water bodies. The second is loading from animal waste generated at animal feeding operations but that is scraped, hauled, and land applied elsewhere in the watershed. According to local NRCS personnel, there is only one AFO facility in the project area that stores manure for use as fertilizer (Hoskins 2006). For the purpose of this assessment, it is considered that any loads generated from land applied manure by this facility are negligible.

Information provided by the NRCS indicates that a total of 10 AFOs and potential AFOs are located in the project area, many of which are working with the NRCS to develop nutrient management plans that will eliminate surface runoff and loading to streams (Hoskins 2006). The general distribution and size of these facilities is provided below in Table 4.1. The exact size and location of winter feeding areas on private land varies between years based on local economics, access to feeding areas and the availability of feed. A specific load for AFO/CAFOs was not calculated in this assessment. It is anticipated that loads from this source are included as part of the load from grazing on private lands as well as the load from diffuse runoff. Additional information on these two sources is provided below.

Table 4.1. AFO facilities located in the Upper Bear River watershed. [1]

Location	Number	Size	Status
WY/UT border to Woodruff	5	5 > 200 animals	One facility under contract with NRCS.
Woodruff to Randolph	2	1 > 200 animals 1 < 200 animals	Both facilities under contract with NRCS.
Randolph to UT/WY border	3	3 > 200 animals	Two facilities under contract with NRCS.

[1] AFO status is defined according to the number of facilities currently under contract with the NRCS to develop nutrient management plans.

4.1.2 GRAZING

Cattle grazing can be a significant pollutant source in many watersheds where historic grazing has taken place. This is especially true when cattle are concentrated in or near the riparian zone surrounding existing streams, water courses, and water bodies. This is quite often the case and has been observed during reconnaissance surveys of the Upper Bear River watershed. Livestock prefer these areas because they provide shade, the best source of forage, and often the only source of drinking water.

Livestock grazing occurs throughout the Upper Bear River watershed on both public and private lands. Figure 4.1 shows the location of BLM and U.S. Forest Service grazing allotment boundaries and privately-owned areas where grazing occurs. Livestock numbers for public lands were provided by federal agencies. Estimates of livestock grazing on private land were provided by USU extension and employees of Deseret Land and Livestock.

The timing of grazing activities within the watershed is important. Animal concentrations near stream courses in the low-lying areas of the watershed are higher during the late fall, winter, and spring months, where animal herds are fed (Figure 4.1). The exact size and location of winter feeding areas on private land varies between years based on local economics, access to feeding areas and the availability of feed. A typical winter grazing pattern that occurs in remote areas of Utah will find animals in lower valley pastures until late November through mid-December or when snow depths make grazing difficult. Animal herds are then moved into smaller pastures that are easily accessible or sometimes feedlots where hay can be distributed to them. Animal herds are moved away from hay feed areas as soon as grass forage is available in the spring season, which can occur as early as March or early April.

During the summer months, many herds are moved away from actively flowing streams located in the low to mid-elevation pastures and on to higher elevation grazing allotments located on public and private lands. The grazing allotments managed by the BLM and Forest Service are primarily used during the late spring through fall. In general, animals are moved onto the federal grazing allotments during May or June and return to private lands in late October. The pattern is similar for higher elevation private lands that are grazed within the watershed. The exact timing of this pattern in the study area is dependent upon winter precipitation and the onset of warmer temperatures in the spring.

Many of the pastures in the low-lying areas of the watershed provide open access to segments of the Bear River and tributary streams. This can result in degradation to stream banks and riparian areas if livestock are not managed properly. In some cases, intense use of winter feeding areas has resulted in heavy manure deposits and stream bank degradation that subsequently contribute to pollutant loading.

4.1.3. IRRIGATION RETURN FLOWS

Use of irrigation water is critical to the agricultural communities located in the study area. Water diverted from the Bear River is used primarily for flood irrigation of pasture areas where a single crop of grass hay is grown each year. A smaller amount of row crops, small grains and alfalfa hay are also irrigated in the study area with flood and sprinkler irrigation methods. If pastures used for winter feeding are flood-irrigated, the potential for transport of manure and pollutant loading to the Bear River can increase.

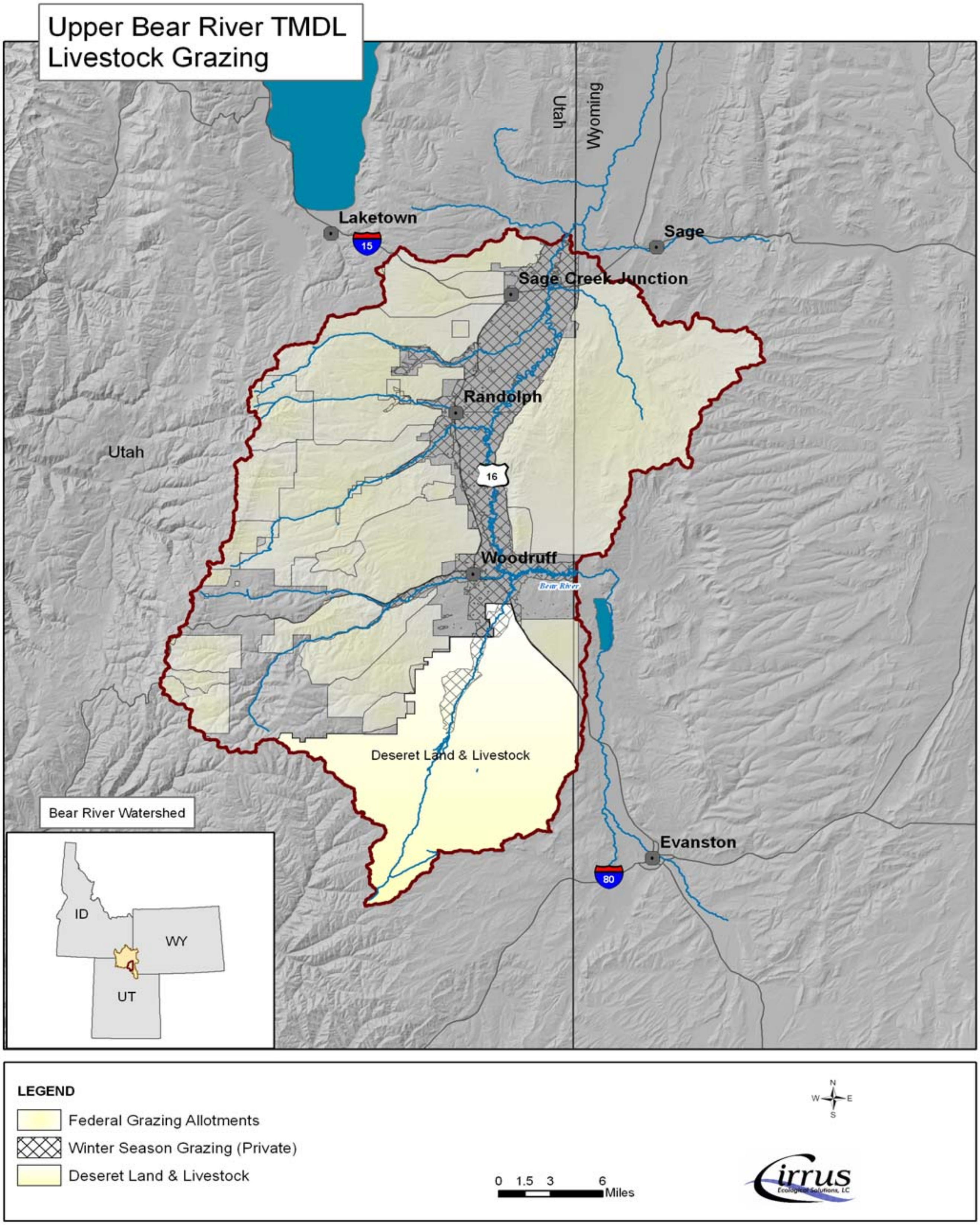


Figure 4.1. Livestock grazing in the Upper Bear River watershed.

Diversion of water from the Bear River for irrigation purposes begins approximately May 1 of each year. The volume of water diverted for irrigation is dependent upon winter season precipitation and the amount of water stored in Woodruff Narrows Reservoir. As mentioned in Section 2.8 Water Budget, the amount of water stored in the reservoir is managed according to the interstate Bear River Compact and senior downstream water rights. Perennial tributaries located on the west side of the project area are intercepted irrigation canals that parallel the Bear River. When this occurs, water volumes (and water quality) from both sources are mixed. Smaller tributaries are completely diverted to canals and used for irrigation purposes, while flows from larger tributaries are released back into the downstream channel through headgate or spillway structures. Water budget studies of the Upper Bear River have indicated that return flows from irrigated lands range from 45 percent to 72 percent of irrigation diversions and are a function of annual precipitation levels and total diverted water volumes (WWDC 2001, Johnson 2006). Return flows can be further partitioned into surface runoff and shallow groundwater recharge. Surface runoff volumes are returned immediately to the Bear River while shallow groundwater recharge may take several months or longer before returning to the river channel.

Reuse of irrigation water in the study area is a common practice. In general, it is believed that downstream irrigation diversions in the study area depend on return flows from upstream water diversions. Previous assessments of irrigation diversion measurements and Bear River flows indicate that Bear River water diverted in the study area may be reused 3-4 times before entering Wyoming (WWDC 2001, Johnson 2006).

The magnitude of loading to the Bear River carried by return flows can be influenced by irrigation volumes, location, surface cover, and susceptibility to erosion and transport. A general assessment of the nature of irrigation return flows was obtained by reviewing flow records and hydrographic survey maps obtained from the Utah Division of Water Rights and irrigated land coverage from the Utah Automated Geographic Reference Center (AGRC). No information was obtained to define areas supported by specific irrigation diversions. In general, the location of irrigation return flows could not be not clearly defined following this review. For the purposes of this TMDL, loads from irrigation return flows are assumed to be included as part of diffuse loads from runoff for irrigated agriculture.

4.1.4 DIFFUSE LOADS FROM RUNOFF

Diffuse loads from runoff are defined for the purposes of this TMDL study as anthropogenic loads associated with surface runoff that are not the result of manure produced by grazing animals. Some examples of diffuse loads include the following:

- Surface runoff and irrigation return flow that contains agricultural chemicals including fertilizers and pesticides.
- Nutrients and other constituents associated with erosion from human disturbed areas (including trails, roads, and dispersed camping sites).
- Nutrients and other constituents associated with erosion from upslope areas disturbed by managed grazing activities. This does not include direct manure loading described above in Section 4.1.2 – Grazing.

Most runoff in the TMDL study area is associated with spring snowmelt, summer thunderstorms that pass through the area and flood irrigation practices. In general, pollutant loading associated with runoff is essentially related to land use, although other physical factors such as geology, soil type, vegetative cover, slope, riparian conditions, etc. are also important. The proximity of each land use category to existing streams is also of consideration in evaluating pollutant loads associated with runoff. In the Upper Bear River watershed, nearly all of the agricultural lands lie within a narrow strip that parallels the Bear River.

The condition of these lands is also of importance, as it is generally accepted that areas in close proximity to existing water courses have a greater likelihood of contributing pollutant loads, especially when poor conditions exist (trampled stream banks, lack of vegetative cover, disturbed soils, etc.). Several canals are known to parallel the Bear River for much of its length in the study area. These canals can intercept surface runoff and flow as well as divert flow from smaller tributaries before it can reach the Bear River. The boundary of areas that can contribute direct surface runoff to the Bear River are shown in Figure 4.2.

4.2 POLLUTANT LOAD CALCULATION FROM EXISTING DATA

Pollutant load calculations based on water quality and flow monitoring data can provide supporting information in determining pollutant load contributions. A review of the original data set, including the number of samples and sample dates should accompany any assessment of pollutant load calculations. This is particularly important when attempting to characterize loads from nonpoint pollutant sources, which are highly dependent upon surface runoff. Pollutant loads should be based on measurements collected across a representative time period that include both drought and high flow conditions as well as all seasons of the year.

Pollutant loads can be calculated at monitoring locations where both flow and water quality concentrations have been measured. Loads calculated from sampling data are considered to be most accurate if measurements of flow and concentration are collected simultaneously (i.e. paired measurements) and over a range of conditions that are believed to be representative of the full range of conditions at a given monitoring location. Uncertainty can be introduced into the calculation of pollutant loads when using observations of flow and water quality that were measured independently of each other.

A simple average approach is often used in the calculation of pollutant loads, wherein the average of all flow measurements is multiplied by the average of all water quality measurements. Loads calculated using this method can be misleading if most flow readings were taken during a different season than water quality measurements (spring vs. fall), or if measurements for each parameter were taken during different years (e.g., flow data from a drought year used with water quality data from a high flow year). Care must be exercised in the selection of data for use in loading calculations.

One way to address the above complexities is to use only paired measurements and not consider the remaining data. In most cases, however, this is not feasible because of the small number of paired observations. Another method of supplementing the simple average approach is to use continuous flow data recorded from a nearby stream flow gage. Calculated average flow values from these sites better represent the variability in streamflow because flow measurements are generally made at a much higher frequency. As a result, monthly or annual averages for these locations may better represent streamflow conditions than an average of a limited number of instantaneous flow measurements.

The highest number of flow and monitoring samples in the study area were collected during two intensive monitoring periods completed in 1998-99 and 2003-04. Pollutant loads were calculated using paired measurements of flow and water quality for stations included during these time periods as well as a longer term that incorporated all available flow and water quality measurements from 1995 to the present time period. Load calculations are shown in Tables 4.2 through 4.5 for Total and Dissolved P, Total Suspended Solids (TSS) and Ammonia, respectively. No measurements of BOD were available at monitoring locations during intensive monitoring periods. Flow measurements collected at USGS 10020300-Bear River below Woodruff Reservoir were used to supplement DWQ flow measurements at this location. A USGS gage (10026500 – Bear River near Randolph) located near Randolph was rendered inactive due to channel migration in the early 1990s. However, there are approximately 40 years when the data record from this station overlaps with the record collected upstream at station USGS 10020300. A linear regression equation was calculated for the period of overlap between these two stations (Appendix Data).

The linear equation was then used to provide flow measurements for pollutant load calculations at DWQ station 4908100 Bear River near Sage Creek Junction during intensive monitoring periods.

The lack of flow measurements collected at mainstem Bear River monitoring sites made it difficult to identify longitudinal trends in pollutant loading. During the 1998-99 monitoring period, water quality samples were collected at several mainstem locations, but no flow data was available. No water quality monitoring data was collected on the Bear River immediately below Woodruff Narrows Reservoir during 2003-04.

Generally speaking, water quality concentrations and loading of TP and TSS increased with distance downstream below Woodruff Narrows Reservoir during 1998-99. The long term (1995-present) TP loads below Woodruff Narrows Reservoir and Sage Creek Junction are virtually identical. However, the number of TP samples (n=11) used for long-term load calculations below Woodruff Narrows reservoir makes it difficult to determine if this is an accurate comparison. In contrast TSS loads increase greatly in the project area for both the 1998-99 and the long term period. A comparison of long-term upstream and downstream loads and concentrations indicates that TSS loads roughly double in the project area while TSS concentration increases by about five times. A review of phosphorus concentrations at mainstem Bear River sites indicates that TP concentrations are generally much greater than Dissolved P. TP loads are likely influenced by the large sediment loads that carry adsorbed phosphorus to the Bear River in the study area.

Dissolved P and Total Ammonia loads generally decreased with distance downstream below Woodruff Narrows Reservoir. Long-term Dissolved P loads show a reduction of about 70 percent while 1998-99 loads are reduced by about 25 percent between Woodruff Narrows Reservoir and Sage Creek Junction. Eleven ammonia samples were collected at Sage Creek Junction in 1998-99 and in 2003-04. All ammonia samples collected in 1998-99 were below the measured detection limit (<BDL) while only one sample in 2003-04 had concentrations that were measurable. The long term Total Ammonia load decreased by roughly 50 percent between Woodruff Narrows Reservoir and Sage Creek Junction.

Load calculations for the Bear River upstream of the WY/UT border quantify the amount of TP and other pollutants contributed to impaired segments of the Bear River in Rich County. The long-term concentration of TP below Woodruff Narrows is slightly greater than the level of 0.05 mg/l recommended by Utah DWQ. The long-term concentration of Dissolved P is slightly less than 0.05 mg/l. Numeric criteria for TSS are no longer utilized to determine impairment in Utah while the criteria for Total Ammonia is dependent upon pH levels. The assessment provided in Chapter 3 for TSS and Total Ammonia samples collected below Woodruff Narrows Reservoir indicated full support of Utah Class 3A beneficial use. Although some improvements could be made to loads of TP and TSS carried by the Bear River into the study area, it is apparent the majority of impairment is a result of local pollutant sources.

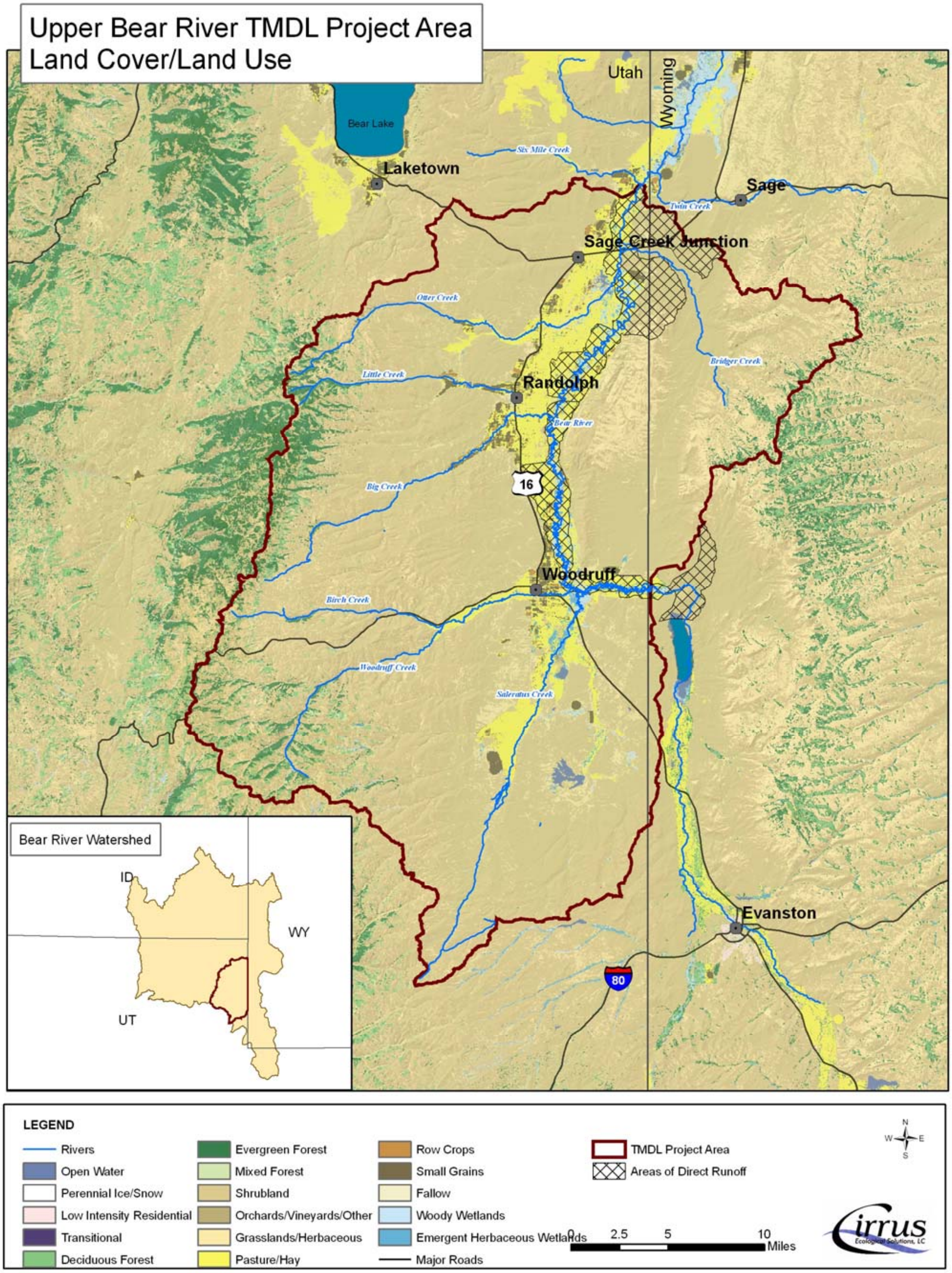


Figure 4.2 Areas contributing direct runoff to the mainstem Bear River channel from Woodruff Narrows Reservoir downstream to the UT/WY border crossing below Randolph.

Table 4.2 Total Phosphorus loading at Utah DWQ monitoring stations in the Upper Bear River watershed.

Time Period	Station	Name	# WQ samples	BDL	Date	Mean (mg/l)	n-flow	# No - flow	Date	Mean (cfs)	Load (Kg/yr)
98-99 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	13	2	1998 - 99	0.072	730	0	1998 - 99	351.02	22,600
	4908180	Big CK @ U-16 xing	13	0	1998 - 99	0.084	13	0	1998 - 99	34.86	2,620
	4908200	Genes Cr @ U-16 xing	13	2	1998 - 99	0.065	12	0	1998 - 99	19.29	1,113
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	13	0	1998 - 99	0.066	0	0	NA	0	0
	4908500	Bear R E of Woodruff	13	0	1998 - 99	0.066	1	0	1998 - 99	250	14,752
	4908600	Saleretus Ck @ U-16 xing	13	0	1998 - 99	0.290	12	0	1998 - 99	17.51	4,539
	4908630	Saleretus Ck @County Rd xing	0	0	NA	0.000	0	0	NA	0	0
	4908900 & 10020300	Bear R BL Woodruff Res	9	0	1998 - 99	0.054	730	0	1998 - 99	333.18	16,099
	4909500	Bear R. at UT/WY State Line	13	7	1998 - 99	0.021	14	0	1998 - 99	427.2	8,019
	5906520	Little Creek above Little Creek Res.	2	0	1998 - 99	0.605	2	0	1998	1.75	945
03-04 intensive monitoring	4908100 & 10026500 [a]	Bear R. E of Sage Ck JCT	14	2	2003-04	0.079	730	0	2003-04	48.95	3,466
	4908180	Big CK @ U-16 xing	13	1	2003-04	0.066	11	0	2003-04	2.559	152
	4908200	Genes Cr @ U-16 xing	9	6	2003-04	0.023	12	4	2003-04	2.264	47
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	14	5	2003-04	0.039	8	0	2003-04	13.53	470
	4908500	Bear R E of Woodruff	14	6	2003-04	0.031	10	0	2003-04	2.929	81
	4908600	Saleretus Ck @ U-16 xing	7	0	2003-04	0.249	12	6	2003-04	1.325	295
	4908630	Saleretus Ck @County Rd xing	9	0	2003-04	0.147	13	4	2003-04	1.175	154
	4908900 & 10020300	Bear R BL Woodruff Res	0	0	NA	0.000	639	0	2003-04	103.72	0
	4909500	Bear R. at UT/WY State Line	0	0	NA	0.000	0	0	NA	0	0
	5906520	Little Creek above Little Creek Res.	2	1	2004		2	0	2004	2.375	0
All data 1995 - present	4908100 & 10026500 [a]	Bear R. E of Sage Ck JCT	30	4	1998 - 2004	0.082	730	0	1998 - 2004	136.01	9,974
	4908180	Big CK @ U-16 xing	28	1	1998 - 2004	0.076	24	0	1998 - 2004	20.06	1,366
	4908200	Genes Cr @ U-16 xing	24	9	1998 - 2004	0.058	24	4	1998 - 2004	10.63	552
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	28	5	1998 - 2004	0.070	8	0	2003-04	13.53	849
	4908500	Bear R E of Woodruff	27	6	1998 - 2004	0.049	12	0	1999 - 2005	24.27	1,055
	4908600	Saleretus Ck @ U-16 xing	21	0	1998 - 2004	0.278	24	6	1998 - 2004	9.471	2,350
	4908630	Saleretus Ck @County Rd xing	9	0	2003 - 2004	0.147	13	4	2003-04	1.175	154
	4908900 & 10020300	Bear R BL Woodruff Res	11	0	1998 - 2001	0.066	2465	0	1998 - 2004	169.85	9,956
	4909500	Bear R. at UT/WY State Line	16	9	1995 - 2001	0.023	14	0	1995-99	427.2	8,664
	5906520	Little Creek above Little Creek Res.	4	1	1998 - 2004	0.323	6	2	1998 - 2004	1.68	483

[a] Flow values for USGS 10026500 Bear River near Randolph were developed from a linear regression equation with USGS 10020300 Bear River below Woodruff Narrows Reservoir. See Appendix Data.

Table 4.3 Dissolved Phosphorus loading at Utah DWQ monitoring stations in the Upper Bear River watershed.

Time Period	Station	Name	# WQ samples	BDL	Date	Mean (mg/l)	n-flow	# No - flow	Date	Mean (cfs)	Load (Kg/yr)
98-99 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	11	5	1998 - 99	0.024	730	0	1998 - 99	351.02	7,514
	4908180	Big CK @ U-16 xing	13	0	1998 - 99	0.084	13	0	1998 - 99	34.86	2,620
	4908200	Genes Cr @ U-16 xing	11	7	1998 - 99	0.024	12	0	1998 - 99	19.29	413
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	11	3	1998 - 99	0.042	0	0	NA	0	0
	4908500	Bear R E of Woodruff	11	3	1998 - 99	0.022	1	0	1998 - 99	250	4,842
	4908600	Saleretus Ck @ U-16 xing	11	0	1998 - 99	0.165	12	0	1998 - 99	17.51	2,572
	4908630	Saleretus Ck @County Rd xing	0	0	NA	0.000	0	0	NA	0	0
	4908900 & 10020300	Bear R BL Woodruff Res	7	2	1998 - 99	0.026	730	0	1998 - 99	333.18	7,766
	4909500	Bear R. at UT/WY State Line	10	6	1998 - 99	0.019	14	0	1998 - 99	427.2	7,153
	5906520	Little Creek above Little Creek Res.	2	0	1998 - 99	0.033	2	0	1998	1.75	51
03-04 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	14	11	2003-04	0.017	730	0	2003-04	48.95	754
	4908180	Big CK @ U-16 xing	13	6	2003-04	0.028	11	0	2003-04	2.559	65
	4908200	Genes Cr @ U-16 xing	9	9	2003-04		12	4	2003-04	2.264	0
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	14	14	2003-04		8	0	2003-04	13.53	0
	4908500	Bear R E of Woodruff	14	10	2003-04	0.018	10	0	2003-04	2.929	47
	4908600	Saleretus Ck @ U-16 xing	7	0	2003-04	0.215	12	6	2003-04	1.325	255
	4908630	Saleretus Ck @County Rd xing	9	2	2003-04	0.092	13	4	2003-04	1.175	97
	4908900 & 10020300	Bear R BL Woodruff Res	0	0	NA	0.000	639	0	2003-04	103.72	0
	4909500	Bear R. at UT/WY State Line	0	0	NA	0.000	0	0	NA	0	0
	5906520	Little Creek above Little Creek Res.	2	2	2004		2	0	2004	2.375	0
All data 1995 - present	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	26	17	1998 - 2004	0.042	730	0	1998 - 2004	136.01	5,048
	4908180	Big CK @ U-16 xing	25	9	1998 - 2004	0.027	24	0	1998 - 2004	20.06	481
	4908200	Genes Cr @ U-16 xing	21	17	1998 - 2004	0.018	24	4	1998 - 2004	10.63	173
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	25	17	1998 - 2004	0.020	8	0	2003-04	13.53	247
	4908500	Bear R E of Woodruff	25	13	1998 - 2004	0.021	12	0	1999 - 2005	24.27	445
	4908600	Saleretus Ck @ U-16 xing	18	0	1998 - 2004	0.184	24	6	1998 - 2004	9.471	1,558
	4908630	Saleretus Ck @County Rd xing	9	2	2003 - 2004	0.092	13	4	2003-04	1.175	97
	4908900 & 10020300	Bear R BL Woodruff Res	8	2	1998 - 2001	0.037	2465	0	1998 - 2004	169.85	5,600
	4909500	Bear R. at UT/WY State Line	11	7	1995 - 1999	0.018	14	0	1995-99	427.2	6,832
	5906520	Little Creek above Little Creek Res.	4	2	1998 - 2004	0.023	6	2	1998 - 2004	1.68	35

[a] Flow values for USGS 10026500 Bear River near Randolph were developed from a linear regression equation with USGS 10020300 Bear River below Woodruff Narrows Reservoir. See Appendix Data.

Table 4.4 Total Suspended Solids loading at Utah DWQ monitoring stations in the Upper Bear River watershed.

Time Period	Station	Name	# WQ samples	BDL	Date	Mean (mg/l)	n-flow	# No - flow	Date	Mean (cfs)	Load (Kg/yr)
98-99 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	13	1	1998 - 99	49.4	730	0	1998 - 99	351.02	15,497,481
	4908180	Big CK @ U-16 xing	13	0	1998 - 99	50.8	13	0	1998 - 99	34.86	1,582,023
	4908200	Genes Cr @ U-16 xing	13	1	1998 - 99	38.4	12	0	1998 - 99	19.29	661,993
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	13	0	1998 - 99	49.2	0	0	NA	0	0
	4908500	Bear R E of Woodruff	13	1	1998 - 99	29.5	1	0	1998 - 99	250	6,594,795
	4908600	Saleretus Ck @ U-16 xing	13	3	1998 - 99	61.2	12	0	1998 - 99	17.51	956,792
	4908630	Saleretus Ck @County Rd xing	0	0	NA	0.0	0	0	NA	0	0
	4908900 & 10020300	Bear R BL Woodruff Res	9	1	1998 - 99	7.4	730	0	1998 - 99	333.18	2,194,873
	4909500	Bear R. at UT/WY State Line	13	11	1998 - 99	1.9	14	0	1998 - 99	427.2	742,759
	5906520	Little Creek above Little Creek Res.	2	0	1998 - 99	538.8	2	0	1998	1.75	842,008
03-04 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	14	1	2003-04	50.6	730	0	2003-04	48.95	2,210,967
	4908180	Big CK @ U-16 xing	13	3	2003-04	36.9	11	0	2003-04	2.559	84,415
	4908200	Genes Cr @ U-16 xing	9	6	2003-04	9.4	12	4	2003-04	2.264	18,909
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	14	1	2003-04	24.3	8	0	2003-04	13.53	294,082
	4908500	Bear R E of Woodruff	14	4	2003-04	7.3	10	0	2003-04	2.929	18,984
	4908600	Saleretus Ck @ U-16 xing	7	2	2003-04	32.1	12	6	2003-04	1.325	37,958
	4908630	Saleretus Ck @County Rd xing	9	2	2003-04	51.5	13	4	2003-04	1.175	54,038
	4908900 & 10020300	Bear R BL Woodruff Res	0	0	NA	0.0	639	0	2003-04	103.72	0
	4909500	Bear R. at UT/WY State Line					0	0	2003-04	0	0
	5906520	Little Creek above Little Creek Res.	2	1	2004		2	0	2004	2.375	0
All data 1995 - present	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	30	2	1998 - 2004	50.1	730	0	1998 - 2004	136.01	6,089,841
	4908180	Big CK @ U-16 xing	28	3	1998 - 2004	46.7	24	0	1998 - 2004	20.06	836,205
	4908200	Genes Cr @ U-16 xing	24	8	1998 - 2004	24.7	24	4	1998 - 2004	10.63	234,372
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	28	1	1998 - 2004	35.3	8	0	2003-04	13.53	426,504
	4908500	Bear R E of Woodruff	27	5	1998 - 2004	17.8	12	0	1999 - 2005	24.27	385,781
	4908600	Saleretus Ck @ U-16 xing	21	5	1998 - 2004	48.8	24	6	1998 - 2004	9.471	412,477
	4908630	Saleretus Ck @County Rd xing	9	2	2003 - 2004	51.5	13	4	2003-04	1.175	54,038
	4908900 & 10020300	Bear R BL Woodruff Res	11	2	1998 - 2001	8.3	2465	0	1998 - 2004	169.85	1,263,915
	4909500	Bear R. at UT/WY State Line	16	13	1995 - 2001	3.6	14	0	1995-99	427.2	1,364,205
	5906520	Little Creek above Little Creek Res.	4	1	1998 - 2004	284.0	6	2	1998 - 2004	1.68	424,799

[a] Flow values for USGS 10026500 Bear River near Randolph were developed from a linear regression equation with USGS 10020300 Bear River below Woodruff Narrows Reservoir. See Appendix Data.

Table 4.5 Total Ammonia loading at Utah DWQ monitoring stations in the Upper Bear River watershed.

Time Period	Station	Name	# WQ samples	BDL	Date	Mean (mg/l)	n-flow	# No - flow	Date	Mean (cfs)	Load (Kg/yr)
98-99 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	11	11	1998 - 99		730	0	1998 - 99	351.02	0
	4908180	Big CK @ U-16 xing	11	10	1998 - 99	0.054	13	0	1998 - 99	34.86	1,693
	4908200	Genes Cr @ U-16 xing	11	10	1998 - 99	0.075	12	0	1998 - 99	19.29	1,292
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	12	11	1998 - 99	0.070	0	0	NA	0	0
	4908500	Bear R E of Woodruff	12	12	1998 - 99		1	0	1998 - 99	250	0
	4908600	Saleretus Ck @ U-16 xing	12	3	1998 - 99	0.191	12	0	1998 - 99	17.51	2,991
	4908630	Saleretus Ck @County Rd xing	0	0	NA	0.000	0	0	NA	0	0
	4908900 & 10020300	Bear R BL Woodruff Res	9	6	1998 - 99	0.046	730	0	1998 - 99	333.18	13,704
	4909500	Bear R. at UT/WY State Line	11	10	1998 - 99		14	0	1998 - 99	427.2	0
	5906520	Little Creek above Little Creek Res.	2	1	1998 - 99		2	0	1998	1.75	0
03-04 intensive monitoring	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	11	10	2003-04	0.060	730	0	2003-04	48.95	2,623
	4908180	Big CK @ U-16 xing	10	9	2003-04	0.090	11	0	2003-04	2.559	206
	4908200	Genes Cr @ U-16 xing	6	5	2003-04	0.070	12	4	2003-04	2.264	142
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	11	11	2003-04		8	0	2003-04	13.53	0
	4908500	Bear R E of Woodruff	10	10	2003-04		10	0	2003-04	2.929	0
	4908600	Saleretus Ck @ U-16 xing	2	2	2003-04		12	6	2003-04	1.325	0
	4908630	Saleretus Ck @County Rd xing	5	4	2003-04	0.080	13	4	2003-04	1.175	84
	4908900 & 10020300	Bear R BL Woodruff Res	0	0	NA	0.000	639	0	2003-04	103.72	0
	4909500	Bear R. at UT/WY State Line	0	0	NA	0.000	0	0	NA	0	0
	5906520	Little Creek above Little Creek Res.	0	0	NA	0.000	2	0	2004	2.375	0
All data 1995 - present	4908100 & 10026500[a]	Bear R. E of Sage Ck JCT	25	24	1998 - 2004	0.060	730	0	1998 - 2004	136.01	7,287
	4908180	Big CK @ U-16 xing	23	21	1998 - 2004	0.072	24	0	1998 - 2004	20.06	1,293
	4908200	Genes Cr @ U-16 xing	19	17	1998 - 2004	0.058	24	4	1998 - 2004	10.63	549
	4908280	Bear R @ Randoplh/Crw Mtn Rd Xing	24	23	1998 - 2004	0.070	8	0	2003-04	13.53	846
	4908500	Bear R E of Woodruff	22	22	1998 - 2004		12	0	1999 - 2005	24.27	0
	4908600	Saleretus Ck @ U-16 xing	15	6	1998 - 2004	0.161	24	6	1998 - 2004	9.471	1,363
	4908630	Saleretus Ck @County Rd xing	5	4	2003 - 2004	0.080	13	4	2003-04	1.175	84
	4908900 & 10020300	Bear R BL Woodruff Res	11	8	1998 - 2001	0.087	2465	0	1998 - 2004	169.85	13,252
	4909500	Bear R. at UT/WY State Line	14	13	1995 - 2001		14	0	1995-99	427.2	0
	5906520	Little Creek above Little Creek Res.	2	1	1998 - 1998		6	2	1998 - 2004	1.68	0

[a] Flow values for USGS 10026500 Bear River near Randolph were developed from a linear regression equation with USGS 10020300 Bear River below Woodruff Narrows Reservoir. See Appendix Data.

4.3 ASSESSMENT OF EXISTING TOTAL PHOSPHORUS LOADS BY SOURCE

As mentioned above, TP loads for AFO facilities are calculated as part of livestock grazing loads. A detailed description of the methods used to calculate loads from this source is included below in section 4.3.1. TP loads for irrigation return flows are considered to be part of the diffuse runoff load calculated from irrigated agriculture. A description of the method used to calculate loads from this source is included below in section 4.3.2.

4.3.1 TOTAL PHOSPHORUS LOADS FROM GRAZING

Livestock grazing is one of the primary land uses in the Upper Bear River watershed. Livestock grazing consists of cattle, sheep, and horses. Land ownership consists of private, state, and federal holdings. Private lands are mostly located in the lower valleys and are primarily used for agricultural purposes such as producing winter forage for livestock in the summer and use as winter feeding areas for livestock. Higher elevation areas provide summer grazing opportunities and are comprised of a mixture of federal and privately owned lands. Sections of state owned lands are scattered throughout the watershed and are mostly incorporated with federal grazing allotments. Federally owned lands are managed by the BLM and Forest Service. Most BLM lands within the watershed are divided into livestock grazing allotments which are managed for livestock and wildlife production along with other natural resource values. BLM lands are primarily grazed by livestock from mid-May through early-October each year. National Forest System (NFS) lands are also grazed by livestock within allotments. These lands are located along the western edge of the watershed and as a result, they are grazed later in the season. The following sections describe pollutant loading contributed to streams in the TMDL study area from grazing on both public and private lands.

4.3.1.1 Grazing on Public Lands

TP loads generated by livestock that graze public land areas in the Upper Bear River watershed were calculated using the following assumptions:

1. Animal numbers within BLM and USFS grazing allotments are based on actual use information, if available, provided by agencies. If actual use figures were not available, permitted livestock numbers are used.
2. The animals are distributed equally over the allotments.
3. Only animal waste deposited in the project area within 100 meters of an existing water body contributes to loading.
4. A delivery ratio of 100 percent is assumed for animal waste deposited within 10 meters of an existing water body and a delivery ratio of 10 percent is assumed for animal waste deposited between 10 and 100 meters of an existing water body.

A summary of TP loading from grazing in BLM and Forest Service allotments are shown in Tables 4.6 and 4.7, respectively. In general, the processes which result in pollutant loading from grazing animals include direct deposition to existing water bodies and surface runoff from areas where livestock have grazed. Given the dispersed nature of grazing activities, it was assumed that only animal waste deposited in the area within 100 meters of an existing water body contributes to loading.

In considering the two mechanisms by which loading occurs, it is also assumed that all manure deposited within 10 meters of an existing water body contributes to loading (delivery ratio = 100 percent simulating direct deposition) and that 10 percent of manure deposited between 10 and 100 meters from an existing water body contributes to loading (delivery ratio = 10 percent). The contributing area associated with these two zones (buffer zones) were calculated by buffering the streams and reservoirs using GIS (Tables 4.6 and 4.7).

According to the Agricultural Waste Management Handbook (NRCS 1992) the average weight of a grazing cow is approximately 454 kg (1,000 pounds) and the average TP production rate is approximately 0.05 kg of total phosphorus/cow/day. In addition, it is assumed that approximately 5 sheep are equivalent to one cow, so the production rate for sheep is 0.01 kg of total phosphorus/sheep/day. Given these numbers, the unit area loads for each animal group was estimated by multiplying the animal density (number of animals per square mile) by the TP production rate.

Annual TP loading to the existing water bodies in the Upper Bear River watershed was calculated for each animal group by multiplying the unit area loads by the areas of the deposition zones (i.e., area of 0 to 10 meter buffer zone or area of 10-100 meter buffer zone), the assumed delivery ratios associated with these zones where manure is deposited (i.e., one for the 0 to 10 meter buffer zone, and 0.1 for the 10 to 100 meter buffer zone), and the number of days that the animals in each animal group spend on the allotment. The loadings from each animal group were then summed to produce a total annual loading. Total annual TP loading from grazing allotments on BLM and NFS lands were approximately 1,602 kg TP/year and 203 kg TP/year, respectively (Tables 4.6 and 4.7).

4.3.1.2 Grazing on Private Lands

TP loading from grazing on private lands were based on the information provided by USU extension (Rothlisberger 2006). Information specific to Deseret Land and Livestock (DL&L) was provided by ranch employees. The following assumptions were used based on the grazing information provided:

Private land grazing:

1. The numbers below indicate cattle that graze private land areas during the winter season only (November 1 through May 1).
2. The TMDL study area contains roughly 40 percent of the total amount of 25,000 cattle that winter in Rich County, based on an estimate from the Utah Department of Agriculture.
3. The number of cattle grazing private land from the Wyoming state border to Woodruff is approximately 1,700 head.
4. The number of cattle grazing private land from Woodruff to Randolph is approximately 3,400 head.
5. The number of cattle grazing private land from Randolph upstream to the Wyoming border is approximately 4,800 head.
6. The distribution of numbers is based on cattle that were weighed at the community scale yard when they were shipped last fall. Some livestock owners have their own scales and do not use the community scale yard. The numbers do not include DL&L.

Deseret Land and Livestock:

1. The average number of livestock kept by DL&L is 3,500 cows (1,100 lbs) from November 1 through April 30, 5,000 cows from May 1 through October 31, and 2,000 yearlings (600-800 lbs) also from May 1 through October 31.
2. Livestock grazing during November 1 through April 30 is primarily on lower irrigated pastures.
3. Livestock grazing on rangeland begins approximately May 1 and ends October 31. Livestock grazing continues to occur on irrigated pastures during this time as well. They are rotated through irrigated pastures according to management schedules.
4. All areas of DL&L that drain to the Bear River are grazed by cattle. Some sheep grazing occurs on upper areas of DL&L, most of which drain into the Weber River Basin. A minimal amount of sheep grazing occurs on the Bear River side of DL&L but is considered insignificant.

In addition, the assumptions of distribution and load contribution applied for grazing in public lands were also applied for private lands. Again it was assumed that manure generated by animals located greater than 100 meters from an existing stream channel does not contribute appreciably to loading. Delivery ratios of 100 percent and 10 percent are assumed for areas within 0 to 10 meter and 10 to 100 meters from water bodies, respectively. The same phosphorus production rate used to calculate loads from public lands grazing was used in these calculations (cow TP production rate = 0.05 kg TP/animal unit/day; yearling TP production rate = 0.045 kg TP/animal unit/day) (NRCS 1992).

A summary of the TP annual loads from grazing on private lands are shown in Table 4.8. Total annual TP loading from private land was approximately 5,445 kg TP/year.

Table 4.6. Total phosphorus loading from livestock grazing on BLM allotments.

Allotment	Animal Group	Animal Type	# of animals	Season of use	Days	Contributing area (mi^2)		Total Land Area (mi^2)	Animal density ($\#/mi^2$)	Unit Area Load (Kg TP/mi^2/ day)	TP loading (kg/yr)			
						0-10m buffer	10-100m buffer				0-10m buffer zone	10-100m buffer zone	animal group	allotment
Big Creek	1	Cattle	600	5/15-9/15	124	0.53	4.77	51	12	0.6	39.41	35.49	74.90	101.36
	2	Cattle	41	6/15-9/15	93				1	0.05	2.46	2.22	4.68	
	3	Cattle	135	6/4-9/15	104				3	0.15	8.26	7.44	15.70	
	4	Sheep	68	6/1-7/15	45				1	0.01	0.24	0.21	0.45	
	5	Sheep	68	9/1-9/15	15				1	0.01	0.08	0.07	0.15	
	6	Sheep	68	10/1-11/30	61				1	0.01	0.32	0.29	0.61	
	7	Sheep	550	6/1-7/14	44				11	0.11	2.56	2.31	4.87	
Cumber-land/ Uinta	1	Cattle (Bridger Pasture)	4,335	5/1-5/15	15	1.87	16.43	140	31	1.55	43.45	38.21	81.66	874.57
			8,381	5/16-6/20	36				60	3	201.83	177.48	379.30	
	2	Cattle (Salt Creek Pasture)	8,684	9/1-9/30	30				62	3.1	173.79	152.83	326.62	
			4,423	10/1-10/15	15				32	1.6	44.85	39.44	84.29	
	3	Horses	10	5/15-10/15	154				0.1	0.005	1.44	1.27	2.70	
Duck Creek	1	Cattle	400	5/10-9/7	121	0.13	1.21	11	36	1.8	28.59	26.34	54.93	74.81
	2	Horses	8	5/10-9/7	121				1	0.05	0.79	0.73	1.53	
	3	Horses	6	7/1-9/7	69				1	0.05	0.45	0.42	0.87	
	4	Sheep	65	5/10-6/30	52				6	0.06	0.41	0.38	0.79	
	5	Sheep	575	5/15-7/1	48				52	0.52	3.28	3.02	6.29	
	6	Sheep	125	10/1-10/30	30				11	0.11	0.43	0.40	0.83	
	7	Sheep	575	9/20-12/1	73				52	0.52	4.98	4.59	9.57	
Eastman	1	Cattle	189	5/10-8/14	97	0.23	2.10	17	11	0.55	7.00	11.19	18.19	22.36
	2	Cattle	65	8/15-9/30	47				4	0.2	2.20	1.97	4.17	

Table 4.6. Total phosphorus loading from livestock grazing on BLM allotments.

Allotment	Animal Group	Animal Type	# of animals	Season of use	Days	Contributing area (mi^2)		Total Land Area (mi^2)	Animal density ($\#/mi^2$)	Unit Area Load (Kg $TP/mi^2/$ day)	TP loading (kg/yr)			
						0-10m buffer	10-100m buffer				0-10m buffer zone	10-100m buffer zone	animal group	allotment
East Woodruff		-	-	Relin-quished to UDWR	-	0.15	1.27	9		0	NA	NA	0.00	NA
Meachum Canyon	1	Cattle	140	7/1-9/30	92	0.07	0.69	4	35	1.75	11.82	11.12	22.94	22.94
Middle Ridge	1	Sheep	80	6/1-10/31	153	0.15	1.29	12	7	0.07	1.61	1.38	2.99	4.12
	2	Sheep	75	6/11-7/10	30				6	0.06	0.27	0.23	0.50	
	3	Sheep	30	6/16-7/15	30				3	0.03	0.14	0.12	0.25	
	4	Sheep	30	11/1-11/15	15				3	0.03	0.07	0.06	0.13	
	5	Sheep	75	11/10-11/24	15				6	0.06	0.14	0.12	0.25	
New Canyon	1	Cattle	1024	5/15-9/05	114	0.72	6.49	61	17	0.85	69.50	62.88	132.38	286.10
	2	Cattle	85	5/15-6/19	36				1	0.05	1.29	1.17	2.46	
	3	Cattle	1251	6/15-9/5	83				21	1.05	62.50	56.55	119.06	
	4	Cattle	62	6/1-9/5	97				1	0.05	3.48	3.15	6.63	
	5	Horses	11	5/15-9/5	114				0.2	0.01	0.82	0.74	1.56	
	6	Sheep	1,100	5/15-6/5	22				18	0.18	2.84	2.57	5.41	
	7	Sheep	340	5/15-9/16	36				6	0.06	1.55	1.40	2.95	
	8	Sheep	900	10/27-12/27	62				15	0.15	6.67	6.03	12.70	
	9	Sheep	500	11/2-11/28	27				8	0.08	1.55	1.40	2.95	
Sage Creek	1	Cattle	274	5/10-9/15	129	0.26	2.32	18	15	0.75	25.09	22.40	47.50	50.96
	2	Sheep	850	12/1-12/15	15				47	0.47	1.83	1.63	3.46	
South Woodruff	1	Cattle	90	5/15-9/30	137	0.26	2.35	19	5	0.25	8.83	8.04	16.87	16.87

Table 4.6. Total phosphorus loading from livestock grazing on BLM allotments.														
Allotment	**Animal Group**	**Animal Type**	**# of animals**	**Season of use**	**Days**	**Contributing area (mi²)**		**Total Land Area (mi²)**	**Animal density (#/mi²)**	**Unit Area Load (Kg TP/mi²/ day)**	**TP loading (kg/yr)**			
						0-10m buffer	**10-100m buffer**				**0-10m buffer zone**	**10-100m buffer zone**	**animal group**	**allotment**
Woodruff Pastures	1	Cattle	387	5/16-6/30	46	0.41	3.75	36	11	0.55	10.44	9.48	19.91	148.13
	2	Cattle	537	5/16-9/15	123				15	0.75	38.05	34.55	72.60	
	3	Cattle	242	7/1-9/15	77				7	0.35	11.12	10.09	21.21	
	4	Sheep	1,639	5/16-5/31	16				46	0.46	3.04	2.76	5.79	
	5	Sheep	210	5/16-6/15	31				6	0.06	0.77	0.70	1.46	
	6	Sheep	540	11/1-1/10	71				15	0.15	4.39	3.99	8.38	
	7	Sheep	614	11/4-12/31	58				17	0.17	4.07	3.69	7.76	
	8	Sheep	210	11/15-1/25	72				6	0.06	1.78	1.62	3.40	
	9	Sheep	785	12/1-1/13	44				22	0.22	3.99	3.63	7.62	
Total TP load from grazing on BLM allotments														**1,602.22**

Table 4.7 Total phosphorus loading from livestock grazing on Forest Service allotments.

Allotment	Animal Group	Animal Type	# of Animals	Season	Days	Contributing area (mi^2)		Total Land Area (mi^2)	Animal density (#/mi^2)	Unit Area Load (Kg TP/mi^2/day)	TP load (kg/yr)			
						0-10m buffer	10-100m buffer				0-10m buffer	10-100m buffer	animal group	allotment
Blake Hollow		Sheep	967	7/01-9/30	92	0.000	0.003	0.3	NA	NA	NA	NA	NA	NA
Bountiful		Sheep	840	7/01-9/30	92	0.069	0.639	7	120	1.2	7.59	7.06	14.65	14.65
Buck Springs		Sheep	1076	7/05-9/25	143	0.011	0.091	1	1076	10.76	16.83	13.94	30.77	30.77
Bug Lake		Sheep	703	6/06-9/30	116	0.009	0.092	1	703	7.03	7.65	7.52	15.16	15.16
Crawford-Frazier	1	Sheep	312	7/16-8/31	46	0.081	0.713	6	52	0.52	1.94	1.70	3.65	4.84
	2	Sheep	312	9/16-9/30	15				52	0.52	0.63	0.56	1.19	
Dairy Ridge		Cattle	150	7/01-8/20	51	0.061	0.536	3	50	2.5	7.77	6.83	14.60	14.60
Davenport		Sheep	591	6/01-9/30	122	0.003	0.034	0.1	NA	NA	NA	NA	NA	NA
Little Monte		Sheep	1100	7/01-9/30	92	0.023	0.206	2	550	5.5	11.86	10.44	22.30	22.30
North Randolph	1	Cattle	473	6/21-9/05	76	0.181	1.669	13	36	1.8	24.80	22.83	47.62	67.89
	2	Cattle	19	6/21-8/31	71				1	0.05	0.64	0.59	1.24	
	3	Cattle	33	6/21/9/15	86				3	0.15	2.34	2.15	4.49	
	4	Cattle	30	6/21-9/20	91				2	0.1	1.65	1.52	3.17	
	5	Cattle	51	7/05-9/20	138				4	0.2	5.00	4.61	9.61	
	6	Cattle	15	6/21-9/30	101				1	0.05	0.92	0.84	1.76	
South Randolph		Cattle	32	6/21-8/31	71	0.222	2.020	13	2	0.1	1.58	1.43	3.01	3.01
Woodruff	1	Cattle	71	7/01-9/15	77	0.163	1.456	9	8	0.4	5.01	4.49	9.49	30.06
	2	Cattle	66	7/01-9/26	88				7	0.35	5.01	4.49	9.49	
	3	Cattle	69	7/06-9/24	80				8	0.4	5.20	4.66	9.86	
	4	Cattle	113	7/01-9/17	79				1	0.05	0.64	0.58	1.22	
Total TP load from grazing on Forest Service allotments														**203.28**

Table 4.8. Total phosphorus loading from livestock grazing on private land.

Land	Animal Group	Animal Type	# of Animals	Season	Days	Contributing area (mi^2)		Total Land Area (mi^2)	Animal Density ($\#/mi^2$)	Unit Area Load (Kg TP/mi^2/ day)	TP load (kg/yr)			
						0-10m buffer	10-100m buffer				0-10m buffer	10-100 buffer	animal group	land grouping
Private														
WY/UT border to Woodruff	1	Cattle	1700	Nov 1-May1	182	0.77	5.78	90	19	0.95	132.07	99.49	231.56	**1,832.31**
Woodruff to Randolph	1	Cattle	3400	Nov 1-May1	182	0.76	5.78	90	38	1.89	263.06	199.04	462.10	
Randolph to UT/WY border	1	Cattle	4800	Nov 1-May1	182	1.27	10.71	90	53	2.67	618.20	520.45	1,138.65	
Private-Deseret L&L														
Deseret L&L	1	Cattle	5000	May 1-Oct 31	184	3.15	26.28	151	33	1.66	958.98	800.51	1,759.49	**2,394.20**
	2	yearlings	2000	May 1-Oct 31	184	3.15	26.38	151	13	0.60	345.43	289.28	634.71	
Deseret L&L winter season only	1	Cattle	3500	Nov 1-Apr 30	181	0.17	1.45	8	433	21.65	649.05	569.45	1,218.51	**1,218.51**
Total TP load from grazing in private lands														**5,445.02**

4.3.1.3 Summary of Total Phosphorus Loads from Grazing

Table 4.9 summarizes pollutant loads from grazing within the Upper Bear River watershed. The total annual TP load generated from livestock grazing within the watershed is 7,250 kg/yr.

Table 4.9. Summary of TP loads from grazing.

Grazing Resource	TP Load (kg/yr)
Bureau of Land Management	1,602
Forest Service	203
Private Land	5,445
Total	7,250

4.3.2 DIFFUSE LOADS FROM RUNOFF

Natural background loads are those that are expected in the absence of human influence and are related to the natural distribution of flow and land cover in the watershed. Diffuse loads from runoff can be considered the current background loads that occur in the watershed given that the land cover distribution has been changed from natural conditions. In other words, diffuse loads from runoff are the current background loads that have replaced the natural background loads in the watershed.

Loading in this category is related to land use, and specific sources within this category include fertilizers and pesticides in agricultural return flows and runoff from agricultural lands. Sediment related phosphorus loading from erosion processes accelerated by grazing and other agricultural practices are also included in this category. It is important to note that while these loads may be related to grazing activities, phosphorus loads associated with animal waste deposited by grazing animals are accounted for above in Section 4.3.1 Total Phosphorus Loads From Grazing and are not part of diffuse loads from runoff.

Land cover in the Upper Bear River watershed is primarily rangeland (approximately 78 percent), with smaller areas of irrigated agriculture (approximately 12 percent) associated with the low lying areas of the watershed adjacent to stream channels. Remaining land cover consists of forest land, non-irrigated agriculture, wetlands, water, urban/residential, and barren. The land cover distribution in the Upper Bear River watershed in terms of acres and percent are shown in Table 2.3. A map of these areas is shown in Figure 2.3.

Diffuse loads from runoff associated with each of the land use categories were calculated using annual export coefficients selected from the literature. These export coefficients represent the amount of TP loading that would be exported from each land use on an annual basis. A list of the export coefficients used is shown in Table 4.10. Appendix - Modeling contains the literature values from which the ranges and selected values were compiled.

Table 4.10. Export coefficients for TP.		
Land Use Category	**Literature Range (kg/ha/yr)**	**Selected Value (kg/ha/yr)**
Urban/Residential/Transportation	0.1 - 30	1
Forest Land	0.01 - 0.9	0.05
Range Land	0.08 - 0.74	0.1
Agriculture	0.1 - 5	1
Wetlands	[a]	0.25
Barren	0.1 - 0.74	0.2
Water		0[b]

[a]Only a single value was found in the literature.
[b]Open water is assumed to have negligible phosphorus export.

In general, the selected values for the export coefficients in Table 4.10 are in the lower part of the ranges found in the literature. These values were selected using professional judgment, but were confirmed by comparing the loads estimated using these values to the measured loads in Section 4.2 of this report to make sure that they are reasonable. One of the highest export coefficients selected was associated with agriculture. This is intended to reflect the influence of return flows from irrigated lands, which appears to be a significant loading process in the Upper Bear River watershed.

Loads for each subwatershed were calculated by multiplying the selected export coefficient values by the area of each land use in each subwatershed. These loads are listed in Table 4.11. The total annual watershed load from diffuse loads associated with runoff is 50,619 kg/yr. Figure 4.3 shows the distribution of loads summarized by land use category. Note that the largest contributor of diffuse loading is from irrigated land areas which comprise only 12% of total land in the study area.

Table 4.11. Estimated annual TP loading to streams in the Upper Bear River watershed from diffuse loads associated with runoff.

HUC	Subwatershed name	Total Phosphorus Loading (kg/yr)
160101010303	Little Creek	**1,106**
160101010305	Upper Big Creek	**1,398**
160101010501	Upper Woodruff Creek	**1,317**
160101010502	Sugar Pine Canyon	**3,303**
160101010503	Lower Saleratus Creek	**3,283**
160101010504	Middle Saleratus Creek	**4,117**
160101010601	Bridger Creek-Bear River	**6,342**
160101010602	Cottonwood Creek-Bear River	**1,063**
160101010603	Birch Creek-Walton Canyon	**1,752**
160101010604	Bear River-Sage Hollow	**14,136**
160101010605	Lower Big Creek	**1,939**
160101010606	Bear River-Whitney Canyon Creek	**2,883**
160101010701	Lower Woodruff Creek	**629**
160101010702	Upper Saleratus Creek	**355**

Table 4.11. Estimated annual TP loading to streams in the Upper Bear River watershed from diffuse loads associated with runoff.		
HUC	**Subwatershed name**	**Total Phosphorus Loading (kg/yr)**
160101010703	Otter Creek	**1,827**
160101010704	Neponset Reservoir	**1,114**
160101010801	Bear River-Brazier Canyon	**392**
160101010802	Bear River-Sage Creek	**3,662**
Watershed Total		**50,619**

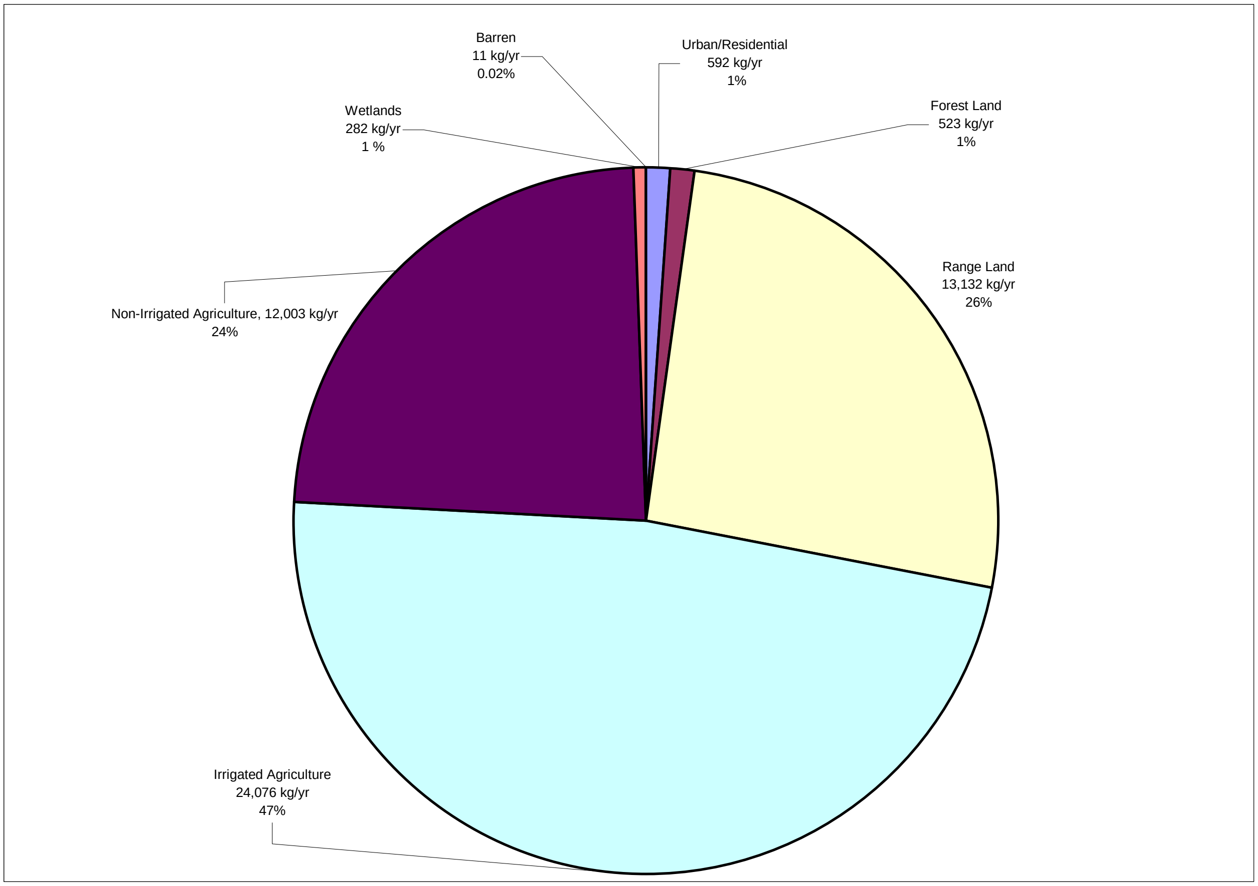


Figure 4.3. Distribution of TP loads from diffuse runoff by land use category. Numbers show estimated load in kilograms per year.

4.3.3 LOADING SOURCE SUMMARY

The significant loadings in the Upper Bear River watershed are summarized in Table 4.12 by source category. Total Watershed Loads are represented in the second column of Table 4.12 and indicate the load of TP delivered to receiving water bodies in the study area including tributaries and the mainstem Bear River. This load is reduced by numerous processes including but not limited to irrigation diversions, adsorption to soil particles and algae uptake. The final TP load at the watershed outlet near Station 4908100 Bear River East of Sage Creek Junction represents the total contribution from all pollutant sources discussed in this section. It is assumed that the long-term (1995-present) annual TP load at Station 4908100 of 9,974 kg/yr is representative of watershed loading for the entire study area. It is also assumed that the distribution of TP loads at the watershed outlet is similar to the distribution of total watershed loads shown in column 2 of Table 4.12 below. The loads contributed by pollutant source at the watershed outlet are shown in column 3 of Table 4.12. Based on the calculations and assumptions detailed in this chapter, the largest contributor of TP loading to the Bear River is irrigated agriculture (41.6 percent). The load shown for this source includes return flow from irrigation, surface runoff produced during storm events and spring snowmelt. Other significant contributions of TP loading include non-irrigated agriculture (20.7 percent) and livestock grazing on private lands (9.4 percent). Loading from livestock grazing on private lands includes those areas adjacent to the Bear River and tributaries where animals are fed during the winter season and incorporates any loading from AFO facilities.

Table 4.12. Existing TP loads in the Upper Bear River watershed.

Source	Total Watershed Load (kg/yr)	Watershed Load Fraction	Watershed Outlet Load (kg/yr)
Livestock Grazing			
BLM allotments	1,602	0.028	276.1
NFS allotments	203	0.004	35.0
Private Land	5,445	0.094	938.5
Diffuse Runoff			
Urban/Residential	592	0.010	102.0
Forest Land	523	0.009	90.1
Range Land	13,132	0.227	2,263.4
Irrigated Agriculture	24,076	0.416	4,149.6
Non-Irrigated Agriculture	12,003	0.207	2,068.8
Wetlands	282	0.005	48.6
Barren	11	0.0002	1.9
Total (kg/yr)	**57,869**		**9,974**

CHAPTER 5: TMDL ANALYSIS

5.1 WATER QUALITY TARGETS

Permissible loading to impaired segments of the Upper Bear River will rely on water quality endpoints that will restore full support of beneficial uses assigned to impaired water bodies located in the study area. Three water bodies located in the study area were included on the 2004 303(d) list and are considered impaired due to low DO concentrations. These water bodies are listed in Table 3.1 and include all of the mainstem Bear River in Rich County as well as Saleratus Creek. The beneficial use assigned to these river segments is Class 3A – cold water species of game fish and other aquatic life. Knowledge of physical conditions in the Saleratus Creek watershed indicate that the beneficial use assigned to Saleratus Creek may be incorrect. To this end, a Use Attainability Analysis (UAA) was conducted for Saleratus Creek. The results of this analysis are included in Appendix UAA.

In general, water quality endpoints are defined in terms of numeric water quality criteria. Although numeric criteria can sometimes be over-protective, they have been set at levels that have historically been observed to protect the beneficial use of waters for which they are specified. Other water quality endpoints can be used in addition to numeric criteria. These endpoints can include indicator values of water quality such as TP or BOD concentrations or biological measures that indicate stream health.

As stated in Section 3.5 (Aquatic Invertebrates), the use of macroinvertebrates as a surrogate measure of water quality is based on the relationship between water quality and the composition of the invertebrate community it supports. The Family Level Biotic Index (FBI, Hilsenhoff 1988), used to assess the general status of organic pollution at selected stations in the Upper Bear River, is a measure of the organic and nutrient pollution contributes to low DO levels. Dissolved oxygen concentrations, in turn, affect the ability of invertebrate species to survive in a particular stream (Hilsenhoff 1987). Thus, it could be anticipated that a reduction in organic matter loading would improve oxygen levels in the water column, which could consequently lead to a change in the macroinvertebrate community structure. For example, the family Ephemerellidae, considered highly intolerant to organic and nutrient pollution, occurred in the Bear River near Sage Creek Junction (Station 4908100) but its contribution to the total abundance of macroinvertebrates at this site was minimal (Table 3.23). Increased oxygen levels could enhance habitat conditions for species in this family and lead to an increase in their abundance. It should be noted that the FBI is a modification of the species-level Biotic Index (BI). The latter would provide a more accurate evaluation of improvements in the degree of organic and nutrient pollution (Hilsenhoff 1987, 1988).

Impairment to river segments is generally based on numeric criteria from field measurements and water quality samples. In most cases, if less than 10 percent of water quality measurements exceed standards, full support status is assigned to the water body. Partial support is assigned if exceedance is between 10 percent and 25 percent, while non-support status is assigned if exceedance is more than 25 percent.

The 30-day average numeric DO criteria for Class 3A waters is 6.5 mg/l. This criteria will be used as the primary endpoint for the Upper Bear River TMDL. In addition to the dissolved oxygen numeric criteria, the water quality standards for the State of Utah specify a pollution indicator value for TP of 0.05 mg/l and 5.0 mg/l for BOD. A water quality modeling assessment was completed for the Upper Bear River to determine the relationship between DO and the physical and chemical factors that may influence DO. A full description of this modeling effort is included below. Results from the model assessment indicated that DO concentrations in the Upper Bear River were more responsive to parameters that reflect organic matter loading than to reductions in TP loads alone. Few measurements of parameters that represent organic matter loading such as Biochemical Oxygen Demand (BOD) or Sediment Oxygen Demand (SOD) have been taken during the past 10 years in the study area. However, TP is a component of the types of organic matter that are commonly found in the study area and will therefore be used in the TMDL. As a result, the 0.05 mg/l TP indicator level will be used to provide support to TMDL development. In summary, the following endpoints will be used to ensure full support of the Class 3A beneficial use:

1. An annual TP load of 6,073 kg/yr at Station 4908100 Bear River East of Sage Creek Junction.

2. No more than 10 percent of samples collected from tributary streams reaching the Bear River will exceed 0.05 mg/l TP or 5 mg/l BOD.

3. Macroinvertebrate communities will measure an FBI index < 4.25 indicating a slight potential for organic pollution.

It is anticipated that if the TMDL target load of 6,073 kg/yr is met, the influence of factors that are primarily responsible for low DO concentrations, including organic matter loading and SOD, will be likewise reduced and full support of DO numeric criteria will be achieved.

5.2 PERMISSIBLE LOADINGS

The permissible load represents the maximum amount of phosphorus that can be assimilated by the Upper Bear River and still meet the water quality endpoint for DO of 6.5 mg/l associated with Class 3A waters. Permissible loading to impaired segments of the Upper Bear River were defined using an assessment of existing water quality and flow data, and modeled response of DO concentration to reductions in pollutant loading. Linkages between pollutant sources and DO concentrations in the Upper Bear River were determined with the QUAL2K river and stream water quality model (Chapra and Pelletier 2003). This model provides a means for determining the response of DO to changes in flow and water quality parameters as well as incorporating the influence of biological growth components (algae) and sediment-water interactions. Levels of DO increase as a result of algal photosynthesis while decreased levels occur from oxidation of organic material, nitrification, and plant respiration. Dissolved oxygen can also be added or removed from water through reaeration depending on the saturation level (Chapra and Pelletier 2003). The QUAL2K model can provide a means for quantifying each of these processes and determine their effect on DO concentrations.

A technical discussion of the model is included in Appendix Modeling at the end of this report. A general description of the model scenarios and model output is included below.

5.2.1 MODELING

In order to determine the longer term influence of drought conditions as well as the seasonal variation of flow and pollutant loading on DO concentration, four time periods were modeled during a wet year and a dry year. These years corresponded to the 1998-99 and 2003-04 intensive monitoring periods in the Bear River Basin. A total of eight model scenarios were assessed (Table 5.1). Average DO concentrations were calculated at four DWQ monitoring locations on the mainstem Bear River and compared to model output during these time periods. During some time periods, only a single DO sample was available at certain monitoring stations. As shown in Table 5.1, there were only three locations where average DO concentrations (measured) were below the 6.5 mg/l water quality endpoint. These time periods correspond to the periods shown in Table 3.16, including April-June and July-September when the greatest percent exceedance in DO concentrations occurred. It is during these periods that water is diverted for irrigation purposes and return flow from irrigated fields and pastures enters the Bear River channel.

Table 5.1. Upper Bear River QUAL2K model scenarios. Dissolved oxygen concentrations shown in bold text indicate concentrations < 6.5 mg/l.

Scenario	Year	Month	Bear River monitor station[1]	Average DO concentration (mg/l)	Average Flow (cms)
Wet Year First Quarter	1998-99	January - March	10020300		3.10
			4908900	10.49	
			4908500	10.36	
			4908280	10.41	
			4908100	10.23	
			10026500		5.22
Wet Year Second Quarter	1998-99	April-June	10020300		24.30
			4908900	9.44	
			4908500	8.36	
			4908280	7.98	
			4908100	7.74	
			10026500		21.25
Wet Year Third Quarter	1998-99	July-September	10020300		7.95
			4908900	8.25	
			4908500	**6.25**	
			4908280	6.60	
			4908100	**5.75**	
			10026500		8.84
Wet Year Fourth Quarter	1998-99	October-December	10020300		2.42
			4908900	8.60	
			4908500	10.14	
			4908280	9.69	
			4908100	10.79	
			10026500		3.67
Dry Year First Quarter	2003-04	January - March	10020300		0.40
			4908900	10.28	
			4908500	8.68	
			4908280	8.67	
			4908100	10.22	
			10026500		1.61
Dry Year Second Quarter	2003-04	April-June	10020300		8.42
			4908900	9.27	
			4908500	9.70	
			4908280	**6.30**	
			4908100	9.87	
			10026500		0.43
Dry Year Third Quarter	2003-04	July-September	10020300		1.33
			4908900	9.20	
			4908500	8.19	
			4908280	7.91	
			4908100	8.30	

Table 5.1. Upper Bear River QUAL2K model scenarios. Dissolved oxygen concentrations shown in bold text indicate concentrations < 6.5 mg/l.

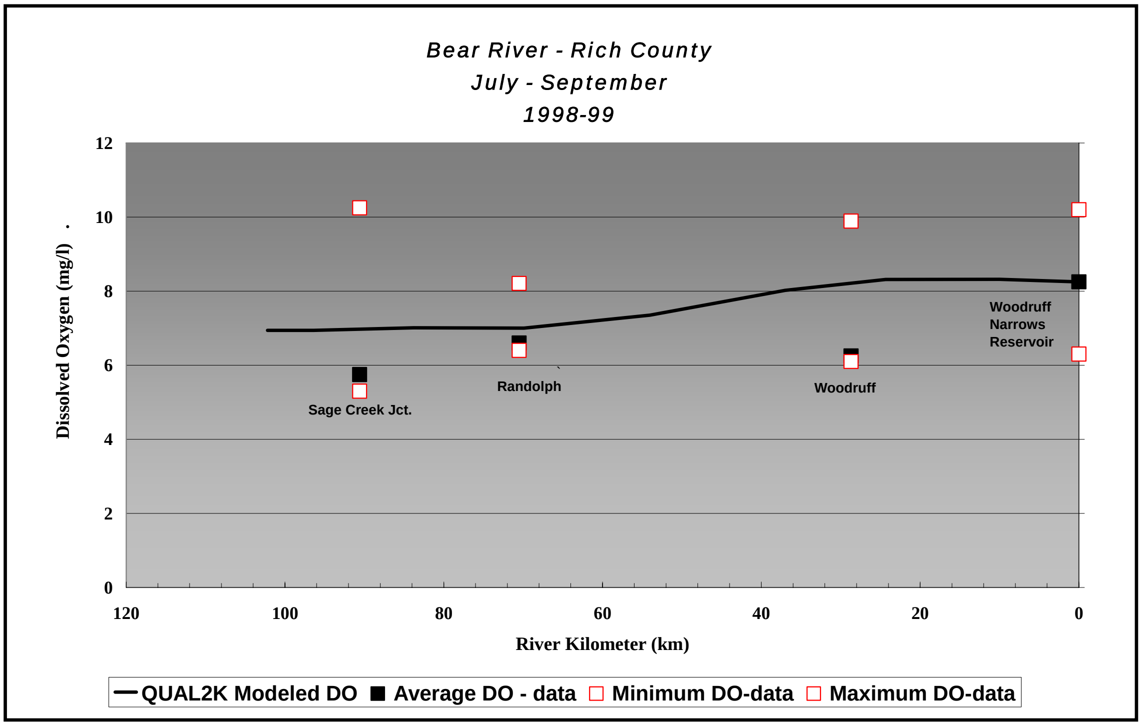
Scenario	Year	Month	Bear River monitor station[1]	Average DO concentration (mg/l)	Average Flow (cms)
			10026500		0.97
Dry Year Fourth Quarter	2003-04	October-December	10020300		0.37
			4908900	10.33	
			4908500	10.16	
			4908280	9.69	
			4908100	11.21	
			10026500		1.23

[1] Mainstem Bear River stations included the following: USGS 10020300 and 4908900 – Bear River below Woodruff Narrows Reservoir, 4908500 – Bear River East of Woodruff, 4908280 – Bear River at Randolph/Crawford Mountain Road crossing, 10026500 – Bear River near Randolph Utah, 4908100 – Bear River East of Sage Creek Junction at U30 Crossing above confluence with Bridger Creek

A water budget approach was taken to determine flow contributions to the Bear River by tributaries, irrigation return flow, groundwater, and surface runoff from snowmelt. Boundary conditions were defined at the upstream project boundary using measured data from USGS 10020300-Bear River below Reservoir near Woodruff Utah. As mentioned in Chapter 4, USGS 10026500-Bear River near Randolph Utah is inactive. In order to define downstream boundary conditions, quarterly flow correlations were developed between USGS 10020300 and USGS 10026500 and used to define flow during 1998-99 and 2003-04. Irrigation diversion amounts from the Bear River were defined using flow records maintained by the Utah Division of Water Rights. Flow contributions from irrigation return flow and groundwater were defined from previous water budget studies (WWDC 2001, Johnson 2006). The remaining flow balance was assigned to tributaries and areas that contribute direct runoff to the mainstem Bear River (Figure 4.2) using a weighted approach based on area and PRISM precipitation amounts. Surface runoff was limited to the second quarter of each year (April-May).

Water quality inputs were defined using DWQ monitoring data where possible. Water quality data for Station 4908900 Bear River below Woodruff Narrows Reservoir was not available during 2003-04. Average water quality values were obtained for this location using pooled measurements collected during two years (1977-78 and 1987-88) with similar low flows. Water quality conditions for irrigation return flows were based on literature values as well as measured data collected from irrigated fields in southern Idaho (Barry 1996, Doran 1981). Water quality of runoff from areas adjacent to the Bear River were also obtained from literature values appropriate for the type of land cover and land use found in these locations.

Model calibration focused upon matching the modeled water quality constituents to average concentrations of measured parameters at the four water quality stations shown in Table 5.1. A primary emphasis was placed upon scenarios that showed the highest percent exceedance of DO criteria. Some adjustment of model output was achieved by varying input values for which no measured data were available. However, these changes were always kept within reasonable ranges for the project area. Modeled output from each of the eight scenarios was reviewed to determine if the difference between modeled and measured values varied between season or year. The fit between modeled and measured DO was generally good for all eight scenarios. During the winter season (January-February), modeled and measured water temperature did not correspond well as model temperatures reached 0^{o} C prior to reaching the end of the last modeled reach. However, other water quality parameters and flow parameters (velocity and travel time) were modeled reasonably well during this same time period by QUAL2K. In reality, the Bear River typically freezes over during the winter months, but continues to flow beneath the surface ice cover. Figure 5.1 shows modeled and measured DO concentrations during those periods when DO concentrations were lowest including the third quarter in 1998-99 and the second quarter in 2003-04. Additional water quality plots of modeled and measured water quality are included in Appendix Modeling.



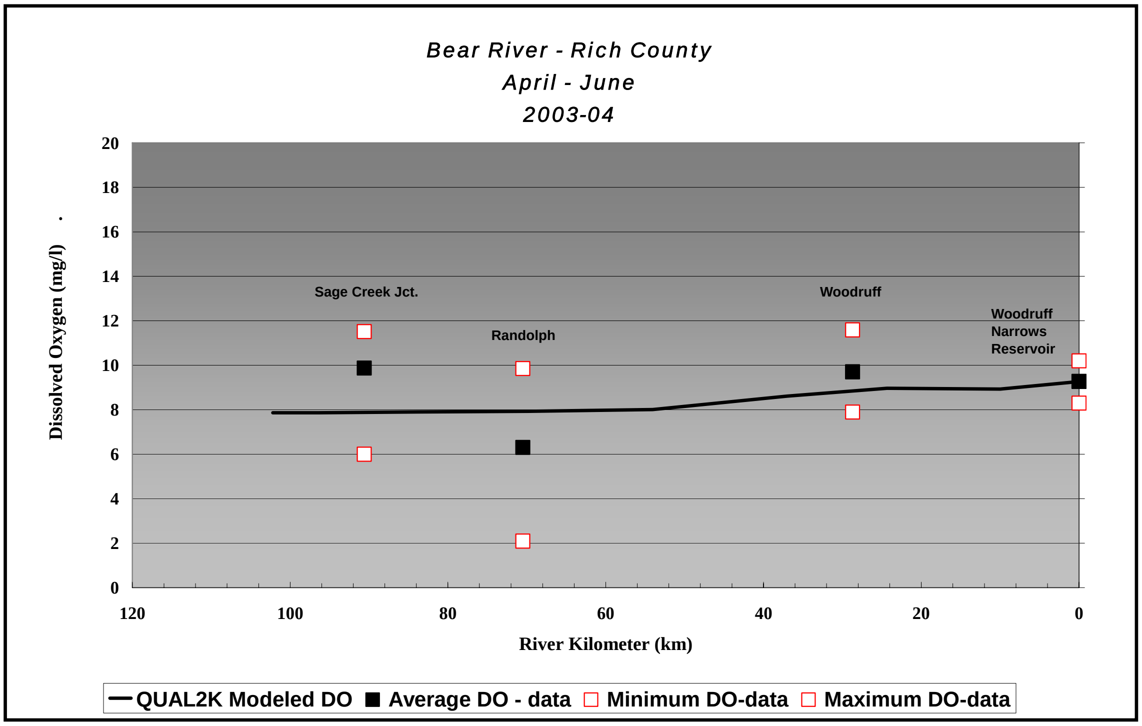


Figure 5.1 QUAL2K modeled DO for impaired segments of the Upper Bear during selected model scenarios.

Following modeling calibration, pollutant loads to the Bear River were reduced by decreasing the concentration of certain water quality parameters including nutrients (phosphorus and nitrogen), sediment, and parameters that are indicative of organic matter loading. Modeled DO concentrations were most responsive to changes in organic matter loading (Table 5.2). Organic matter loading is represented in the QUAL2K model through measured concentrations of BOD (mg/l) and rates of SOD ($gO_2/m^2/d$). Reductions in nutrient concentrations resulted in decreased DO concentrations. This is considered to be a response to decreased algal photosynthesis. An additional reason for the lack of response by modeled DO could be a result of DO saturation. Modeled DO saturation levels were high in some of the modeled scenarios which also concurs with many field measurements of DO saturation collected during 2003-04 in the Upper Bear River. Conditions such as these tend to mask the response of processes that remove oxygen from the water column.

The QUAL2K model has indicated that DO response in the Upper Bear River system would occur more quickly under load reductions of organic matter rather than from Total P. Organic matter loading can be characterized through measurements of water column measurements of BOD as well as measurements of SOD from sediment deposits in the Bear River channel. BOD measurements in the study area are generally limited to a few stations during 1977-1990. No BOD measurements were identified for the modeled time periods at mainstem Bear River monitoring sites. SOD levels are a response to oxidation of organic matter in channel-bottom sediments (Chapra 1997). The source of organic matter can be the result of loading from any organic source in the Upper Bear River watershed and could possibly include vegetative particulate matter (leaves, litter, grass, algae, etc), animal manures, and even small amounts of organic rich soil. SOD levels build up over time and do not respond immediately to reductions in organic matter loading. It is reasonable to expect that if TP loads were reduced, a corresponding decrease would also occur in other water quality parameters such as BOD and ultimately SOD levels in the impaired Bear River segments. The distribution of Total P, BOD and SOD concentrations in the sources of organic matter found in the Upper Bear River watershed would require additional analysis that are beyond the scope of this TMDL. It is assumed that if the annual load at Station 4908100 corresponding to a 0.05 mg/l concentration of TP is achieved, organic matter loading will be reduced sufficiently to restore full beneficial use to impaired segments of the Upper Bear River.

Table 5.2. Response of DO concentration in the Upper Bear River for scenarios with measured average DO concentrations < 6.5 mg/l. The values shown indicate the percent change in modeled DO concentration to a 90 percent decrease in selected pollutants of concern.

Station[1]	Initial modeled DO concentration (mg/l)	TP (%)	NH4 (%)	NO3 (%)	TSS (%)	BOD (%)	SOD (%)
July – September 1998-99 (Wet Year Third Quarter)							
4908900	**8.25**	0.00	0.00	0.00	0.00	0.00	0.00
4908500	**7.88**	-3.61	-1.84	-3.64	0.24	5.51	0.54
4908280	**7.56**	-4.57	-1.37	-5.63	0.36	6.12	3.54
4908100	**6.80**	-2.38	-0.28	-4.06	0.12	3.09	11.80
April – June 2003-04 (Dry Year Second Quarter)							
4908900	**9.27**	0.00	0.00	0.00	0.00	0.00	0.00
4908500	**8.92**	-8.57	-4.10	-3.40	0.41	3.93	0.52
4908280	**8.27**	-8.46	-1.53	-7.42	0.45	4.15	4.14
4908100	**7.11**	-2.06	0.12	-2.73	0.15	2.04	11.02

[1]Stations include the following: 4908900 – Bear River below Woodruff Narrows Reservoir, 4908500 – Bear River East of Woodruff, 4908280 – Bear River at Randolph/Crawford Mountain Road crossing, and 4908100 – Bear River East of Sage Creek Junction at U30 Crossing above confluence with Bridger Creek.

5.3 SEASONALITY

The Clean Water Act requires that TMDLs include seasonality. Seasonality is addressed in this TMDL through modeling water quality on a quarterly basis during both wet and dry years. The wet year corresponds to flows that exceed the 80th percentile annual flow while the dry year is below the 10th percentile annual flow. It is anticipated the flow and water quality records are of sufficient length and frequency to reflect seasonal and interannual changes in precipitation, streamflow and water quality. In addition, the model scenarios were selected to represent a variety of climatic and hydrologic conditions that will clearly define the linkage between DO and other water quality parameters. As a result, the model scenarios will provide a credible and sound basis for developing load reductions that are protective of water quality in the Upper Bear River.

5.4 MARGIN OF SAFETY

The Clean Water Act Also requires that TMDLs include a Margin of Safety (MOS). Generally, this MOS is incorporated into the TMDL via the use of conservative assumptions or is specified explicitly by reserving a particular amount of the permissible loading as a MOS. This TMDL uses conservative assumptions to address the MOS. Conservative assumptions have been made during this assessment and are associated with watershed loading calculations, computer modeling, and selection of the water quality endpoints in the Upper Bear River. It is expected that these assumptions will contribute the necessary MOS in the specified load reductions. In addition, this TMDL will provide full support to previous TMDLs developed for downstream segments of the Bear River in Idaho.

In addition to the conservative assumptions listed above and throughout this document, the TMDL recommended for the Upper Bear River will be evaluated in the future as BMPs/BATs are implemented and additional water quality data is acquired. Follow-up monitoring will be executed to ensure that water quality is improving and water quality standards are being met upon implementation of this TMDL.

5.5 TMDL TARGET LOAD

The TMDL Target Load for the Upper Bear River will need to meet the desired water quality endpoint for DO in the project area as well as consider the influence that discharge from the project area will have on downstream Bear River segments. It should also achieve a balance between the known level of monitoring data, model output, and cost of BMPs/BATs needed to achieve the target load. This assessment recognizes the need to apply concentration limits to pollutant sources that are not overly stringent but still achieve the desired endpoints.

Modeling of water quality and flow has indicated that TP loads are not as influential on DO concentrations in the Upper Bear River as loading from organic matter (SOD and BOD). However, TP loads are a component of organic matter loads that influence levels of SOD and BOD and as such, can provide a means for measuring progress toward load reductions that will result in full support of DO water quality endpoints. Existing and allowable TP loads are shown below in Table 5.3 for Station 4908900 based on the 0.05 mg/l indicator level utilized by the DWQ. Annual TP loads are shown for a wet (1998-99), dry (2003-04) and average years. The total load reduction shown for the average year is 3,886 kg/yr or a 39 percent reduction to the existing annual TP load.

Table 5.3. Existing and allowable annual TP loading to the Upper Bear River measured at Station 4908900 Bear River East of Sage Creek Junction. Allowable loads are based on 0.05 mg/l Total P.					
Time Period	**Average TP Concentration (mg/l)**	**Average Flow (cfs)**	**Annual Load (kg/yr)**	**Allowable Load (kg/yr)**	**Reduction (%)**
1998-99	0.072	351.02	22,600	15,673	31
2003-04	0.079	48.95	3,453	2,186	37
Average (1995-present)	0.082	136.01	9,959	6,073	39

It is anticipated that if the 39 percent load reduction for TP is met at Station 4908900, full support to the 6.5 mg/l water quality endpoint for DO will be achieved for both segments of the Bear River in the project area as well as provide support to maintaining the beneficial use in downstream segments of the Bear River. This is based on (1) an extensive review of water quality monitoring data (including measurements of DO, nutrients, BOD, and SOD), (2) modeled response of DO concentrations in the Upper Bear River to response of water quality inputs, (3) use of conservative assumptions, and (4) best professional judgment.

5.6 FUTURE GROWTH

The TMDL process must account for the influence of future growth on pollutant loading. The impact of future growth patterns and trends on water quality in the study area was generally completed through the year 2030. Projections of future land use patterns and trends within the watershed provide important information related to potential changes in water quality over time. This section includes historic and future population trends, historic agricultural activities, future economic projections, and an analysis of future non-point pollutant sources.

5.6.1 BEAR RIVER BASIN ECONOMIC AND POPULATION GROWTH TRENDS

Three Bear River Basin counties, Rich, Cache, and Box Elder, comprise approximately seven percent of the population in the State of Utah. The 2000 US census indicated that the portion of the basin within Utah had an estimated population of 136,097. The population in this portion of the basin was projected to increase to 203,705 by 2020 and to 297,597 by 2050. This increase corresponds to approximately 50 percent (2 percent annually) over the next 20 years and 119 percent (approximately 1.6 percent annually) over the next 50 years (UDWR 2004).

In general, Utah's population and economic growth rates are projected to continue to out-pace most of the nations through the year 2020. The Governor's Office of Planning and Budget (GOPB) estimated that the population in Rich County in 2000 of 1,961 would increase to 2,447 by 2020 and to 2,809 by 2050. The most recent population projections for Rich County are shown in Table 5.4.

Table 5.4. Population projections for Rich County, Utah (2000-2050).

Area	Year						
	2000	2005	2010	2020	2030	2040	2050
Rich County	1,961	2,086	2,147	2,447	2,636	2,724	2,809
Garden City town	357	390	401	457	492	509	525
Laketown town	188	191	197	224	242	250	257
Randolph city *	483	494	508	579	624	645	665
Woodruff town *	194	198	204	233	251	259	267
Balance of Rich County	739	813	837	954	1,028	1,062	1,095

Source: GOPB (2005)
* Municipalities within the Upper Bear River TMDL project area.

Employment in Rich County is expected to grow at a slower rate when compared to the projections for the state. Natural resources and mining related employment in the county is slowly declining. Projections for this sector indicate that employment will decrease by approximately 14 percent and 47 percent by 2020 and 2050, respectively. Other employment is expected to remain constant or grow at varying rates. Currently, the natural resources and mining sector account for approximately 20 percent of the county's total economy. By 2050, it is projected that this sector will account for approximately five percent of the county's economy (Table 5.5). Agriculture and agricultural-related services account for approximately four percent of the basin's total economy (UDWR 2004).

Table 5.5. Employment projections by category for Rich County and Utah.

Year	2001		2005		2020		2050	
Sector	Rich County	Utah	Rich County	Utah	Rich County	Utah	Rich County	Utah
Natural Resources & Mining	248	32,282	237	31,459	166	28,228	85	29,463
Construction	87	95,869	85	98,937	107	141,999	113	198,791
Manufacturing	103	127,828	97	123,039	113	150,920	150	266,491
Trade, Trans., Utilities	149	259,741	148	271,735	157	342,687	162	452,827
Information	na	36,535	na	33,770	na	41,166	na	51,711
Financial Activity	49	130,519	50	143,752	56	194,359	66	271,310
Professional & Business Svs	29	181,034	27	199,315	32	301,647	40	556,671
Education & Health Svs	80	134,218	93	156,429	173	294,044	486	801,429
Leisure & Hospitality	100	115,490	101	125,644	111	175,690	116	248,618
Other Services	91	72,467	112	81,394	143	113,366	209	178,493
Government	191	206,594	198	216,936	247	299,991	262	396,728
Total	1,127	1,392,577	1,148	1,482,410	1,305	2,084,097	1,689	3,452,532

Source: GOPB (2005).

Despite the small contribution of agriculture to the overall economy of the state, this sector continues to be a major source of water consumption in the Bear River Basin. Land use data for the Utah portion of the Bear River Basin indicated that in 2003 a total of 101,938 acres were used for agriculture, of which 70,693 were irrigated cropland. In recent decades, municipal and industrial water use throughout the state has increased mainly in heavily populated areas while agricultural use has declined. However, in the Bear River Basin the conversion of agricultural to urban land use coupled with the increase of water use for municipalities and industries has not resulted in reductions of agricultural water use. This has been possible due to the abundant water supply in the basin. The conversion of agricultural to urban land use has lead to the reduction of dry farm acreage and not irrigated farm acreage (UDWR 2004).

Availability of water will not limit growth in the near future for most areas of the Bear River Basin. Although significant growth is expected during the next decades, existing water supplies for most of the basin's municipalities are expected to meet projected future demands. Estimates and projections of municipal and industrial water use in Rich County are shown in Table 5.6. Water deficiency is not a cause of serious concern in Rich County. However, Randolph is currently operating at near-capacity levels. Given that Randolph's current water-use rate is more than double the county average, it is likely that conservation efforts in the city would resolve delivery problems that may arise over the next five decades (UDWR 2004).

Table 5.6. Projected culinary municipal and industrial (M&I) demand and supply for public community water systems in Rich County, Utah.

Name	Reliable system source capacity[1]	2020			2050		
		Population	Water Demand[2] (ac-ft/yr)	Surplus (S) or Deficit (D)	Population	Water Demand[2] (ac-ft/yr)	Surplus (S) or Deficit (D)
Garden City	771	428	418	356 (S)	507	424	347 (S)
Laketown City Water System [3]	235	225	194	41 (S)	267	198	37 (S)
Mountain Meadow Park Imp. District	325	120	14	311 (S)	139	14	311 (S)
Randolph City [3]	276	579	280	4 (D)	686	284	8 (D)
Woodruff Culinary Water System [3]	52	223	45	7 (S)	276	46	6 (S)
County Total		1,585	951	708	1,875	966	693

[1] Reliable system source capacity represents the volume of water, which when divided by the average annual per capita use, gives the population that can reliably be served by the existing system under peak demand conditions.
[2] Calculated demand for 2020 and 2050 include 12.5 percent and 25 percent conservation, respectively.
[3] Public water systems within the Upper Bear River TMDL project area.
Source: Based on the projected culinary supply and demand table shown in UDWR (2004) - Bear River Basin- Planning for the future. Population estimates in this table are higher than those presented in Table 5.4.

In addition to considering the future population growth in the Utah portion of the Bear River Basin, it is also necessary to take into account the future population growth in the upstream portion of the basin located in Wyoming. The Upper Bear River watershed encompasses portions of Uinta County and a remote portion of Lincoln County before entering the study area. Due to the remote nature of Upper Bear land areas in Lincoln County, this assessment will focus on Uinta County only. Projections for Uinta County indicate that future population growth could range from approximately two percent to 102 percent by 2030 (Table 5.7).

Table 5.7. Population projections for Uinta County in the Wyoming portion of the Bear River Basin

Total Population	Year		
	1999	2030 Low projection[1]	2030 High projection[2]
Uinta County	13,900	14,160	28,160

[1] Low projection based on the assumption of simultaneous low activity levels in each of the key economic sectors makes this scenario a supportable lower bound for planning purposes.
[2] High projection based on the aggressive assumption that each of the key economic sectors will reach its highest reasonable growth simultaneously. This scenario represents an upper bound for planning purposed.
Source: Bear River Basin Water Plan (2001)

Employment in the portion of Uinta County within the Bear River Basin is likely to increase from three to 104 percent by the year 2030 (Table 5.8). The agricultural sector has historically been a major contributor to the economy of the basin. However, this sector has grown little in recent years and its share to the total economy has declined (WWDC 2001). Recent census data indicated that less than three percent of the employable population in the Bear River area in Uinta County worked in the agriculture sector. The contribution of agriculture to the total employment in Uinta County is likely to decrease. It is estimated that by 2030 less than two percent of the workforce would be employed in agricultural related activities in Uinta County (Table 5.8).

Table 5.8. Employment projections for the portion of the Upper Bear River Basin within Uinta County, Wyoming in the Bear River area only (1999-2030).

	1999 Employment	2030--Low Scenario [1]	2030--High Scenario [1]
Agriculture	260	245	260
Tourism/Visitor Related	640	1,040	1,500
Energy Related	900	0	900
Other Industry (Manuf./Bus. Services)	650	1,170	3,700
Highway/Railroad Construction and Service	100	100	100
State/Federal Government	500	500	500
Net Outcome	800	1,200	1,500
Indirect Basic/Local Service Employment	5620	5,530	11,000
Total Employment	**9,500**	**9,785**	**19,460**

[1] High and low scenarios developed through an economic base approach. Low scenario reflects a slow down in the economy. High scenario assumes each sector reaches the highest reasonable growth.
Source: Bear River Basin Water Plan (2001).

Recent water diversion data indicated that agriculture presents the highest water demand (i.e., 98 percent) from the Bear River Basin in Wyoming. In 2001, estimates of the total annual water demand ranged from 300,601 acre-feet to 425,923 acre-feet during normal and high demand years, respectively. Future projections show that by 2030, an increase of approximately seven percent would be possible during normal and high demand years (Table 5.9). Despite the lack of growth in agriculture, this sector will continue to comprise most of the water demand in the basin. Overall, changes in water demand by 2030 are relatively small due to the continued domination of the agricultural sector (WWDC 2001).

Table 5.9. Projected annual water diversion demand for the Bear River Basin in Wyoming.

Demand Type	1999 Demand year (ac-ft)		Low Scenario[1] Demand year (ac-ft)		High Scenario[2] Demand year (ac-ft)	
	Normal	**High**	**Normal**	**High**	**Normal**	**High**
Agriculture	295,196	419,713	277,265	394,736	312,188	443,850
Municipal	4,446	5,030	4,342	4,938	8,364	9,550
Rural Domestic	500	500	504	504	959	959
Industrial	459	680	NA	NA	494	731
Environmental	NA	NA	15,305	21,434	NA	NA
Total	**300,601**	**425,923**	**297,778**	**421,614**	**322,055**	**455,091**

[1] Low scenario based on the lowest growth reasonable likely to occur in main economic sectors.
[2] High scenario based on the most growth reasonably likely to occur in main economic sectors. Assumes that each sector will achieve its highest likely growth simultaneously.
Source: Bear River Basin Water Plan (2001)

5.6.2 MUNICIPAL GROWTH TRENDS

The analysis of census data indicated that population size at the municipalities of Laketown, Randolph, and Woodruff has remained relatively stable or decreased in the past 100 years (Figure 5.2). Although Laketown is not located in the study area, it is addressed here in order to identify the potential for regional effects on growth. The municipalities in Rich County are relatively small. Randolph, the largest municipality in the county, has a population of 494. Population growth was not observed during the 1990s in Laketown and Randolph while a population increase was observed at Woodruff (Figure 5.2).

Population projections indicate that growth is anticipated for Laketown, Randolph, and Woodruff. Based on the population projections shown in Figure 5.2, it is estimated that the population of all municipalities will increase approximately 20 percent and 37 percent by 2020 and 2050, respectively.

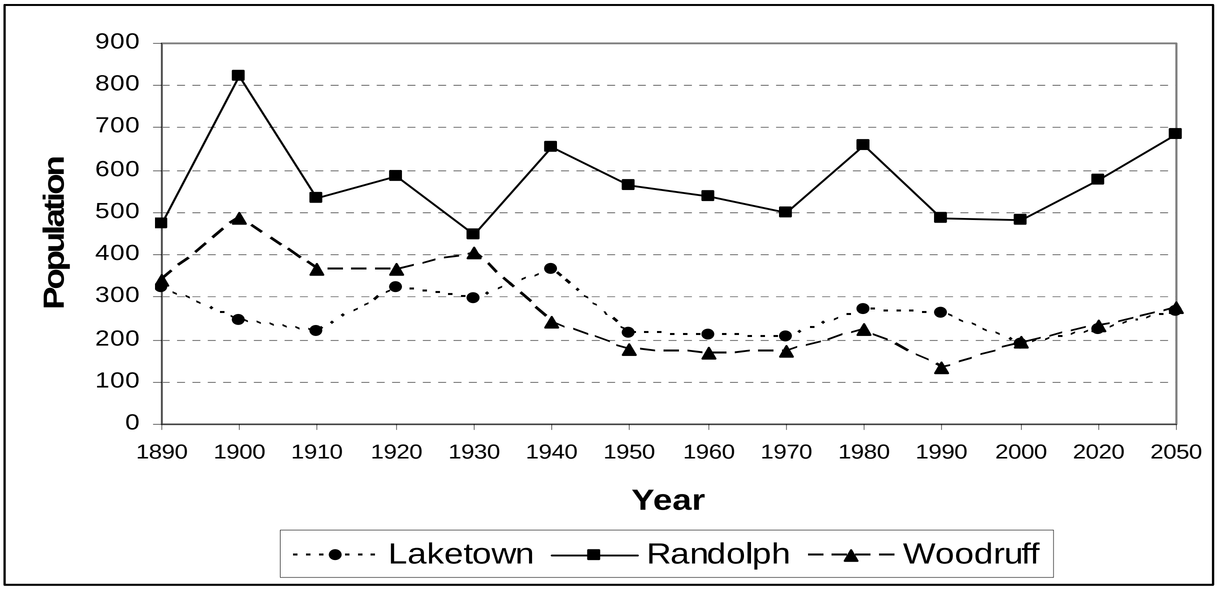


Figure 5.2. Historic population and projections for Laketown, Randolph, and Woodruff. Based on GOBP historic data and projections cited in UDWR (2004) - Bear River Basin-Planning for the future.

In general, the main sources of employment in Laketown include education, health, and social services followed by agriculture, forestry, fishing and hunting, and mining related occupations. The largest proportion of employed population in Randolph and Woodruff fill occupations in the agriculture, forestry, fishing and hunting, and mining industry. Education, health, and social services also provide jobs for a large proportion of the population in these municipalities (Table 5.10).

Table 5.10. Number and percentage of employed population by industry in Laketown, Randolph, and Woodruff.

Industry	Laketown	Randolph	Woodruff
	Number (percent)		
Agriculture, forestry, fishing and hunting, and mining	17 (16.5)	46 (27.4)	26 (34.2)
Construction	13 (12.6)	13 (7.7)	6 (7.9)
Manufacturing	6 (5.8)	3 (1.8)	0
Wholesale trade	3 (2.9)	2 (1.2)	0
Retail trade	3 (2.9)	23 (13.7)	8 (10.5)
Transportation and warehousing, and utilities	2 (1.9)	6 (3.6)	2 (2.6)
Information	0	2 (1.2)	0
Finance, Insurance, real state, and rental and leasing	0	5 (3.0)	0
Professional, scientific, management, administrative, and waste management	6 (5.8)	3 (1.8)	0
Educational, health, and social services	40 (38.8)	32 (19)	22 (28.9)
Arts, entertainment, recreation, accommodation and food services.	11 (10.7)	11 (6.5)	3 (3.9)
Other Services (except public administration)	2 (1.9)	12 (7.1)	4 (5.3)
Public Administration	0	10 (6)	5 (6.6)

Source: U.S Census Bureau (2000 Census dataset).

5.6.3 LIVESTOCK TRENDS

Utah cattlemen had an average of 861,600 cattle and calves on farms and ranches from 1981 to 2005. Within this period, all cattle and calf numbers in the state ranged from 770,000 to 950,000 animals in 1987 and 1983, respectively (Table 5.11). During the past 25 years, Rich County has contributed five to six percent of the total cattle production in the state. Cattle numbers in Rich County have ranged from 37,000 in 1987 to 56,000 in 1999.

Utah sheep and lamb inventories from 1981 to 2005 averaged 462,120 animals, ranging from 265,000 in 2004 to 650,000 in 1981. Sheep numbers in Rich County for this period have ranged from 9,500 to 22,000 in 1999 and 1984, respectively. The production of sheep in the county contributed approximately four percent of the production in the state from 1984 to 1991 and has decreased by one or two percent since the early 1990s (Table 5.11).

Table 5.11. Livestock numbers for Utah and Rich County (1981-2005).

Year	All Cattle and Calves			Breeding Sheep And Lambs		
	Utah Total	Rich County	Percent of State	Utah Total	Rich County	Percent of State
1981	875,000	40,600	5	650,000	NA	NA
1982	920,000	43,500	5	636,000	NA	NA
1983	950,000	47,000	5	590,000	NA	NA
1984	865,000	43,000	5	568,000	22,000	4
1985	800,000	39,000	5	515,000	20,000	4
1986	790,000	38,000	5	484,000	17,000	4
1987	770,000	37,000	5	464,000	19,000	4
1988	800,000	42,000	5	478,000	20,000	4
1989	800,000	44,500	6	503,000	20,500	4
1990	780,000	44,000	6	509,000	19,000	4
1991	810,000	50,000	6	508,000	18,000	4
1992	800,000	47,000	6	488,000	14,600	3
1993	850,000	48,000	6	490,000	13,400	3
1994	860,000	47,000	5	480,000	16,000	3
1995	890,000	50,000	6	470,000	13,500	3
1996	910,000	52,000	6	460,000	13,000	3
1997	930,000	53,000	6	440,000	12,000	3
1998	910,000	53,000	6	420,000	10,000	2
1999	890,000	56,000	6	400,000	9,500	2
2000	910,000	55,000	6	400,000	13,500	3
2001	910,000	52,000	6	390,000	12,700	3
2002	920,000	52,000	6	365,000	12,000	3
2003	880,000	40,000	5	310,000	NA	NA
2004	860,000	40,000	5	265,000	NA	NA
2005	860,000	40,000	5	270,000	NA	NA
Average	861,600	46,144		462,120	15,563	
Min	770,000	37,000		265,000	9,500	
Max	950,000	56,000		650,000	22,000	

Source: USDA (2006).

Cattle numbers in Rich County increased steadily from 1987 to 1999. Since then, numbers have decreased in response to the drought with the largest drop occurring from 2002 to 2003. Cattle numbers have remained stable in the past three years. Conversely, the production of sheep experienced a decreasing trend from 1982 to 2002. The most recent increase in sheep numbers was observed from 1999 to 2000, but a decrease was observed from 2000 to 2002 (Figure 5.3)

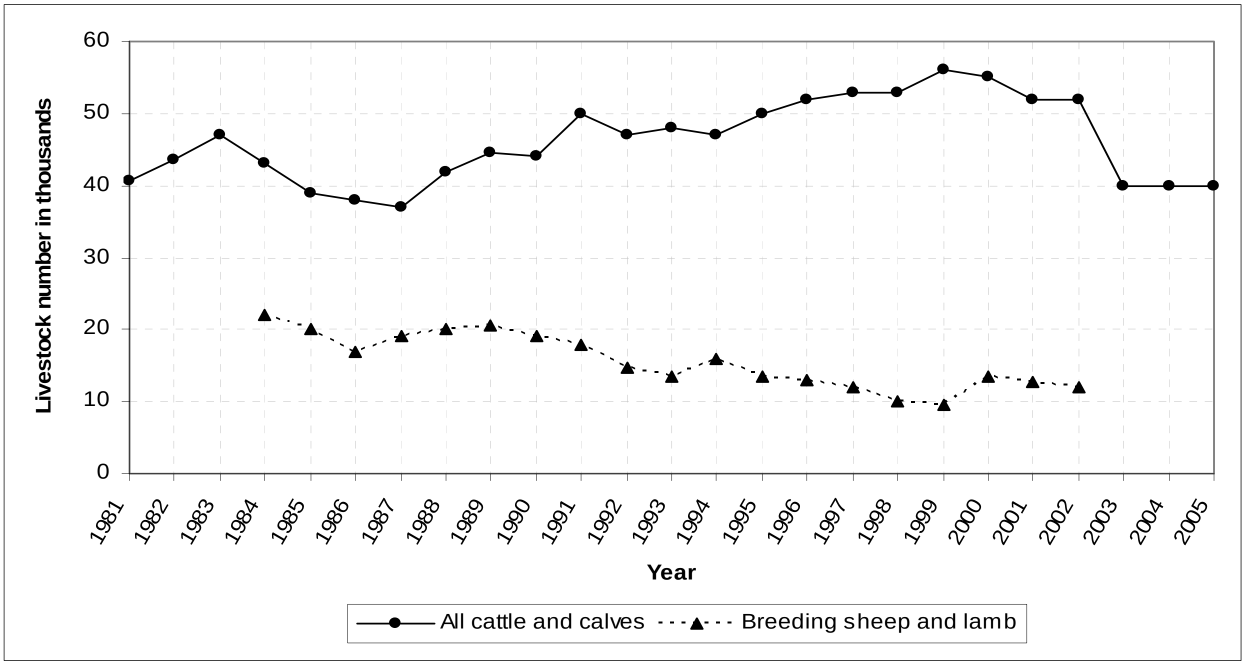


Figure 5.3. Livestock numbers in Rich County from 1981 to 2005. Source: USDA (2006).

5.6.4 FUTURE POLLUTANT SOURCE ANALYSIS

Potential future changes to the amount and type of non-point source pollution would be primarily associated with land use changes that may occur in non-municipal areas of the watershed. Such changes could result from variations in agricultural practices (including the type of crops, irrigation design, and livestock grazing practices), the presence of animal feeding operations, and the development of residential areas outside of municipal boundaries. In turn, changes associated with land use could affect diffuse loads from runoff. A brief discussion of these potential scenarios is provided below along with the associated potential impacts (if any) to water quality.

5.6.4.1 Future Loading - AFOs

The amount of irrigated cropland, the type of crop grown, and cropping practices used during production, including tillage and irrigation methods, affect non-point source pollution associated with crop production. As stated previously, agriculture continues to be a major water use in both the Utah and Wyoming portions of the Bear River Basin. The primary component contributing to production of non-point source pollution is the use of fertilizers including both processed chemical fertilizers and non-processed fertilizers (manure).

The agriculture sector throughout the Upper Bear River basin has grown little in recent years. The contribution of this sector to the economy of Rich County in Utah and Uinta County in Wyoming remain very small (less than five percent). However, despite the increase of water use for other sectors (e.g., municipal and industrial use), and the conversion of agricultural land to urban, a significant reduction in the demand of water for agriculture is not likely any time soon.

The Bear River Basin experienced a very small decrease (less that one percent) in irrigated croplands from 1986 to 2003. In Rich County, the total irrigated acreage decreased from 73,436 acres in 1986 to 70,693 in 2003. This corresponds to a reduction of approximately four percent (UDWQ 2004). Based on future population projections for Rich County, the conversion of agricultural to urban lands may lead to a small reduction of water use in irrigated croplands. Overall, agricultural activity throughout the basin is expected to decline slightly during the next few decades.

Along with the expected decline in agricultural activity, animal feeding operations are likely to continue operating at current rates or experience slight declines. Therefore, an increase in stream loading from animal feeding operations is not anticipated.

5.6.4.2 Future Loading – Livestock grazing

Livestock numbers in Rich County remain relatively constant (for cattle) or have decreased (for sheep) (Figure 5.3). Based on livestock number trends for the county, it is anticipated that grazing will remain relatively constant or decline in the coming years. A decline in sheep numbers is more likely than a decreasing trend in cattle production. Therefore, it is assumed that the potential for future nutrient loading from livestock grazing is small and may decline over time.

5.6.4.4 Future Loading – Diffuse Runoff

Based on the projected growth of population and municipal areas, it is possible that the expected decrease of non-point source loads from agricultural activity could be balanced by non-point source loads that result from urban and industrial expansion. Although the patterns of land use will likely change in the future, the management of existing land use categories may remain the same or improve. Consequently, a change in non-point source loading from surface runoff is not anticipated.

The use of flood irrigation practices will likely be maintained or slightly decrease during the next several decades. Increased water demand in the Bear River Basin will likely create a need for greater efficiency and management of water. It is likely that future loading from irrigation return flows will remain the same or slightly decrease if some conversion from flood irrigation to a more efficient irrigation method takes place.

5.6.4.5 Future Loading – Summary

Based on the assessment of future growth trends in the study area, it is anticipated that slight changes may occur to land cover and land use. These changes are associated with the general decline experienced in many agricultural areas in Utah during the past decade. It is anticipated that these changes will be slight in the Upper Bear River watershed and that no net increase in TP loads to the Bear River will occur.

5.7 ALLOCATION OF POLLUTANT LOADS

The process used to allocate pollutant loads between sources in the TMDL study area has considered many factors. Some of these include public involvement, existing plans for implementing BMP/BATs in the study area, cost, projected future load from pollutant sources, and effectiveness of BMPs. The loading summary for the Upper Bear River is included below in Table 5.12. The necessary reduction of TP loading to the Upper Bear River is approximately 39 percent. Table 5.13 shows the allocation of the permissible load to the major pollutant sources and the required reductions in loading from each source. The measures needed to achieve the load allocations shown in Table 5.13 are included in Appendix PIP.

Table 5.12. Summary of TP loads for the Upper Bear River TMDL.[1]

Category	Allocation (kg/yr)
Existing load to Upper Bear River[2]	9,974
Permissible load (loading capacity)	6,073
Reserve for future growth	0
Load allocation	6,073
Necessary reduction	3,901 (39%)

[1]Load allocations shown in this table represent loads to Station 4908900 Bear River East of Sage Creek Junction.
[2]Based on flow and water quality data 1995-2005.

Table 5.13. Allocation of permissible TP loads to the Upper Bear River.[1]

Source	Watershed Outlet Load (kg/yr)	Watershed Outlet Load Allocation per TMDL (kg/yr)	Reduction (%)	Total Watershed Load (kg/yr)	Total Watershed Load Allocation per TMDL (kg/yr)
Livestock Grazing					
BLM allotments	276.1	193.27	30	1,602	1,121
NFS allotments	35	24.5	30	203	142
Private Land	938.5	656.95	30	5,445	3,810
Diffuse Runoff					
Urban/Residential	102	81.6	20	592	473
Forest Land	90.1	72.08	20	523	418
Range Land	2,263.40	1,471.21	35	13,132	8,533
Irrigated Agriculture	4,149.60	2,074.8	50	24,076	12,034
Non-Irrigated Agriculture	2,068.80	1,448.16	30	12,003	8,399
Wetlands	48.6	48.6	0	282	282
Barren	1.9	1.9	0	11	11
Total (kg/yr)	**9,974**	**6,073**		**57,869**	**35,224**

[1]Watershed outlet loads are calculated at Station 4908900 Bear River East of Sage Creek Junction. Total watershed loads represent loading at the pollutant source and not loading at the watershed outlet.