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Bear River Sediment TMDL Public Notice

Prepared for

Wyoming Department of Environmental Quality

Prepared by

SWCA Environmental Consultants

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BEAR RIVER SEDIMENT TMDL
PUBLIC NOTICE

Prepared for

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WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER QUALITY DIVISION
BEAR RIVER SEDIMENT TMDL

TMDL SUMMARY TABLE

Waterbody Name	**Bear River**
Waterbody ID	WYBR160101010303_01
Location	From the confluence with Woodruff Narrows Reservoir upstream to the confluence with Sulphur Creek; Uinta County, Wyoming
Causes of Impairment	Sediment, Habitat Modification
Impaired Designated Uses	2AB, Cold Water Fishery, Aquatic Life other than Fish
List Date	2002
Priority Ranking	2012
Current Load (tons/day total suspended solid [TSS])	68.1
Loading Capacity (tons/day TSS)	55.0
Margin of Safety (tons/day TSS)	5.5
Wastewater Treatment Plant Waste Load Allocations (tons/day TSS)	City of Evanston (WY0020095): 0.36 Town of Bear River (WY0031712): 0.07 Pilot Travel (Flying J) (WY0035700): 0.01 **Total: 0.45**
Stormwater Load Allocations (tons/day TSS)	None, no municipal separate storm sewer systems (MS4) in watershed
Nonpoint Source Load Allocations (tons/day TSS)	Upstream: 5.6 Sulphur Creek: 0.9 Impaired segment: 36.8 City of Evanston stormwater: 0.01 Yellow Creek: 0.5 *Subtotal: 43.8* Natural background: 5.2 **Total: 49.0**
Future Growth Waste Load Allocations (tons/day TSS)	None, wastewater treatment plants are not planning expansion
Defined Targets/Endpoints TSS	TSS 30 mg/L
Watershed Nonpoint Sources	Instream erosion
Regulated Point Sources	City of Evanston (WY0020095) Town of Bear River (WY0031712) Pilot Travel (Flying J) (WY0035700)

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EXECUTIVE SUMMARY

This document represents the total maximum daily load (TMDL) analyses of an impaired segment of the Bear River within the Upper Bear River Sub-basin in fulfillment of the requirements by the Clean Water Act. The overall goal of this TMDL process is to restore and maintain water quality in the impaired segment of the Bear River to a level that protects and supports its designated uses (e.g., drinking water, game and non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value). This TMDL was developed by SWCA Environmental Consultants under the direction of the Wyoming Department of Environmental Quality (WDEQ).

Based on a monitoring assessment completed by WDEQ, Water Quality Division (WQD) in 1998 (WDEQ 2001a), the Bear River from the confluence of Sulphur Creek to Woodruff Narrows Reservoir was determined not to be supporting its designates uses for "cold water fishery and aquatic life other than fish" due to excess sediment in the river. Therefore, WDEQ added this segment of the Bear River to their 303(d) list in 2002 (WDEQ 2012a). This report defines the TMDL and water quality targets that, when attained, will bring the impaired segment of the Bear River into full support of the uses designated by the State of Wyoming.

The impaired segment of the Bear River is in Uinta County, Wyoming. The county seat is the City of Evanston. The City of Evanston, located within the Bear River watershed, was founded in 1868 and settled in the late 1800s to early 1900s. In 2010, Uinta County had an estimated population of 21,118 and the City of Evanston had an estimated population of 12,359 (U.S. Census Bureau 2010). Uinta County's population has increased at an average of 5.5% annually in recent years.

For the purposes of this TMDL, the Bear River watershed was defined as the approximately 152,946-acre drainage area within the Upper Bear River sub-basin that contributes sediment load to the impaired segment. Elevations in the Bear River watershed range from 7,500 feet in its upper reaches to 6,500 feet at Woodruff Narrows Reservoir. Surface waters in the Bear River watershed are used to provide irrigation water and water supply for some rural and urban residents. The Bear River watershed includes three primary drainages: Bear River, Sulphur Creek, and Yellow Creek. The Bear River flows north through Uinta County, Wyoming, before reaching Woodruff Narrows Reservoir. In the Bear River watershed, Sulphur Creek discharges from Sulphur Creek Reservoir and flows northwest for approximately 6 miles before joining the Bear River southeast of the City of Evanston. In the Bear River watershed, Yellow Creek discharges from Barker Reservoir and flows northeast for approximately 24 miles before joining the Bear River northeast of the City of Evanston. Land uses vary greatly in the Bear River watershed and include urban areas, agriculture lands, irrigated and non-irrigated hay meadows, wildlife habitat, and rangeland.

Hydrologic and climate data from 1981 to 2012 were used in this TMDL to describe seasonal patterns in the system, to identify periods of critical sediment loads, and to calculate sediment loads. In the Bear River watershed, peak flows typically occur in May and June and are the direct result of snowmelt in the headwaters and throughout the watershed. In the Bear River watershed, some spring snowmelt is stored in two reservoirs (Sulphur Creek Reservoir and Barker Reservoir) that provide irrigation and drinking water. Below the reservoirs, water is also diverted through numerous irrigation diversion canals and ditches.

Water quality data from 2007 to 2012, in addition to 16 stream surveys conducted in the summer of 2013, were used for analysis in this TMDL. Data were obtained from the U.S. Geological Survey (USGS), the Uinta County Conservation District (UCCD), the Utah Department of Environmental Quality, and WDEQ. Biannual water quality and flow data available from UCCD over a 5-year period (2007–2012) were the most complete and were used in the calculation of sediment loads. These UCCD data were available at four stations along the length of the Bear River and one station on Sulphur Creek. Water

quality parameters in the UCCD data that relate directly to sediment included total suspended solids and turbidity. Supplemental information was available from habitat surveys conducted along the Bear River and Sulphur Creek by WDEQ in 1999 to assess beneficial use status of these waterbodies. Additional flow data from three USGS stream gages on the Bear River and one on Sulphur Creek were used to develop flow and load duration curves.

The sediment TMDL identifies the current sediment load and the sediment load capacity for the impaired segment of the Bear River. Sediment loads associated with seasonal flows are described separately for high-, medium-, and low-flow periods, as defined by individual flow duration curves developed for separate reaches of the impaired segment. The primary source of sediment to the impaired segment is instream erosion within the impaired segment, making up 77% of the total sediment load. Nonpoint source loads from tributaries and upstream reaches make up most of the remaining total sediment load. There are three point sources of sediment: one discharges directly to the impaired segment, and two discharge to tributaries of the impaired segment. Point sources make up less than 1% of the total sediment load to the impaired segment. The overall sediment load reduction required for the impaired segment is 13.1 tons per day, or a 19% overall reduction.

A watershed-based implementation plan was developed for the Bear River watershed. This plan outlines a strategy to reduce sediment loads and to attain Wyoming's water quality standards for the impaired segment of the Bear River. This implementation plan was developed for and submitted to stakeholders in the watershed, and includes the nine key elements identified by the U.S. Environmental Protection Agency.

Recommended management and implementation measures to reduce sediment loads are defined and described in the implementation plan as potential tools for watershed stakeholders. These management measures focus primarily on reducing instream erosion. In addition, required financial and technical resources are identified for each management measure so that stakeholders can estimate time and labor costs for recommended sediment reduction strategies. Furthermore, an implementation schedule and interim milestones for nonpoint source management measures are also established. These milestones provide a general framework to track progress of watershed implementations geared toward improving water quality. An effectiveness monitoring plan was also developed and is included in this TMDL document.

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ABBREVIATIONS

°F	degrees Fahrenheit
BANCS	Bank Assessment for Nonpoint source Consequences of Sediment
BEHI	bank erosion hazard index
BLM	Bureau of Land Management
BMP	best management practices
BURP	beneficial use reconnaissance project
cfs	cubic feet per second
CWA	Clean Water Act
DMR	data monitoring report
EPA	U.S. Environmental Protection Agency
FDCs	flow duration curves
HUC	Hydrologic Unit Code
I-80	Interstate 80
IDEQ	Idaho Department of Environmental Quality
mg/L	milligrams per liter
MGD	million gallons per day
MOS	margin of safety
MS4	municipal separate storm sewer systems
LA	load allocation
NBS	near bank stress
NCDC	National Climate Data Center
NLCD	National Land Cover Database
NMAS	National Map Accuracy Standards
NSQD	National Stormwater Quality Database
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NTU	nephelometric turbidity units
PIP	public involvement plan
PLA	Prediction Level Assessment
RLA	Reconnaissance Level Assessment
RRISSC	Rapid Resource Inventory for Sediment and Stability Consequence
TAC	technical advisory committee
TMDL	total maximum daily load
TSS	total suspended solid
UCCD	Uinta County Conservation District

UDEQ	Utah Department of Environmental Quality
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WARSSS	Watershed Assessment of River Stability and Sediment Supply
WBD	Watershed Boundary Dataset
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department
WLA	wasteload allocation
WQD	Water Quality Division
WRCC	Western Regional Climate Center
WYPDES	Wyoming Pollutant Discharge Elimination System

1 INTRODUCTION AND BACKGROUND

1.1. Purpose

This document presents the total maximum daily load (TMDL) study for the Bear River in fulfillment of Clean Water Act (CWA) requirements delegated to the State of Wyoming by the U.S. Environmental Protection Agency (EPA).

A TMDL study describes the amount of an identified pollutant that a specific stream, lake, river, or other waterbody can contain while preserving its designated uses and state water quality standards. Once the state has identified the pollutant load from both point and nonpoint sources, management measures can be implemented to reduce the daily load of pollutants until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL study, it is submitted to the EPA for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was expanded in 1972 and became known as the CWA. The purpose of the CWA is to improve and protect the physical, chemical, and biological integrity of the nation's waters. The CWA requires EPA or delegated authorities such as states, tribes, and territories to evaluate the quality of waters, establish beneficial uses, and define water quality criteria to protect those uses. Section 303(d) of the CWA requires that every 2 years, each state must submit to the EPA a list of waterbodies that do not meet state water quality standards. This list is the "303(d) list," and waterbodies identified on the list are referred to as *impaired waters*. For impaired waters, the CWA requires a TMDL study for each pollutant responsible for impairment of its designated use(s).

The Wyoming Department of Environmental Quality (WDEQ), Water Quality Division (WQD) collects biological and water quality data to evaluate the quality of the waters of the State of Wyoming. Based on a monitoring assessment completed by the WQD in 1998 (WDEQ 2001a), the Bear River from the confluence of Sulphur Creek to Woodruff Narrows Reservoir was determined not to be supporting its designated uses for "cold water fishery and aquatic life other than fish" due to excess sediment in the river. Therefore, WDEQ added this segment of the Bear River to their 303(d) list in 2002 (WDEQ 2012a). This report defines the TMDL and water quality targets that, when attained, will bring the impaired segment of the Bear River into full support of the uses designated by the State of Wyoming.

1.2. Problem Description

In 1998, the WQD completed a monitoring assessment of the Bear River from the headwaters near the Utah-Wyoming state line to the inlet of Woodruff Narrows Reservoir (WDEQ 2001a). The results of this assessment showed a modification of the aquatic habitat due to excess sediment.

Excessive sediment, especially fine sediment like silts and clays, both directly and indirectly affects the health of fish populations. Three major direct effects of excess sediment on fishes are 1) behavioral effects, such as inability to see prey or feed normally; 2) physiological effects, such as gill clogging; and 3) effects due to sediment deposition, such as burial and suffocation of eggs and larvae. Indirect effects include 1) changes in prey composition due to shifts in macroinvertebrate communities, and 2) changes in habitat due to sediment deposition and loss of submerged aquatic vegetation (EPA 2003).

Excess sediment along the impaired segment of the Bear River has caused increased sedimentation on sample riffles (embeddedness), declining cold water game fish density, and a shift in the "clean water" benthic macroinvertebrate taxa to those that tolerate excess sediment (WDEQ 2001a).

1.2.1. Designated Use Support Determination and Associated Water Quality Standards

Protection of waters under the CWA consists of three main components: 1) designating uses, 2) establishing water quality criteria to protect those uses, and 3) developing and applying antidegradation policies and procedures.

The State of Wyoming has designated surface water uses, water quality criteria to protect those uses, and antidegradation policies and procedures in *Water Quality Rules and Regulations Chapter 1, Wyoming Surface Water Quality Standards* (hereafter Wyoming's surface water quality standards; WDEQ 2013a). Section 2(b)(ix) of the surface water quality standards defines designated uses as "those uses specified in water quality standards for each water body or segment whether or not they are being attained" (WDEQ 2013a:1-3). The designated uses that are protected for Wyoming's surface waters are listed and described in Section 3 of the surface water quality standards and include agriculture, fisheries, industry, drinking water, recreation, scenic value, aquatic life other than fish, wildlife, and fish consumption. These uses are defined in Wyoming's surface water quality standards as follows (WDEQ 2013a:1-9–1-10):

> (a) Agriculture. For purposes of water pollution control, agricultural uses include irrigation and/or livestock watering.
>
> (b) Fisheries. The fisheries use includes water quality, habitat conditions, spawning and nursery areas, and food sources necessary to sustain populations of cold water game fish, warm water game fish and nongame fish. This use does not include the protection of aquatic invasive species or other fish which may be considered "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within their appropriate jurisdictions.
>
> (c) Industry. Industrial use protection involves maintaining a level of water quality useful for industrial purposes.
>
> (d) Drinking water. The drinking water use involves maintaining a level of water quality that is suitable for potable water or intended to be suitable after receiving conventional drinking water treatment.
>
> (e) Recreation. Recreational use protection involves maintaining a level of water quality which is safe for human contact. It does not guarantee the availability of water for any recreational purpose. The recreation designated use includes primary contact recreation and secondary contact recreation subcategories.
>
> (f) Scenic value. Scenic value use involves the aesthetics of the aquatic systems themselves (odor, color, taste, settleable solids, floating solids, suspended solids and solid waste) and is not necessarily related to general landscape appearance.
>
> (g) Aquatic life other than fish. This use includes water quality and habitat necessary to sustain populations of organisms other than fish in proportions which make up diverse aquatic communities common to the waters of the state. This use does not include the protection of human pathogens, insect pests, aquatic invasive species or other organisms which may be

considered "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within their appropriate jurisdictions.

(h) Wildlife. The wildlife use includes protection of water quality to a level which is safe for contact and consumption by avian and terrestrial wildlife species.

(i) Fish consumption. The fish consumption use involves maintaining a level of water quality that will prevent any unpalatable flavor and/or accumulation of harmful substances in fish tissue.

Wyoming's surface waters are classified according to their designated uses using a hierarchical system described in Wyoming's surface water quality standards (WDEQ 2013a). There are four major classes of surface water in Wyoming with various subcategories within each class. This approach places waters into Classes 1–4 (Table 1.1) based on their designated uses, with Class 1 waters being managed for the highest and Class 4 the lowest water quality, respectively.

Table 1.1 provides a summary of Wyoming's surface water classifications (far left column) and associated designated uses (top row). For each surface water class, a "Yes" indicates that a designated use is protected for that class, whereas a "No" indicates that the use is not protected for that class (WDEQ 2013b).

Table 1.1. Wyoming's Surface Water Classes and Designated Uses

Class	Drinking Water	Game Fish	Non-game Fish	Fish Consumption	Other Aquatic Life	Recreation	Wildlife	Agriculture	Industry	Scenic Value
1*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2D	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3D	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

Source: WDEQ (2013b).

Notes: "Yes" indicates the use is protected for that water class, whereas "No" indicates that it is not protected for that water class.

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the national parks and wilderness areas are Class 1; however, all do not support fisheries or other aquatic life uses (e.g., hot springs, ephemeral waters, wet meadows; WDEQ 2013b).

The State of Wyoming has classified the Bear River (in Wyoming) as a Class 2AB surface water. Waters classified as Class 2AB are defined by the WDEQ as follows in the Wyoming surface water quality standards:

> Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the *Wyoming Surface Water Classification List*. Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses. (WDEQ 2013a:1-10).

Section 305(b) of the CWA requires states to describe the water quality condition of all their waters and determine whether these waters support their designated uses. As stated in the *Wyoming Water Quality Assessment and Impaired Waters List (2012 Integrated 305(b) and 303(d) Report)* (hereafter the integrated report; WDEQ 2012a), Wyoming's Watershed Monitoring Program is responsible for providing most of the information used in determining whether designated uses are supported for the surface waters of the state; however, other groups (e.g., the U.S. Geological Survey [USGS] and Wyoming's 34 conservation districts), also contribute substantially. These data are used to determine water quality condition following methods outlined in *Wyoming's Method for Determining Water Quality Condition of Surface Waters and TMDL Prioritization Criteria for 303(d) Listed Waters* (WDEQ 2013c). This methodology is revised periodically to maintain consistency with changes in the state's water quality standards and to comply with Wyoming's "Credible Data" Law.

Generally, a water is deemed to be non-supporting of one or more designated uses (i.e., impaired) if any narrative or numeric criteria are exceeded, or if designated uses are shown to be adversely affected by anthropological activities (WDEQ 2013c).

Wyoming's integrated report (WDEQ 2012a) lists the Bear River (between Sulphur Creek and Woodruff Narrows Reservoir) as not supporting its "cold water fishery and aquatic life other than fish" designated uses due to sedimentation, and this segment was added to the 303(d) list in 2002.

The second component of the protection of waters under the CWA is the establishment of water quality criteria to protect designated uses. Wyoming's water quality standards applicable to sediment for the impaired "cold water fishery and aquatic life other than fish" uses of the Bear River consist of both narrative descriptions and numeric limits for individual pollutants and desired conditions (Table 1.2).

Table 1.2. Narrative and Numeric Surface Water Quality Standards Applicable to the Impaired Designated Use of the Bear River

Parameter	Water Quality Standard Reference	Standard/Description
Settleable solids	Section 15	In all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank, or bottom deposits shall not be present in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life, or wildlife.
Floating and suspended solids	Section 16	In all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities that could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life, or wildlife.
Turbidity	Section 23	(a) In all cold water fisheries and drinking water supplies (classes 1, 2AB, 2A, and 2B), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than ten (10) nephelometric turbidity units (NTUs). (b) In all warm water or nongame fisheries (classes 1, 2AB, 2B and 2C), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 15 NTUs.

Source: Wyoming's surface water quality standards (WDEQ 2013a).

The water quality standards listed above for sediment are defined to prevent sediment from exceeding quantities that would impair designated uses. This approach allows for flexibility in managing sediment TMDLs, but also requires interpretation on a site-specific basis to identify appropriate numeric targets. The numeric sediment target set for the Bear River TMDL is protective of all Class 2AB uses designated for the Bear River. Numeric sediment targets developed for this TMDL are discussed and presented in section 2.

The third component for the protection of waters under the CWA consists of antidegradation policies and procedures. Wyoming's Antidegradation Policy, described in Section 8 of Wyoming's surface water quality standards (WDEQ 2013a:1-14–1-15) states the following:

> Water uses in existence on or after November 28, 1975 and the level of water quality necessary to protect those uses shall be maintained and protected. Those surface waters not designated as Class 1, but whose quality is better than the standards contained in these regulations, shall be maintained at that higher quality. However, after full intergovernmental coordination and public participation, the department may issue a permit for or allow any project or development which would constitute a new source of pollution, or an increased source of pollution, to these waters as long as the following conditions are met:
>
> (i) The quality is not lowered below these standards;
>
> (ii) All existing water uses are fully maintained and protected;
>
> (iii) The highest statutory and regulatory requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint sources have been achieved; and

(iv) The lowered water quality is necessary to accommodate important economic or social development in the area in which the waters are located.

(b) The Water Quality Administrator (administrator) may require an applicant to submit additional information, including, but not limited to, an analysis of alternatives to any proposed discharge and relevant economic information before making a determination under this section.

(c) The procedures used to implement this section are described in the *Antidegradation Implementation Policy*.

1.2.2. Waterbody Identification Number, Listing Dates, and Impairments

The waterbody identification number for the impaired segment of the Bear River is WYBR160101010303_01. This 36.5-mile segment of the Bear River was added to the 303(d) list in 2002 due to impairment of its designated use for cold water fishery and aquatic life other than fish.

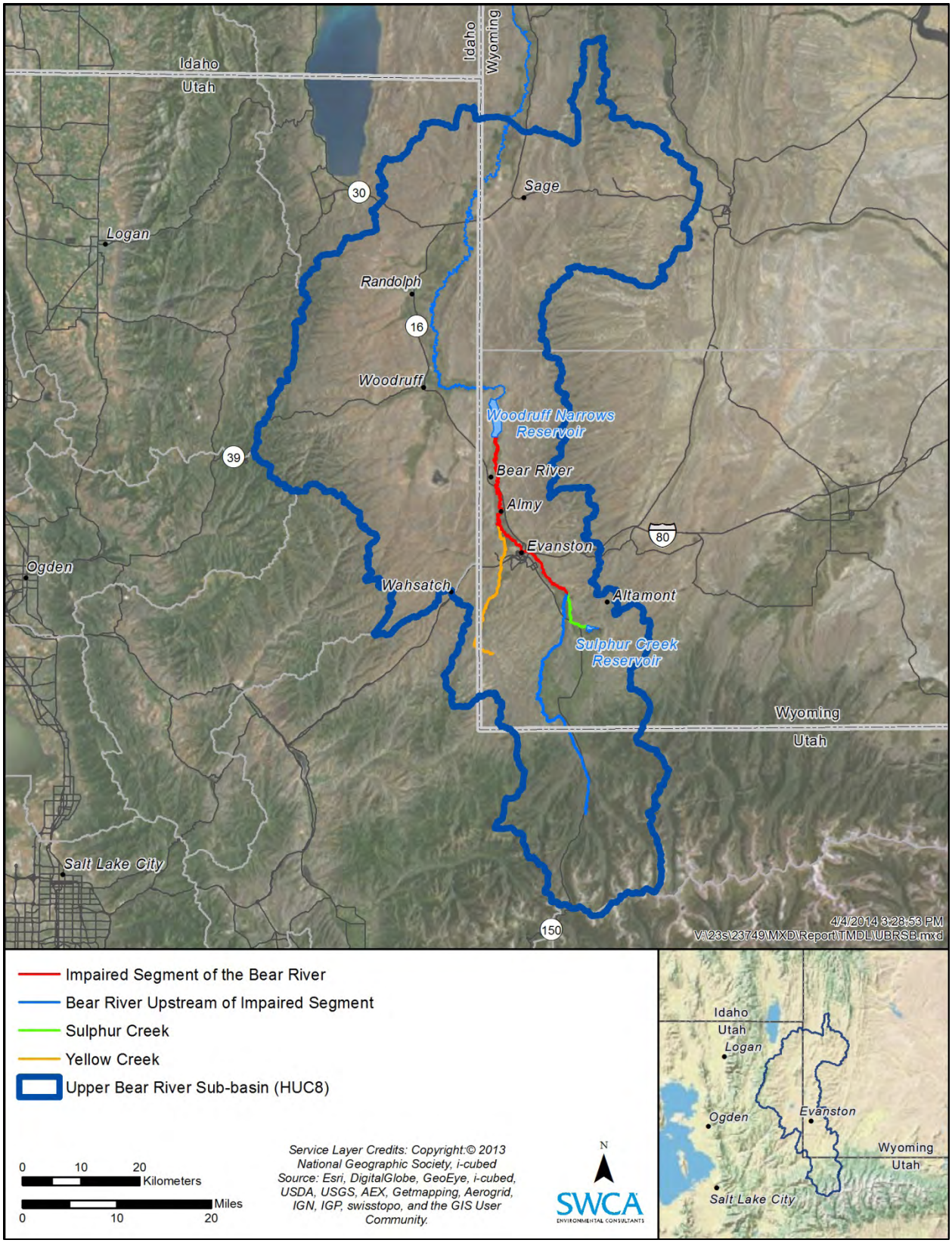
1.2.3. Study Boundaries

Definition of the study boundaries for the Bear River TMDL began with an evaluation of the Watershed Boundary Dataset (WBD) developed under the leadership of the Subcommittee on Spatial Water Data, which is part of the Advisory Committee on Water Information and the Federal Geographic Data Committee. The USDA Natural Resources Conservation Service, along with many other federal agencies and national associations, has representatives on the Subcommittee on Spatial Water Data. The USGS states the following:

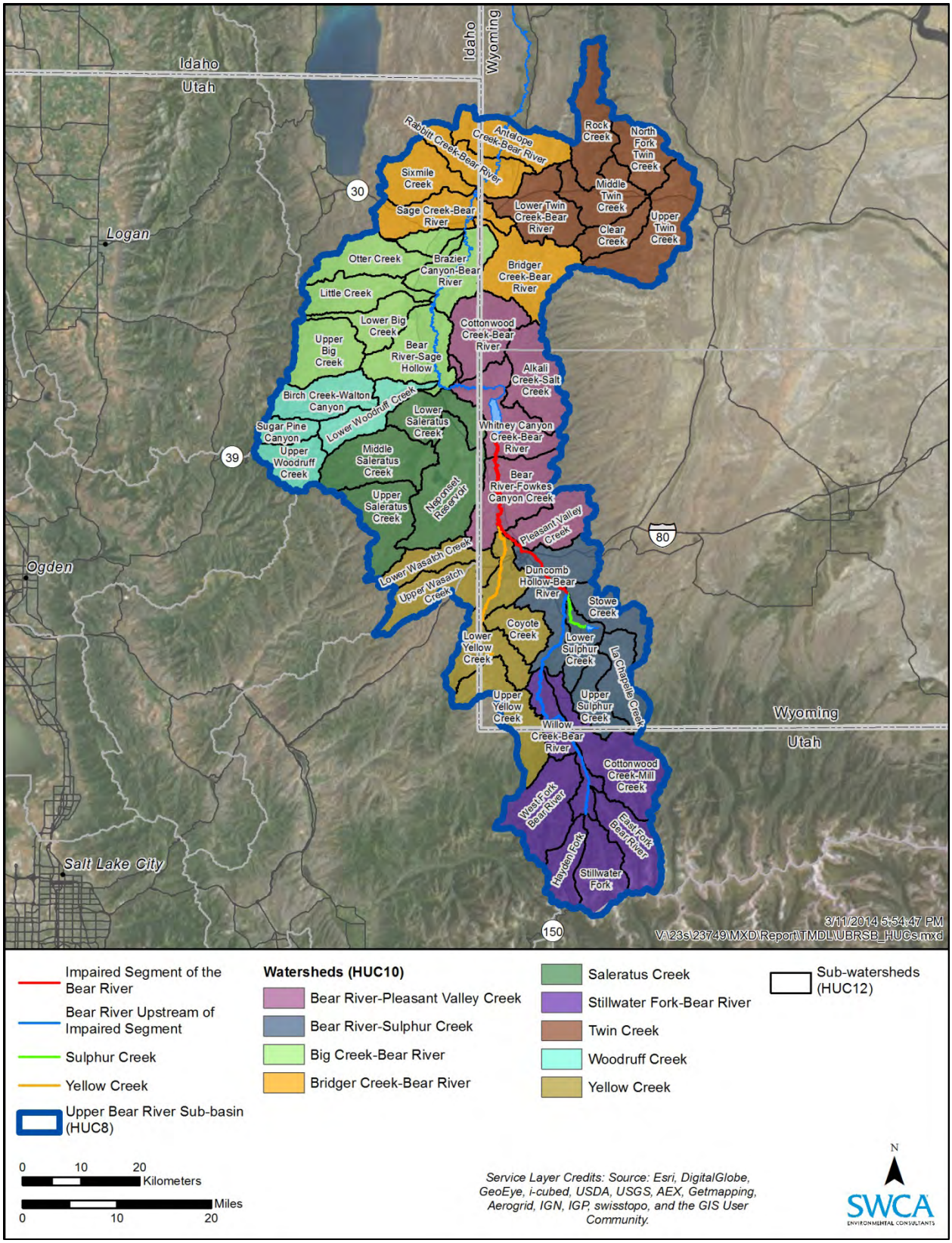
> The Watershed Boundary Dataset (WBD) defines the areal extent of surface water drainage to a point, accounting for all land and surface areas. Watershed Boundaries are determined solely upon science-based hydrologic principles, not favoring any administrative boundaries or special projects, nor particular program or agency. The intent of defining Hydrologic Units (HU) for the Watershed Boundary Dataset is to establish a base-line drainage boundary framework, accounting for all land and surface areas. At a minimum, the WBD is being delineated and georeferenced to the USGS 1:24,000 scale topographic base map meeting National Map Accuracy Standards (NMAS). Hydrologic units are given a Hydrologic Unit Code (HUC). For example, a hydrologic region has a 2-digit HUC. A HUC describes where the unit is in the country and the level of the unit. (USGS 2013)

The WBD places the impaired segment of the Bear River within the Upper Bear River Sub-basin. The 8-digit Hydrologic Unit Code (HUC8) for the sub-basin is 16010101 and includes 2,009 square miles of land in Wyoming and Utah (Map 1.1).

As shown on Map 1.2, the WBD subdivides the Upper Bear River Sub-basin into nine HUC10 watersheds and numerous HUC12 sub-watersheds.



Map 1.1. Upper Bear River sub-basin.

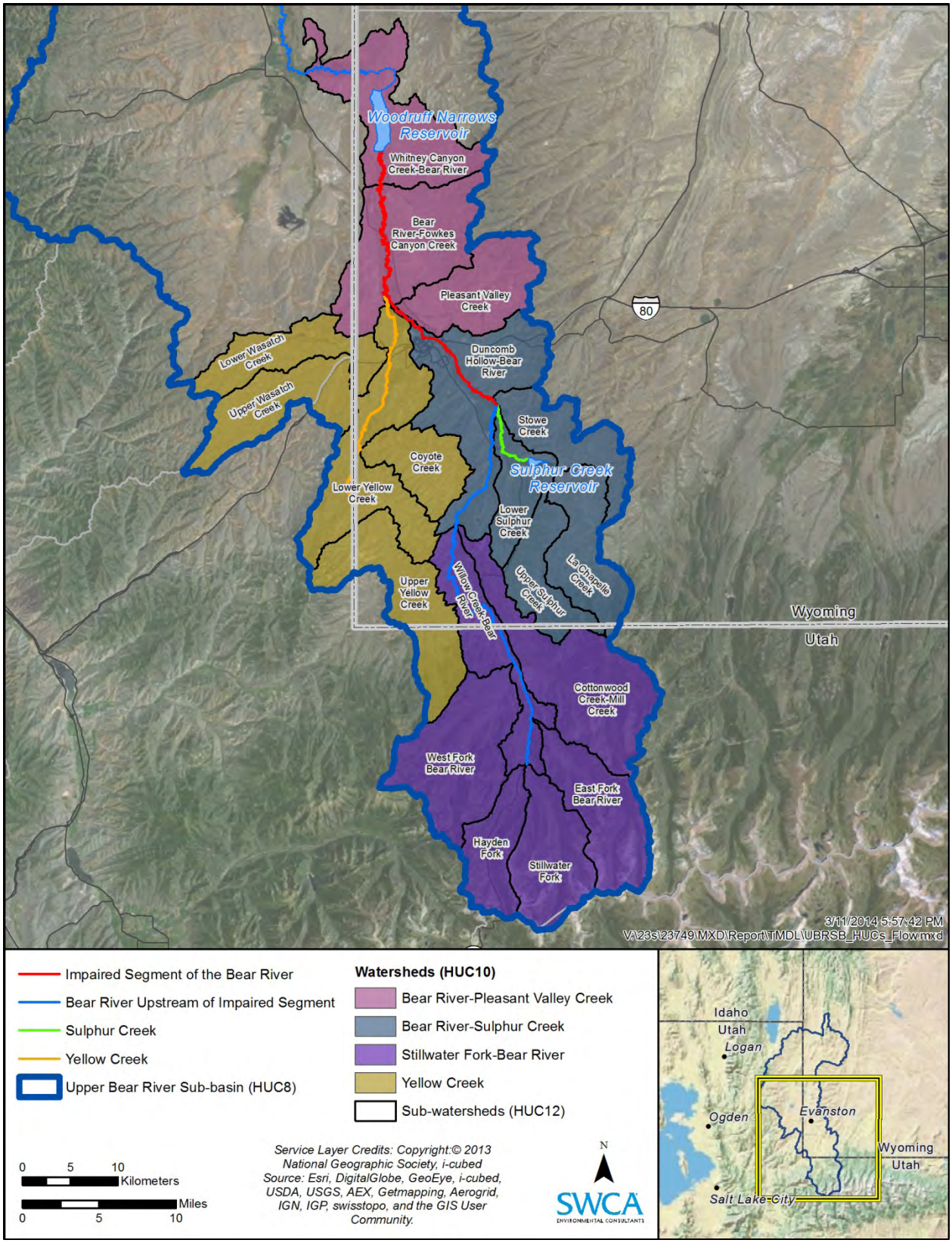


Map 1.2. Upper Bear River sub-basin watersheds and sub-watersheds.

The study boundaries for the Bear River TMDL are refined by including only those sub-watersheds that naturally drain to the 36.5-mile impaired segment of the Bear River. These HUC12 sub-watersheds are within the four HUC10 watersheds listed in Table 1.3 and shown on Map 1.3.

Table 1.3. Watersheds and Sub-Watersheds that Could Drain to the Impaired Segment

Watershed	Sub-Watershed
Stillwater Fork-Bear River	West Fork Bear River
	Hayden Fork
	Stillwater Fork
	East Fork Bear River
	Cottonwood Creek-Mill Creek
	Willow Creek-Bear River
Bear River-Sulphur Creek	La Chapelle Creek
	Upper Sulphur Creek
	Lower Sulphur Creek
	Stowe Creek
	Duncomb Hollow-Bear River
Yellow Creek	Upper Yellow Creek
	Lower Yellow Creek
	Coyote Creek
	Upper Wasatch Creek
	Lower Wasatch Creek
Bear River-Pleasant Valley Creek	Pleasant Valley Creek
	Bear River-Fowkes Canyon Creek
	Whitney Canyon Creek-Bear River

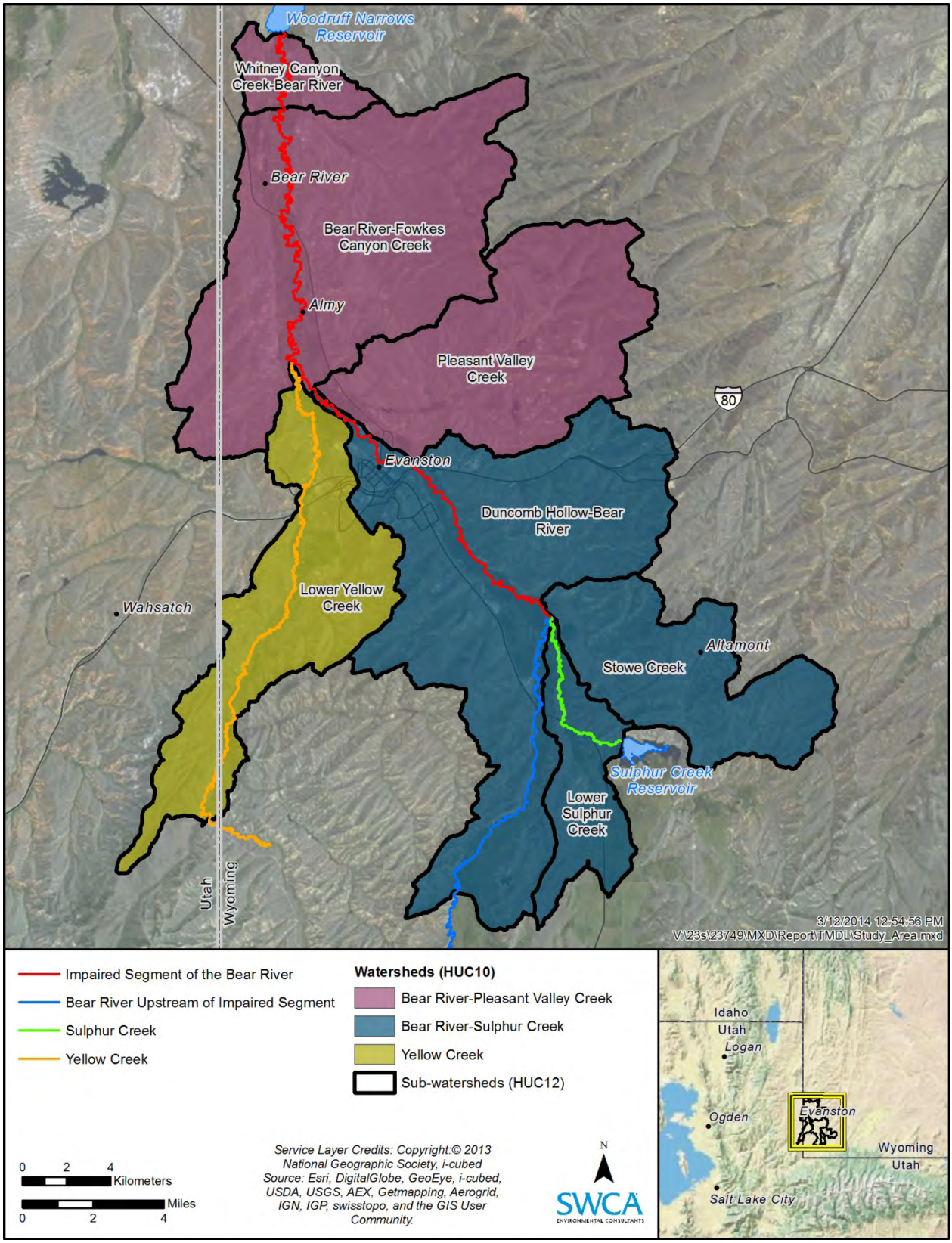


Map 1.3. Upper Bear River sub-watersheds that flow to the impaired segment.

As described above, Map 1.3 shows the sub-watersheds that should drain to the impaired segment of the Bear River, according to the USGS WBD. However, there are areas in these sub-watersheds that do not drain to the impaired segment due to topographic and hydrologic divides. These areas were delineated by creating a watershed layer using a geographic information system that uses digital elevations to define flow directions for a given point. Using this method, it was determined that areas in four of the HUC12 sub-watersheds shown on Map 1.3 do not drain to the impaired segment. These areas are excluded from the study boundaries and are described as follows:

- Below and adjacent to Woodruff Narrows Reservoir in the Whitney Canyon Creek-Bear River sub-watershed
- Above Barker Reservoir and an unnamed reservoir on Sage Creek in the Lower Yellow Creek sub-watershed
- Above and adjacent to Sulphur Creek Reservoir in the Lower Sulphur Creek sub-watershed
- Upper portion of the Stowe Creek sub-watershed at Thirtythree Pond.

To define the southern study boundaries of the Bear River TMDL, the entire Duncomb Hollow-Bear River sub-watershed was included. This sub-watershed includes 15 miles of the unimpaired upstream reach. The resulting study boundaries for the Bear River TMDL are shown on Map 1.4. For purposes of this TMDL report, the area within the Bear River study boundaries shown on Map 1.4 is hereafter referred to as the Bear River watershed.



Map 1.4. Bear River watershed.

1.3. Regional Setting

1.3.1. History

The Bear River flows from high in the Uinta Mountains, northeast through Wyoming and Idaho, and then south where it terminates at Great Salt Lake in Utah. Through this extensive course, the high alpine conifer forests of the Uintas give way to wide valleys in Wyoming, most of which have been converted to pastureland and lands used for grazing and agriculture. Undisturbed acreage adjacent to these areas is typically covered by low shrubs, sagebrush, and grass. Historically, the Bear River Valley was home to both Fremont and Shoshone Indians, with fur trappers entering the area in the early nineteenth century. The valley experienced the likes of such famous trappers as Jedediah Smith, B.L.E. Bonneville, Black Harris, and Osborn Russell, many of whom attended the annual trapper's rendezvous held in the valley in 1825 and 1827 (Utah History to Go! 2014).

Central to the Bear River watershed is the City of Evanston, located in the southwestern corner of Wyoming. Evanston is the county seat of Uinta County and has a rich history founded primarily upon the Union Pacific Railroad. The town was named for James Evans who acted as lead surveyor for the eastern half of the railroad route through Wyoming territory in the middle of the nineteenth century (Bogart 2009). The railroad arrived in the region in November of 1868 but it was not until 1870 that the town truly blossomed to life. Plentiful timber and water resources along the Bear River made Evanston an ideal refueling station for transcontinental locomotives. Additionally, in 1871, a machine shop and a 20-stall railroad service station were constructed, providing Evanston with longevity that was not enjoyed by other railroad towns (Evanston Chamber of Commerce 2014). The magnitude of influence of the railroad on the town was evidenced by street layouts that were oriented to the railroad tracks rather than compass points (Bogart 2009).

The presence of the railroad encouraged a plethora of pioneers to settle in Evanston, many of whom started essential businesses such as banks, grocery stores, hotels, bars, restaurants, and churches (Figure 1.1). These businesses served not only the townspeople, but the farmers, ranchers, and coal miners working the mines outside of town (Evanston Main Street 2014). Other early residents included Chinese contract workers for both the railroad and coal mining industries. The 1880 census listed more than 100 Chinese in Evanston; however, a massacre in 1885 dramatically reduced the population (Bogart 2009).

Figure 1.1. Downtown Evanston, approximately 1877. Wyoming Tales and Trails (courtesy of wyomingtalesandtrails.com).

Evanston also reaped the benefits of the construction of the first transcontinental automobile route known as the Lincoln Highway. The highway passed directly through Evanston's downtown district, bringing

with it a multitude of adventurers eager to experience the freedom of the new west. As automobile traffic increased, a tourist haven was created on the eastern edge of town adjacent to the county fairgrounds. Garages, service stations, and hotels soon followed to adequately accommodate the abundance of motorists (Bogart 2009). Even with the construction of the new highway, the lifeblood of Evanston continued to be the railroad industry. After completion of the Pacific Railroad, fresh produce and meat could be shipped eastward from California; however, both required refrigeration. This need gave rise to the use of railroad cars equipped with ice bunkers.

Barbara Allen Bogart (2009) writes that the Union Pacific Railroad consistently implemented new construction projects from 1897 through 1913. One of these projects was an icing station where water was taken from the Bear River and placed into two large ponds (Figure 1.2); from these ponds, ice was harvested in the winter and stored in long wooden storage buildings at trackside. Another large project was the construction of a larger locomotive service station that could house up to 28 cars at a time; it included a machine shop with generators that supplied electricity.

Figure 1.2. Cutting ice on the Bear Ponds, Evanston, undated (courtesy of Wyoming Tales and Trails, undated).

Throughout most of the twentieth century, Evanston remained economically stable, with a slow and steady growth in population from approximately 2,600 in 1910 to 4,400 in 1970 (Bogart 2009). However, this slow and steady growth changed dramatically with the oil boom of the 1980s, where the city of Evanston expanded from 2.2 square miles to 9.0 square miles and the population reached 11,000 by 1990. As this great boom began to recede and the downtown dwindled, the Evanston Urban Renewal Agency was formed. This agency proactively addressed preservation and economic renewal of the city. In congruence with this effort, the Better Environment and River Project was founded in 1983 to restore the portion of the Bear that flows through Evanston (Figures 1.3 and 1.4). This organization succeeded in transforming the heavily degraded river and surrounding uplands into a community park (the “Bear River Greenway”) by restoring ice ponds for recreational use and constructing a pathway and footbridges along the river to link downtown with the Bear River State Park to the south (Bogart 2009).

Figure 1.3. Beginning of Bear River Greenway restoration project about 2006 (used with permission from the Bear River Greenway).

Figure 1.4. Completed Bear River Greenway restoration project showing one of the foot bridges about 2009 (used with permission from the Bear River Greenway).

As described at the beginning of this section, the Bear River flows through three states, and this has required the development of interstate agreements. These agreements began with the Bear River Compact of 1958, which was amended in 1980. This compact, along with the bylaws of the Bear River Commission, various court decrees, and the laws of the States of Wyoming, Idaho, and Utah, establishes a framework under which the waters of the Bear River are divided. This framework regulates how the quantity of water in the Bear River is distributed to water users in the three states. In addition to water quantity, the water quality of the Bear River is also a concern of many organizations and committees. One of these organizations, the Bear River Basin Water Quality Task Force (also called the Bear River Task Force), was organized in 1993 and has coordinated much of the water quality work within the three states.

The WDEQ is a member of the tri-state Bear River Task Force and has coordinated monitoring programs to collect water quality data for the development of comprehensive TMDLs.

Despite the many booms and busts experienced by the City of Evanston, it continues to be a prime example of the quintessential western existence in which hard work and perseverance prevail over the hardships of western life. Barbara Allen Bogart best summarizes the history of Evanston as follows:

> During its century and a half, Evanston has experienced its share of Wyoming's boom and bust pattern and undergone dramatic changes. But its core identity persists—as a small town with strong pride in its past. (Bogart 2009:124).

1.3.2. Population and Growth Trends

As of the 2010 census (U.S. Census Bureau 2010), the population of Uinta County, Wyoming, was 21,118. Its county seat is the City of Evanston. Evanston is a growing community, and the surrounding areas are also expanding. Between 1990 and 2000, Evanston grew at a rate of 5.5% (City of Evanston 2014). The current population is estimated to be approximately 12,359 residents (Table 1.4).

As of the 2010 census (U.S. Census Bureau 2010), there were 4,540 households, and 3,135 families residing in the City of Evanston. The population density was 1,203.4 inhabitants per square mile. There were 5,111 housing units at an average density of 497.7 per square mile. The Town of Bear River, north of Evanston, is a small rural community in the Bear River Watershed. As of the 2010 census, there were 518 people residing in the Town of Bear River.

Between 2010 and 2030 the population of Wyoming is estimated to increase 19%, whereas Uinta County, the City of Evanston and the Town of Bear River are estimated to increase 11%.

Table 1.4. Population near the Bear River Watershed and Surrounding Area

	Population 2010	Estimated Population 2020	Estimated Population 2030
Wyoming	563,626	622,360	668,830
Uinta County	21,118	22,580	23,440
City of Evanston	12,359	13,215	13,718
Town of Bear River	518	554	575

Note: All table data from Wyoming Department of Administration and Information: Economic Analysis Division (2011).

1.3.3. Climate

The climate of the Bear River watershed is typical of semiarid regions in southwestern Wyoming, with long, cold, dry winters, and short, warm, slightly wetter summers. Climate data for the Bear River watershed are available from two climate stations maintained by the Western Regional Climate Center (WRCC): the Evanston 1E, Wyoming station (483100) and the Uintalands, Utah station (428900).

The Evanston 1E station is in the City of Evanston at an elevation 6,860 feet (41°16’00”N, 110°57’00” W), and has been in operation since December 1890. Data from this station are representative of the climate along the impaired segment. Climate data from this station show that the watershed receives approximately 1 inch of precipitation per month, with the highest precipitation in May and lowest in January (Table 1.5).

Table 1.5. Climate Summary for Evanston 1E Station

Month	Average Min. Temperature (°F)	Average Max. Temperature (°F)	Average Total Precipitation (inches)	Average Total Snowfall (inches)
January	10.6	32.0	0.66	13.2
February	12.3	34.3	0.68	8.1
March	20.9	43.8	0.81	5.0
April	27.0	53.5	1.05	2.0
May	34.3	63.1	1.61	1.0
June	40.7	73.0	1.26	0.2
July	46.8	81.4	0.83	0.0
August	46.4	79.9	1.06	0.0
September	38.2	70.7	1.26	0.3
October	29.2	57.7	1.16	1.6
November	19.1	42.1	1.12	6.1
December	10.3	31.6	0.70	9.8
Monthly Average	**28.1**	**55.4**	**1.0**	**3.9**
Annual Total	**N/A**	**N/A**	**12.20**	**47.3**

Source: National Climate Data Center (NCDC) climate normals for 1981–2010 (NCDC 2014).

Note: N/A = not applicable.

There is a large amount of variability in the average monthly rainfall, with average standard deviations of approximately 75% of the monthly averages (Figure 1.5). Note in Figure 1.5, the monthly standard deviations for the period of record are symbolized with black bars.

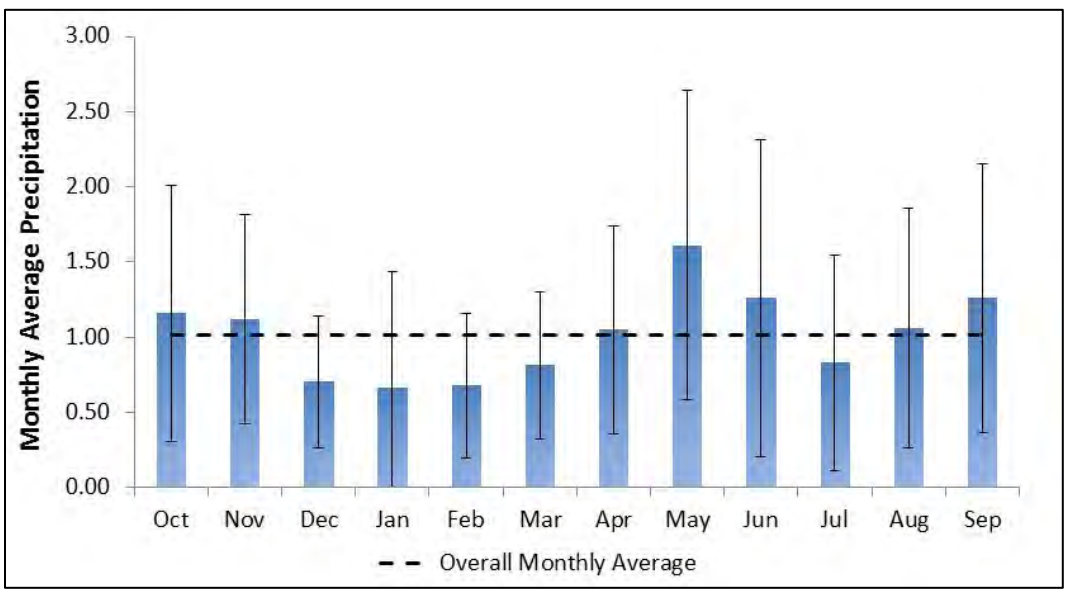


Figure 1.5. Average monthly rainfall for the Evanston 1E climate station (NCDC USC00483100) for 1981–2010.

On the other hand, there is considerably less variability in annual totals, with the standard deviation being approximately 25% of the annual average (Figure 1.6). These results indicate that in general, there is much more variability in average monthly rainfall than there is in the average annual rainfall. Note in Figure 1.6, years that have a month with more than 5 days of missing data are in red (incomplete data), and the overall average only uses data from years will full datasets (complete data).

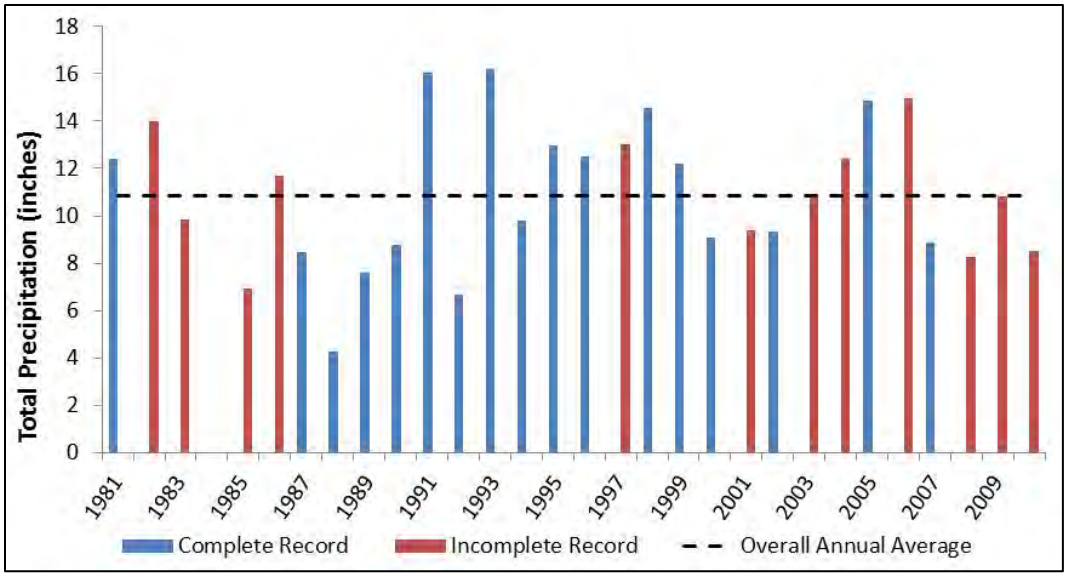


Figure 1.6. Annual rainfall for the Evanston 1E climate station (NCDC USC00483100) for 1981–2010.

The Uintalands station is at an elevation of 8,140 feet, just north of the Uinta Mountains in Utah, at coordinates 40°57'00"N 110°48'00"W; it operated from 1977 to 1989. Climate in the headwaters of the Bear River is much wetter than in the impaired segment near Evanston, with average monthly rainfall approximately twice as high, and snowfall approximately four times as high (Table 1.6). Therefore, a large percentage of the flow delivered to the impaired segment of Bear River originates from precipitation and snowmelt from its headwaters.

Table 1.6. Climate Summary for Uintalands Station

Month	Average Min. Temperature (°F)	Average Max. Temperature (°F)	Average Total Precipitation (inches)	Average Total Snowfall (inches)
January	6.6	32.7	1.49	24.7
February	7.9	34.5	1.72	27.5
March	13.5	38.7	2.80	41.4
April	20.7	46.7	2.44	23.7
May	28.5	55.7	2.39	16.2
June	36.0	67.7	1.19	0.9
July	41.8	73.9	1.42	0.0
August	40.9	73.1	1.79	0.1
September	33.6	63.9	1.80	5.0
October	25.0	52.7	1.99	18.2

Table 1.6. Climate Summary for Uintalands Station

Month	Average Min. Temperature (°F)	Average Max. Temperature (°F)	Average Total Precipitation (inches)	Average Total Snowfall (inches)
November	13.6	38.0	2.24	38.4
December	7.8	33.5	1.58	28.0
Monthly Average	**23.0**	**50.9**	**1.9**	**18.7**
Annual Total	**N/A**	**N/A**	**22.86**	**224.1**

Source: WRCC values from 1977-1989 (WRCC 2014).

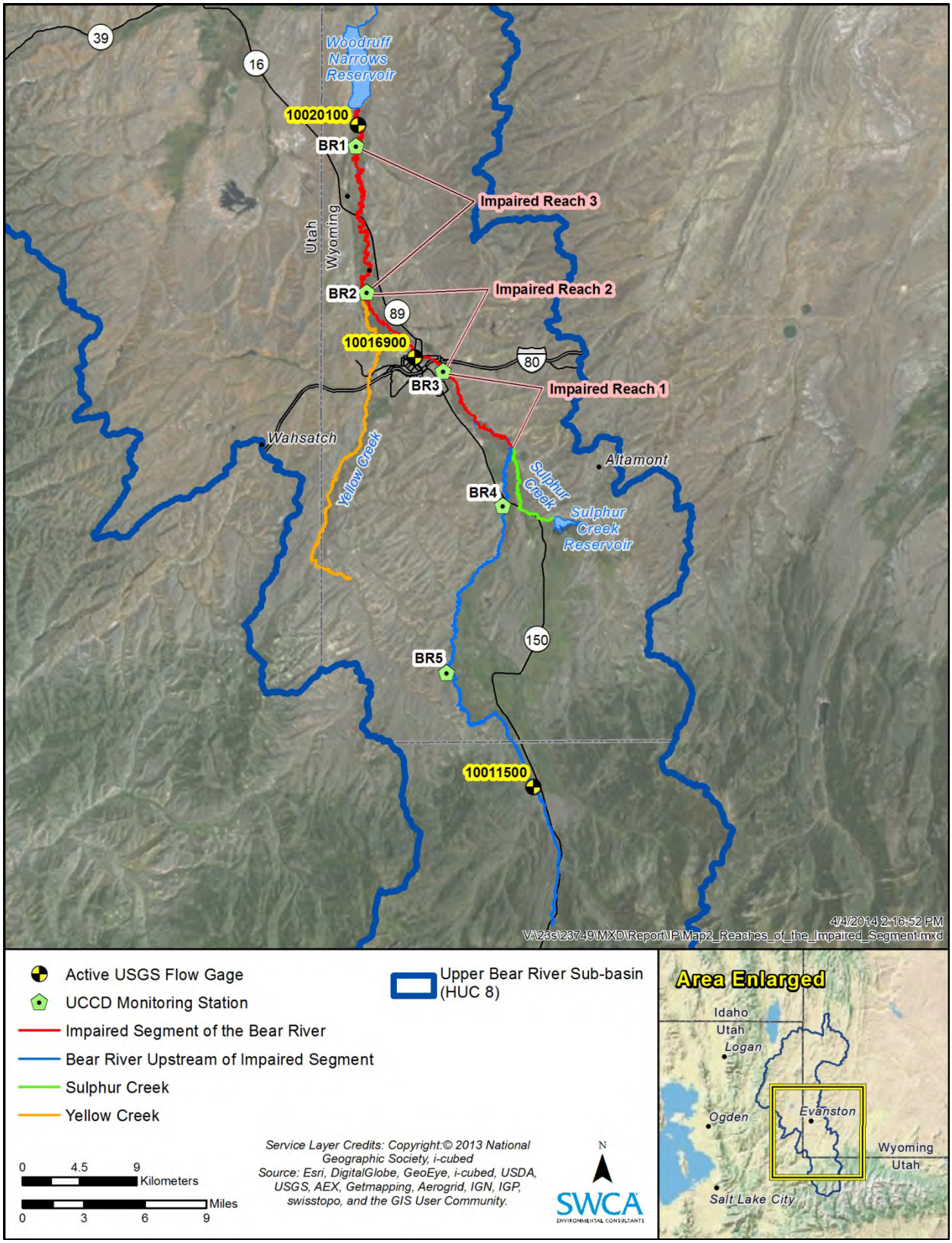
Note: N/A = not applicable.

1.4. Watershed Characterization

1.4.1. Physical Boundaries of the Watershed

The Bear River watershed defined for this report consists of multiple HUC12 sub-watersheds (see section 1.2.3 Study Boundaries and Map 1.4). The watershed drains approximately 240 square miles (153,000 acres) and encompasses the City of Evanston and the communities of Almy and Bear River.

For purposes of this TMDL report, the term *segment* applies only to the impaired segment; *reach* applies to the reaches defined within the impaired segment (i.e., Reach 1, Reach 2, and Reach 3; Map 1.5), the upstream reach, and reaches of Sulphur and Yellow Creeks; and *section* applies to areas where field surveys (e.g., bank erosion hazard index [BEHI]/near bank stress [NBS]) were conducted.



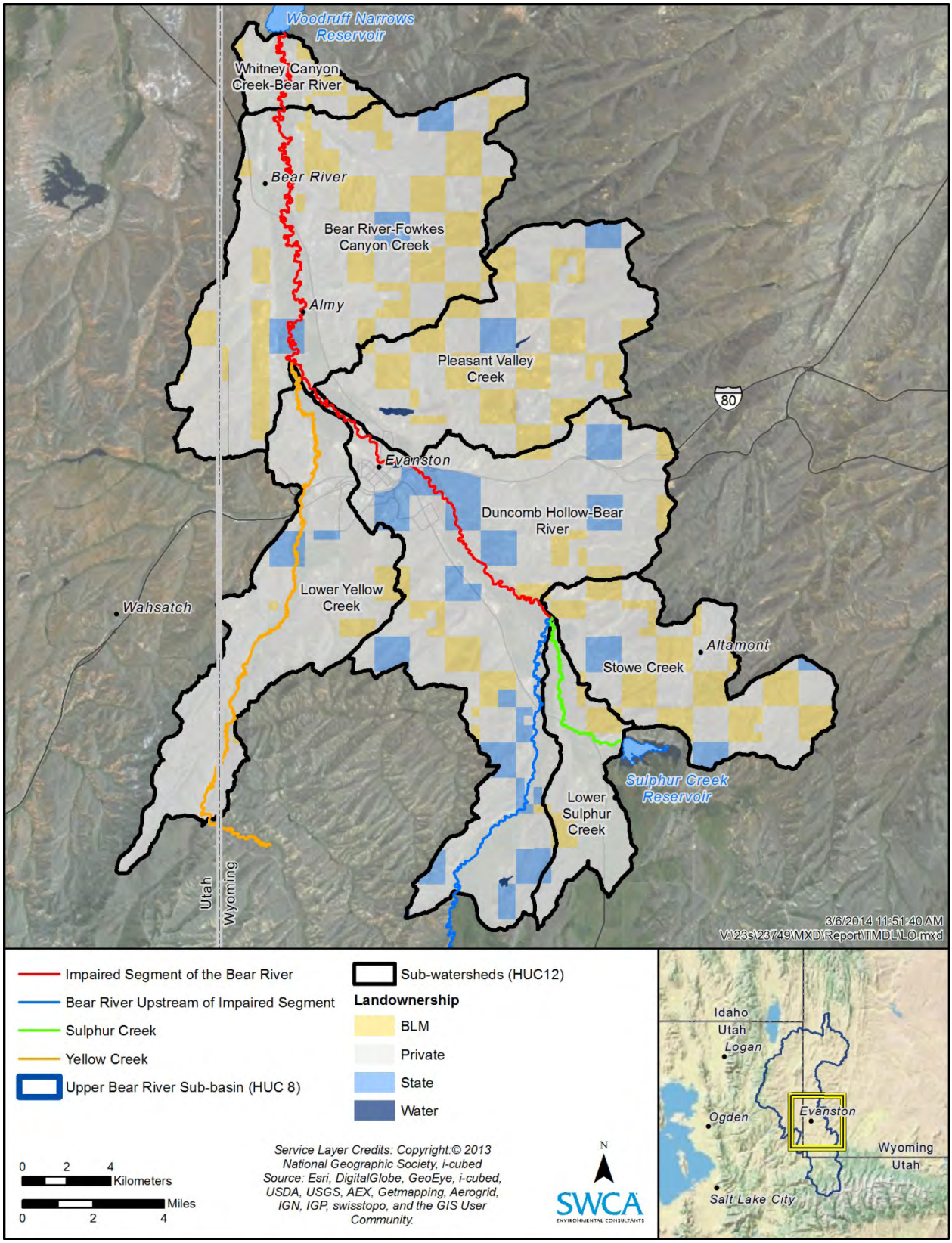
Map 1.5. Bear River impaired segment, reaches, and tributaries.

1.4.2. Land Ownership, Land Use, and Land Cover

Land ownership in the Bear River watershed is predominately privately owned, with some BLM and state lands. In total, private lands represent 72% of the watershed, BLM 19%, and state lands 8% (Table 1.7 and Map 1.6).

Table 1.7. Land Ownership in the Bear River Watershed

Sub-watershed (listed from top to bottom of the watershed)	Acres					Percentage of Acres			
	Private	BLM	State	Open Water	Total	Private	BLM	State	Open Water
Lower Sulphur Creek	6,906	1,001	80	7	7,995	86%	13%	1%	0%
Stowe Creek	9,206	5,542	1,194	0	15,942	58%	35%	7%	0%
Duncomb Hollow-Bear River	29,649	3,771	7,772	57	41,248	72%	9%	19%	0%
Pleasant Valley Creek	15,191	7,473	1,121	126	23,911	64%	31%	5%	1%
Lower Yellow Creek	19,899	826	760	0	21,486	93%	4%	4%	0%
Bear River-Fowkes Canyon Creek	26,954	9,831	1,731	0	38,516	70%	26%	4%	0%
Whitney Canyon Creek-Bear River	2,919	928	0	0	3,847	76%	24%	0%	0%
Total	**110,725**	**29,372**	**12,659**	**190**	**152,946**	**72%**	**19%**	**8%**	**0%**



Map 1.6. Land ownership in the Bear River watershed.

The primary land uses in the Bear River watershed are agricultural and include grazing, hay, and small grain production. There is canal and ditch development along the entire Bear River for agricultural irrigation purposes. Areas surrounding the main stem of the Bear River, Sulphur Creek, and the lower reaches of Yellow Creek have been converted to irrigated pasture and hay meadows. In these areas, riparian forests and wood wetlands have been removed by clear cutting, vegetation treatments, or grazing. The impaired segment of the Bear River has very limited areas of riparian forests or woody wetlands present. Conversion of riparian and upland vegetation to urban development occurs around the City of Evanston (Map 1.7).

The predominant land cover (greater than 1%) in the Bear River watershed is summarized in Table 1.8 and Table 1.9. Approximately 94% of the land in the Bear River Watershed is covered by shrub/scrub (65%), grasslands (15%), pasture/hay (10%), and wetlands (4%).

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Table 1.8. Predominant Land Cover in the Bear River Watershed (acres)

Sub-Watershed (listed from top to bottom of the watershed)	Shrub/ Scrub	Grassland/ Herbaceous	Pasture/ Hay	Emergent Herbaceous Wetlands	Woody Wetlands	Developed	Evergreen Forest	Deciduous Forest
Lower Sulphur Creek	3,791	103	3,587	75	83	191	107	48
Stowe Creek	13,194	1,984	178	158	9	–	361	56
Duncomb Hollow-Bear River	25,979	5,058	4,306	783	1,196	3,014	518	294
Pleasant Valley Creek	11,880	9,196	774	424	67	271	276	833
Lower Yellow Creek	15,944	465	2,127	1,013	62	1,329	537	25
Bear River-Fowkes Canyon Creek	25,589	6,333	3,499	1,158	945	185	233	482
Whitney Canyon Creek-Bear River	2,486	68	772	293	209	–	–	20
Total	**98,864**	**23,207**	**15,243**	**3,904**	**2,570**	**4,990**	**2,032**	**1,759**

Table 1.9. Predominant Land Cover in the Bear River Watershed (percentage acres)

Sub-Watershed (listed from top to bottom of the watershed)	Shrub/Scrub	Grassland/ Herbaceous	Pasture/ Hay	Emergent Herbaceous Wetlands	Woody Wetlands	Developed	Evergreen Forest	Deciduous Forest
Lower Sulphur Creek	47.4%	1.3%	44.9%	0.9%	1.0%	2.4%	1.3%	0.6%
Stowe Creek	82.8%	12.4%	1.1%	1.0%	0.1%	–	2.3%	0.4%
Duncomb Hollow-Bear River	63.0%	12.3%	10.4%	1.9%	2.9%	7.3%	1.3%	0.7%
Pleasant Valley Creek	49.7%	38.5%	3.2%	1.8%	0.3%	1.1%	1.2%	3.5%
Lower Yellow Creek	74.1%	2.2%	9.9%	4.7%	0.3%	6.2%	2.5%	0.1%
Bear River-Fowkes Canyon Creek	66.4%	16.4%	9.1%	3.0%	2.5%	–	0.6%	1.3%
Whitney Canyon Creek-Bear River	64.6%	1.8%	20.1%	7.6%	5.4%	–	–	0.5%
Total	**64.6%**	**15.2%**	**10.0%**	**2.6%**	**1.7%**	**3.3%**	**1.3%**	**1.1%**

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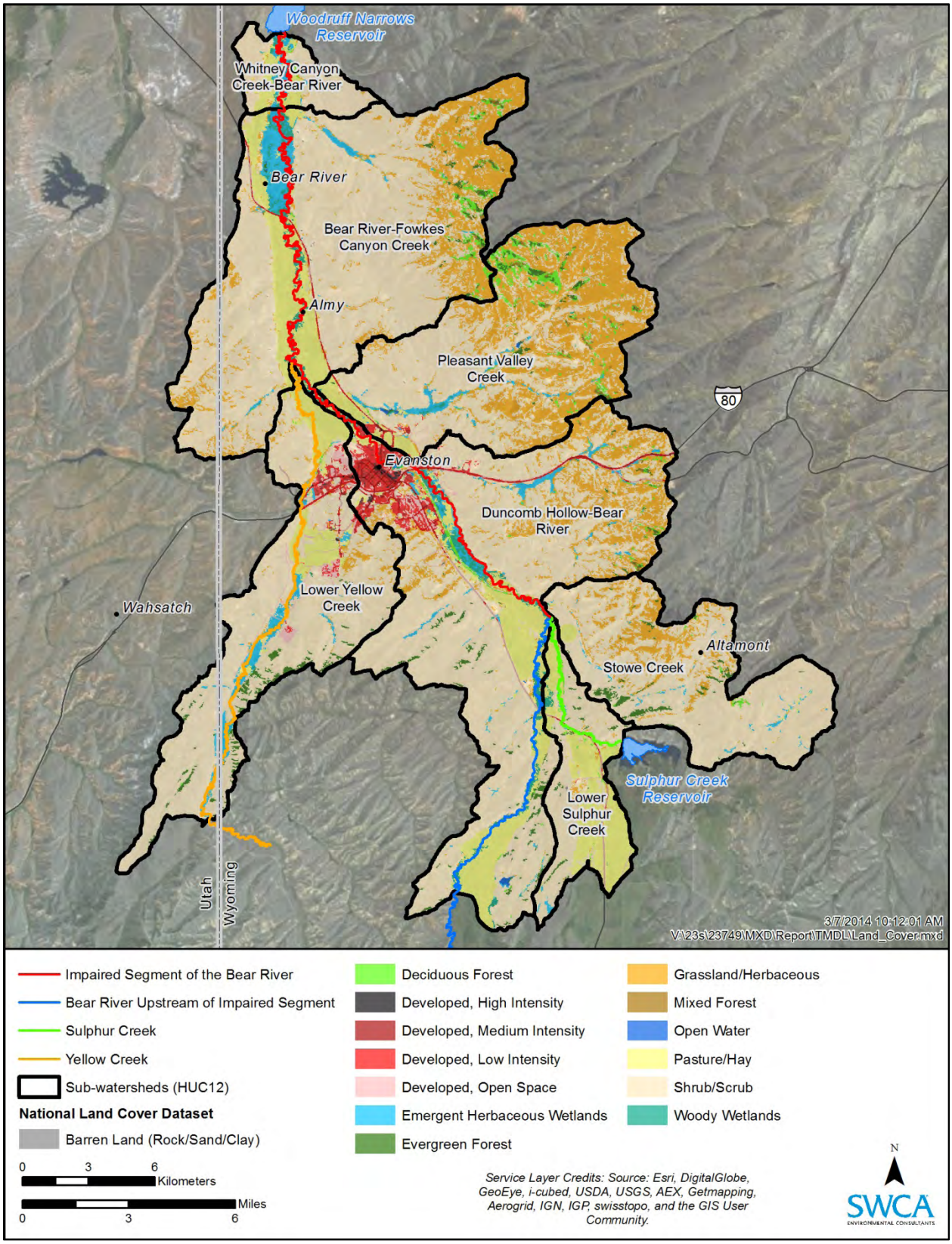

Map 1.7. Land cover in the Bear River watershed.

1.4.3. Geology and Soils

The geology of the Bear River watershed consists of fine-grained, easily erodible sedimentary formations that create naturally highly erodible soils. The geologic units that make up approximately 90% of the geology in the watershed are listed and described below in order of occurrence (also see Table 1.10 and Table 1.11).

- Wasatch Formation, main body (Tw): Interbedded mudstone, sandstone, siltstone, and claystone
- Alluvium and colluvium (Qa): Unconsolidated clay, silt, sand, and gravel
- Fowkes Formation (Tf): Tuffaceous mudstone, siltstone, and sandstone, with some fossiliferous limestone
- Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths Formations (Kss): siltstones and mudstones with sandstone and quartzite interbeds, with some fossiliferous limestone
- Gannett group (Kg): mudstone, siltstone, and sandstone, with some limestone interbeds
- Evanston Formation (Tke): claystone and siltstone, containing sandstone and coal interbeds, frequent boulder conglomerate beds

Table 1.10. Predominant Geology in the Bear River Watershed (acres)

Sub-watershed (listed from top to bottom of the watershed)	Wasatch Formation, Main Body (Tw)	Alluvium and Colluvium (Qa)	Fowkes Formation (Tf)	Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths Formations (Kss)	Gannett Group (Kg)	Evanston Formation (Tke)
Lower Sulphur Creek	280	5,710	–	580	500	146
Stowe Creek	6,618	659	–	1,650	771	662
Duncomb Hollow-Bear River	28,689	9,904	92	1,361	470	209
Pleasant Valley Creek	17,451	836	3,097	445	1,031	1,051
Lower Yellow Creek	5,176	6,983	2,741	582	296	453
Bear River-Fowkes Canyon Creek	10,114	5,787	11,065	2,105	3,124	2,408
Whitney Canyon Creek-Bear River	924	1,205	1,447	112	151	8
Total	**69,251**	**31,084**	**18,442**	**6,835**	6,343	**4,938**

Table 1.11. Predominant Geology in the Bear River Watershed (percentage acres)

Sub-watershed (listed from top to bottom of the watershed)	Wasatch Formation, Main Body (Tw)	Alluvium and Colluvium (Qa)	Fowkes Formation (Tf)	Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths Formations (Kss)	Gannett Group (Kg)	Evanston Formation (Tke)
Lower Sulphur Creek	4%	71%	–	7%	6%	2%
Stowe Creek	42%	4%	–	10%	5%	4%
Duncomb Hollow-Bear River	70%	24%	0%	3%	1%	1%
Pleasant Valley Creek	73%	3%	13%	2%	4%	4%
Lower Yellow Creek	24%	32%	13%	3%	1%	2%
Bear River-Fowkes Canyon Creek	26%	15%	29%	5%	8%	6%
Whitney Canyon Creek-Bear River	24%	31%	38%	3%	4%	0%
Total	**45%**	**20%**	**12%**	**4%**	**4%**	**3%**

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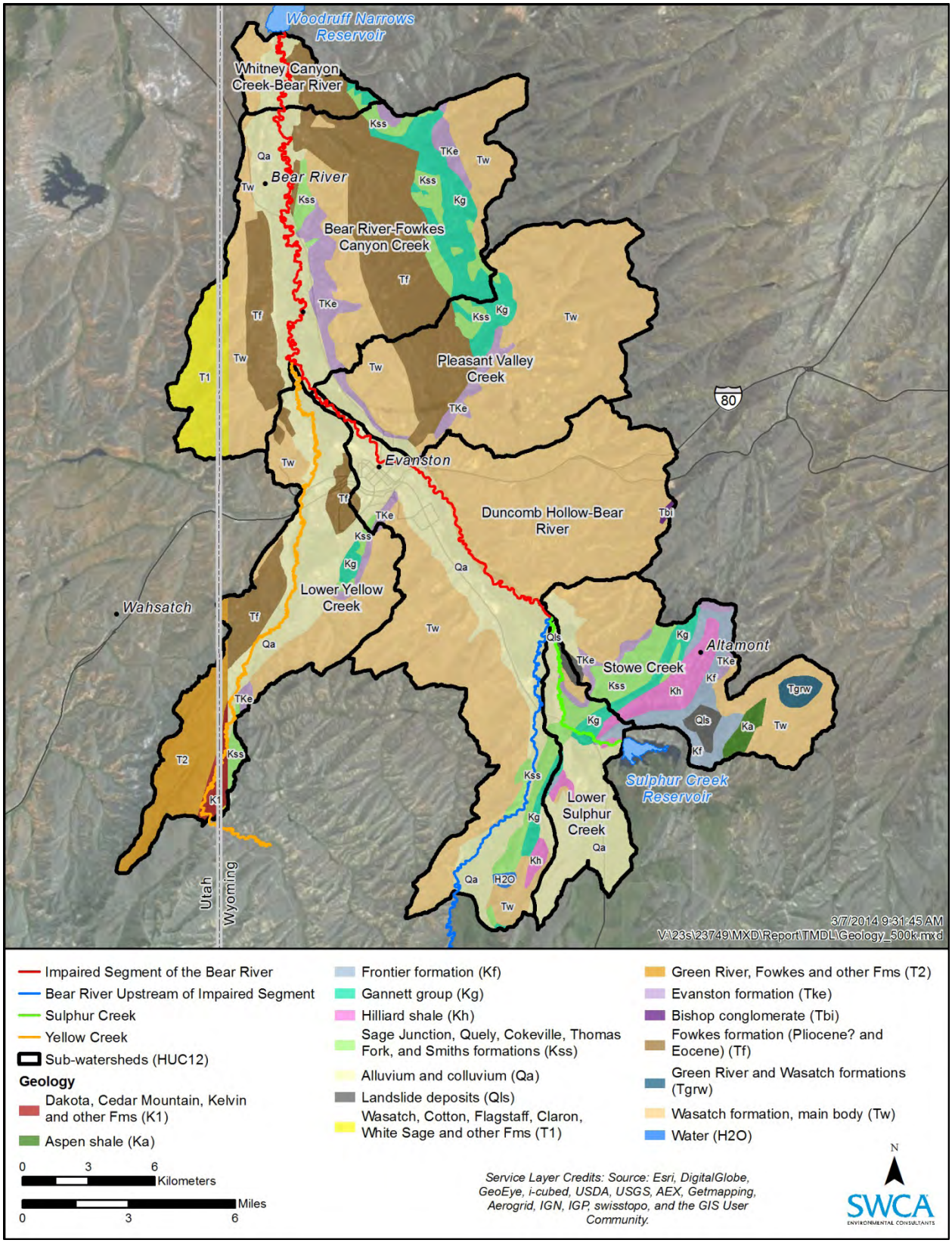
Along the upstream unimpaired reach of the Bear River, the geology consists of alluvium and colluvium, and some outcrops of the Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths Formations (Map 1.8).

In the lower Sulphur Creek sub-watershed, the predominant geology consists of alluvium and colluvium; however, as Sulphur Creek flows from the reservoir, it crosses several small geologic units including the Frontier Formation (Kf), Hilliard Shale (Kh), Gannett Group (Kg), Sage Junction, Quely, Cokeville, Thomas Fork, and Smiths Formations (Kss), and Evanston Formation (Tke) (see Map 1.8).

Along Reach 1 of the impaired segment, the Bear River flows along the cliffs of the Wasatch Formation (Tw) and alluvium/colluvium (Qa). Below the City of Evanston, along Reach 2 and 3, the Bear River is mostly situated in alluvium and colluvium (see Map 1.8).



Map 1.8. Geology in the Bear River watershed.

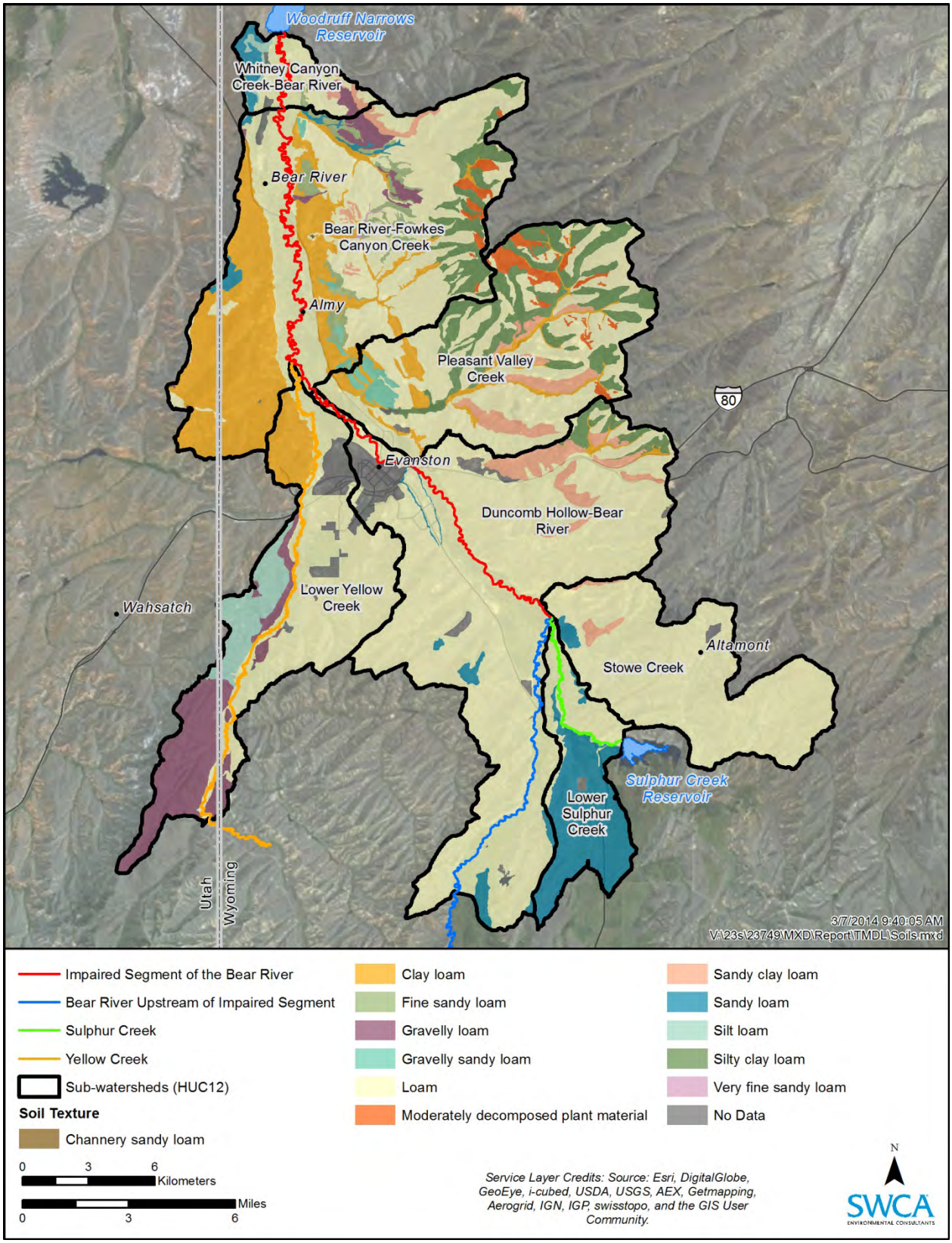
The predominant soil types along the impaired segment of the Bear River are loams and loam mixtures: loam (66%), clay loam (11%), silty clay loam (6%), and sandy loam (5%) (Tables 1.12 and 1.13). The Bear River channel is situated entirely in loams (Map 1.9).

Table 1.12. Predominant Soils in the Bear River Watershed (acres)

Sub-watershed (listed from top to bottom of the watershed)	Loam	Clay Loam	Silty Clay Loam	Sandy Loam
Lower Sulphur Creek	2,472	–	–	5,431
Stowe Creek	15,235	–	–	254
Duncomb Hollow-Bear River	35,494	210	818	907
Pleasant Valley Creek	12,908	1,896	5,473	–
Lower Yellow Creek	10,959	1,631	–	–
Bear River-Fowkes Canyon Creek	18,511	12,850	2,396	491
Whitney Canyon Creek-Bear River	2,313	–	–	623
Total	**97,892**	**16,588**	**8,688**	**7,706**

Table 1.13. Predominant Soils in the Bear River Watershed (percentage acres)

Sub-watershed (listed from top to bottom of the watershed)	Loam	Clay Loam	Silty Clay Loam	Sandy Loam
Lower Sulphur Creek	31%	–	–	69%
Stowe Creek	96%	–	–	2%
Duncomb Hollow-Bear River	90%	1%	2%	2%
Pleasant Valley Creek	54%	8%	23%	–
Lower Yellow Creek	54%	8%	–	–
Bear River-Fowkes Canyon Creek	48%	33%	6%	1%
Whitney Canyon Creek-Bear River	62%	–	–	17%
Total	66%	11%	6%	5%



Map 1.9. Soils in the Bear River watershed.

1.4.4. Surface Water Hydrology

The hydrology of a river system is its defining attribute. The timing, quantity, and duration of flows are the central organizing processes for the behavior of river ecosystems, and thus are key to understanding and developing a TMDL. As described in section 1.3.3, the Bear River is a snow melt–dominated river. The headwaters of the Bear River are in the Uinta Mountains of Utah and Wyoming, where elevations range up to 13,000 feet and receive up to 40 inches of precipitation a year. Most of this precipitation falls predominantly as snow, where it is stored until the spring melt. Years with high snow packs and warm spring weather can release large amounts of water to the Bear River, resulting in floods.

In the Bear River watershed, some spring snowmelt is stored in two reservoirs (Sulphur Creek Reservoir and Barker Reservoir) that provide irrigation and drinking water. Water is also diverted to and from these reservoirs through interbasin diversions. Below the reservoirs, water is also diverted through numerous irrigation diversion canals and ditches.

Within the Bear River watershed, flow measurements have been collected along the Bear River, Sulphur Creek, and Yellow Creek by several agencies and groups. Flow measurements are available from active and historical USGS flow gages, and at locations where water quality samples were collected by UCCD, WDEQ, and Utah Department of Environmental Quality (UDEQ). For purposes of characterizing the overall hydrology of the Bear River, continuous flow data from three active USGS gages were used (Table 1.14 and Map 1.10).

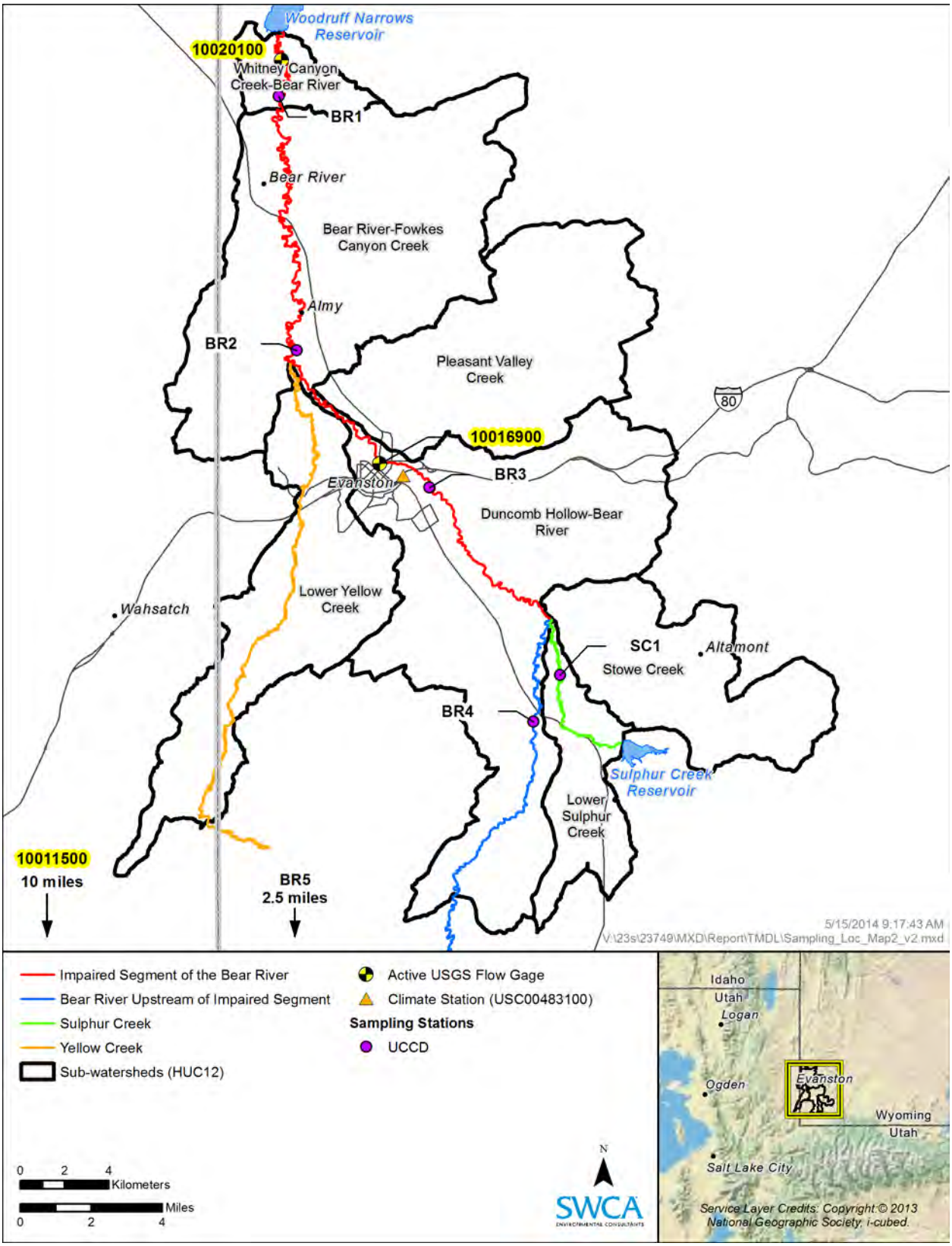
Table 1.14. Active USGS Flow Gages on the Bear River

Station Number	Station Name	Period of Flow Record
10011500	Bear River near the Utah-Wyoming state line	1942–present
10016900	Bear River at Evanston, Wyoming	1984–present
10020100	Bear River above Reservoir, near Woodruff, Utah	1961–present

Little is known about the flows in Yellow Creek. There was a USGS flow gage (10017000) on Yellow Creek, near the Wyoming-Utah state line that operated from 1943 to 1978. However, it is located above most major irrigation diversions and does not represent flows at the mouth of Yellow Creek. Flows are low at the mouth of Yellow Creek (i.e., less than 5 cubic feet per second [cfs]) for most of the year, but during spring snowmelt, flows generally range from 20 to 30 cfs, and can peak as high as 100 cfs (personal communication, Donald Shoemaker, Water Commissioner for District IV, to John Christensen, SWCA, November 20, 2013).

To further characterize the hydrology of the Bear River and Sulphur Creek, flow duration curves were developed. A flow duration curve illustrates the percentage of time, or probability, that flow in a river will equal or exceed a particular value. Flow duration curve analysis is a method involving the frequency of historical flow data. Typically, low flows are exceeded most of the time, whereas high flows, such as those resulting in floods, are exceeded infrequently. Because TMDL load analyses rely on paired flow and water quality data, flow duration curves were developed for locations along the Bear River where sediment water quality data were available. The UCCD has established monitoring stations in the watershed along the Bear River and on Sulphur Creek. Flow and water quality have been measured at these stations biannually since 2007. These stations are identified as BR4, BR3, BR2, BR1, and SC1.

During some UCCD monitoring events, the flow at a station could not be measured because of high flows and unsafe conditions. Because of this, flows were estimated by correlating flows measured at those locations with the nearest USGS gage (Table 1.15).



Map 1.10. USGS flow gages and sampling stations useful for the Bear River TMDL.

Table 1.15. Correlation Used to Calculate UCCD Monitoring Station Flow Duration Curves

UCCD Monitoring Station	USGS Gage Used for Correlation	Number of Measurements	Slope of Best-Fit Line
BR4	10011500	5	0.614 (0.982)
BR3	10016900	6	1.055 (0.991)
BR2	10016900	6	0.818 (0.993)
BR1	10020100	7	0.952 (0.990)
SC1	*	7	0.974 (0.932)

Note: Values in parentheses are coefficients of determination (R^2) of the best-fit line through the origin.

* Sulphur Creek Reservoir releases were used for correlation. Data from Don Shoemaker provided via handwritten notes to SWCA on November 20, 2013

Correlations yielded tight fits (lowest $R^2 = 0.932$, though samples sizes are low), indicating that flow measurements made at UCCD monitoring stations are accurate. These correlations were used to estimate flow duration curves (FDCs) at each UCCD monitoring station (Figures 1.7 through 1.11). To simplify the data, FDCs were divided into three flow regimes based on the percentage of days that flow is exceeded: high (< 20%), medium (20%–80%), and low (> 80%). Results of the FDCs show that flow increases by approximately 250% from BR4 (Bear River above confluence with Sulphur Creek) to BR3 (Bear River near Bear River State Park) on average. However, flows decrease significantly from BR3 all the way downstream to Woodruff Narrows Reservoir. This is likely due to irrigation diversions, but could also be due to groundwater recharge (i.e., these reaches are losing water to the aquifer).

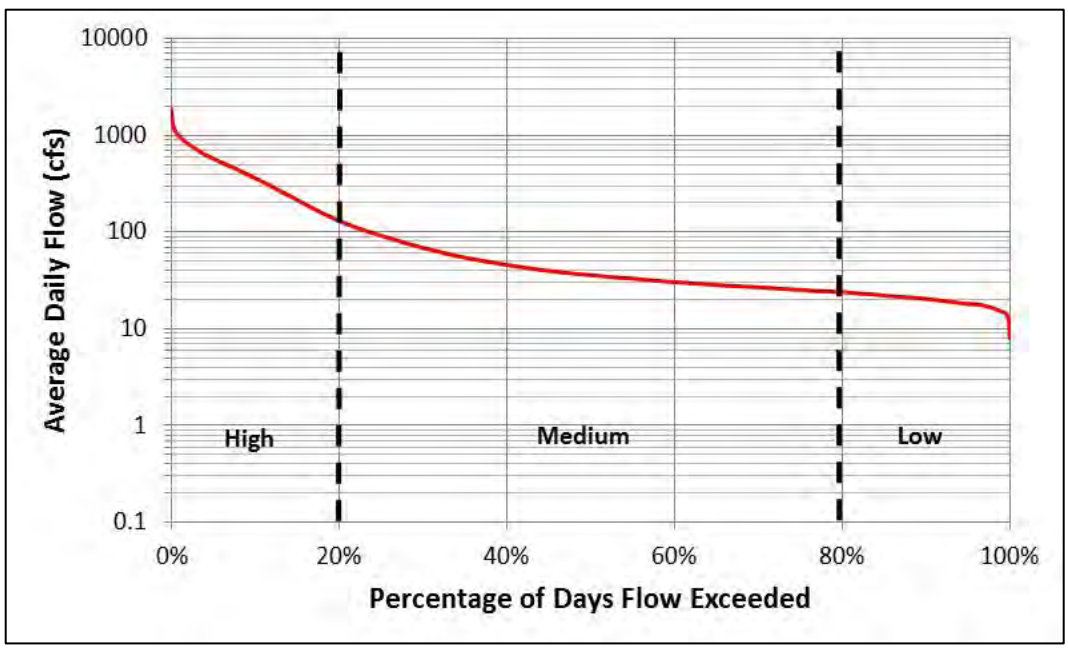


Figure 1.7. Estimated flow duration curve for BR4.

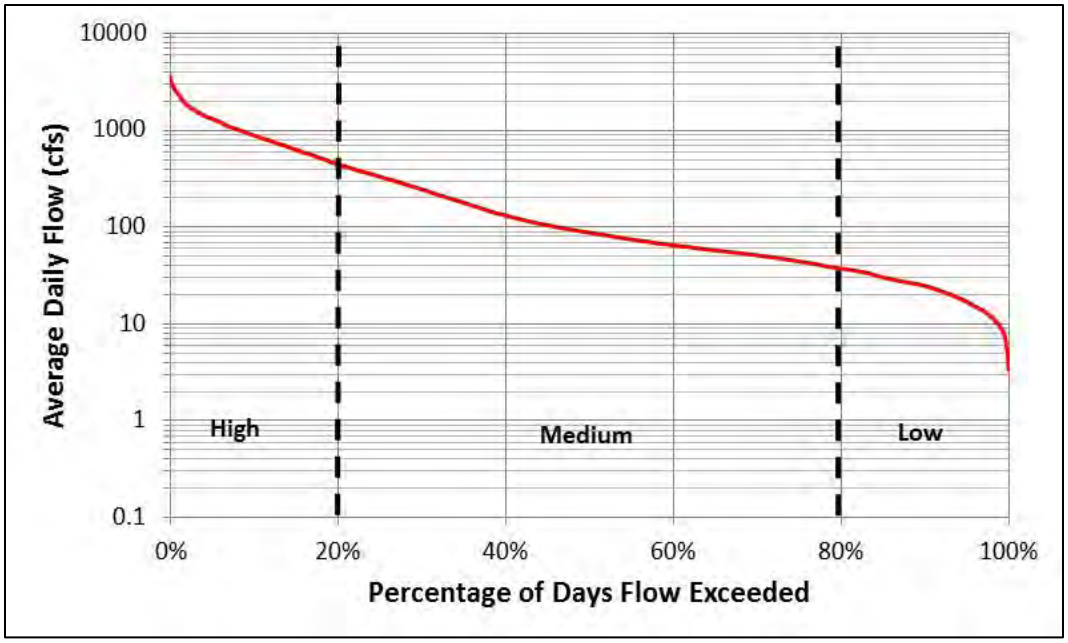


Figure 1.8. Estimated flow duration curve for BR3.

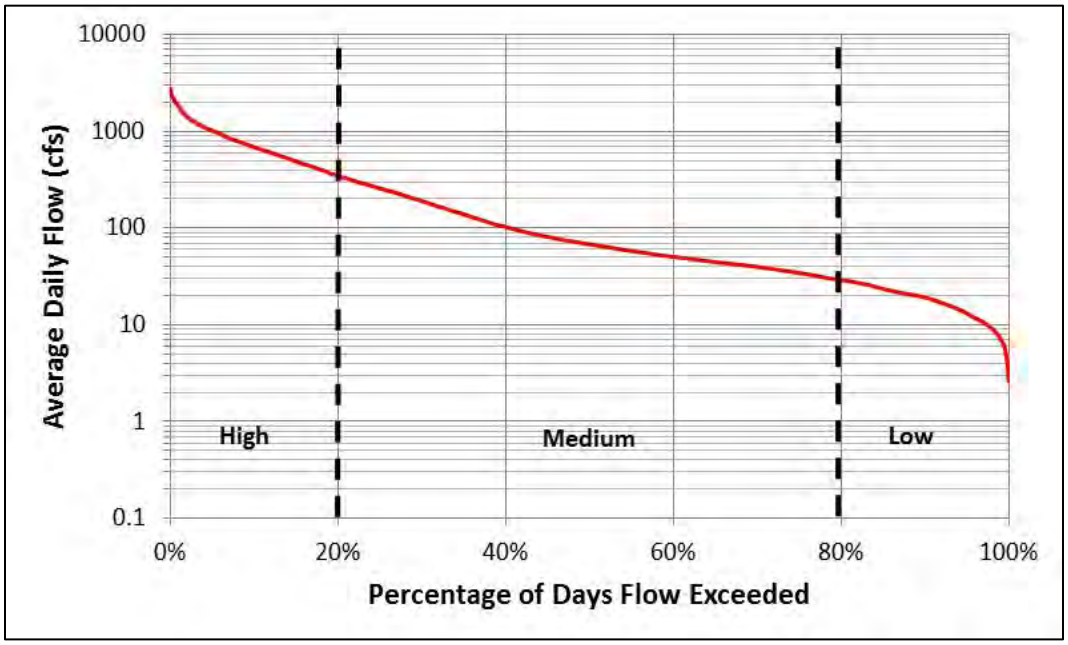


Figure 1.9. Estimated flow duration curve for BR2.

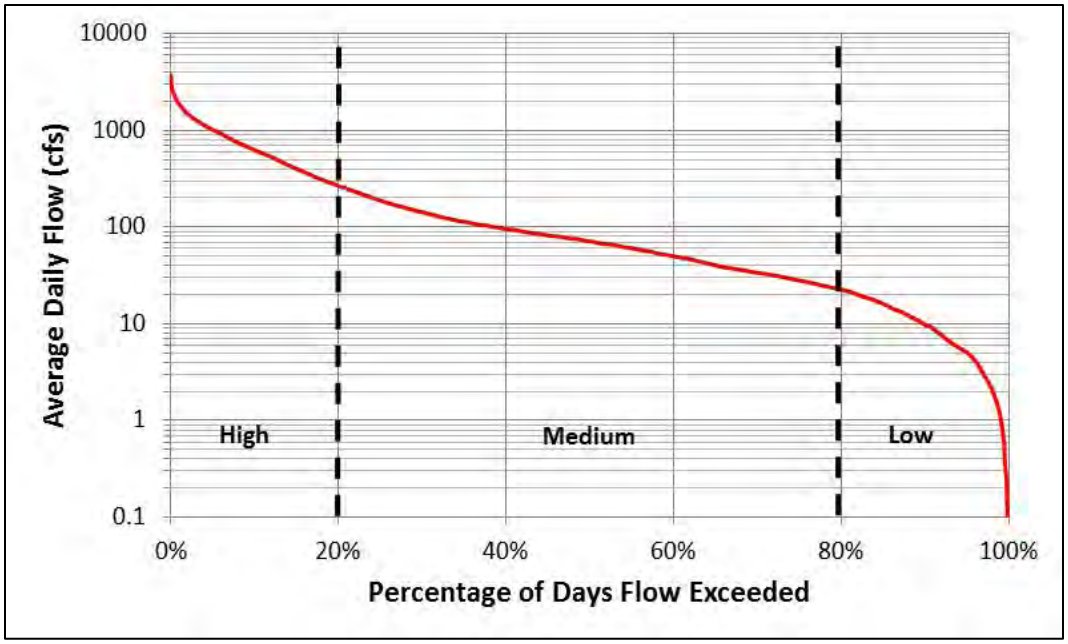


Figure 1.10. Estimated flow duration curve for BR1.

Lower Sulphur Creek is entirely controlled by releases from Sulphur Creek Reservoir, as evidenced by the abnormal concave shape of the FDC and strange behavior at the tail of the FDC (Figure 1.11). As the largest tributary to the impaired segment, Sulphur Creek plays a major role in the hydrology of the Bear River, and therefore Sulphur Creek Reservoir also has important downstream effects on the Bear River. These effects are discussed in more detail section 3.3.2.2.

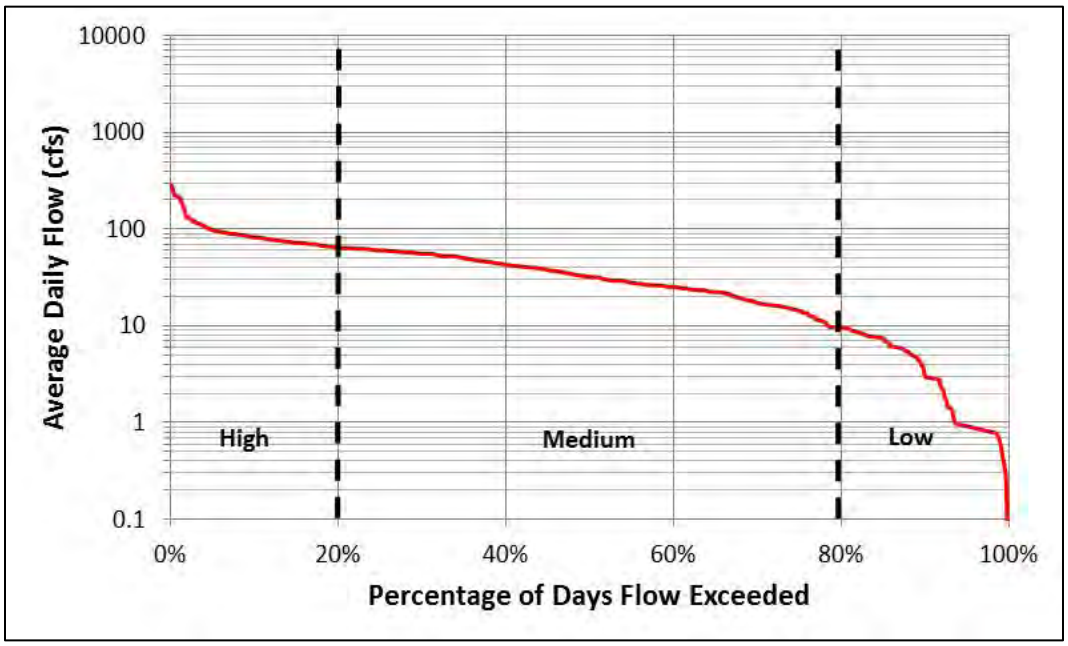


Figure 1.11. Estimated flow duration curve for SC1.

The other major tributary to the impaired segment of the Bear River is Yellow Creek, which enters the Bear River just northwest of Evanston. Little is known about the flows in Yellow Creek near its

confluence with the Bear River. There was a USGS flow gage (10017000) on Yellow Creek near the Wyoming-Utah state line that operated from 1943 to 1978 (Figure 1.12). However, it is upstream of most major irrigation diversions and does not necessarily represent flows at the mouth of Yellow Creek, especially because it has no data from the past 35 years. Flows are low at the mouth of Yellow Creek (i.e., less than 5 cfs) for most of the year, but during spring snowmelt, flows generally range from 20 to 30 cfs, and can peak as high as 100 cfs (personal communication, Donald Shoemaker, Water Commissioner for District IV, to John Christensen, SWCA, November 20, 2013). Based on available information, an average high flow of 25 cfs was estimated for Yellow Creek at its confluence with the Bear River.

A summary of all flow duration curves is shown in Figure 1.13.

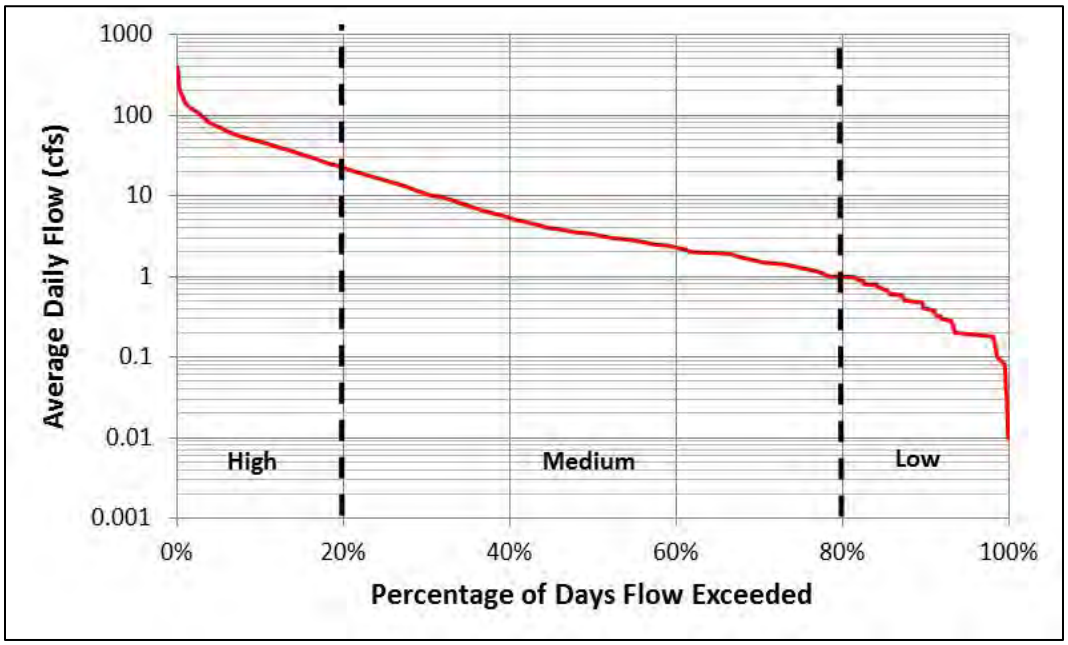


Figure 1.12. Flow duration curve for USGS gage 10017000.

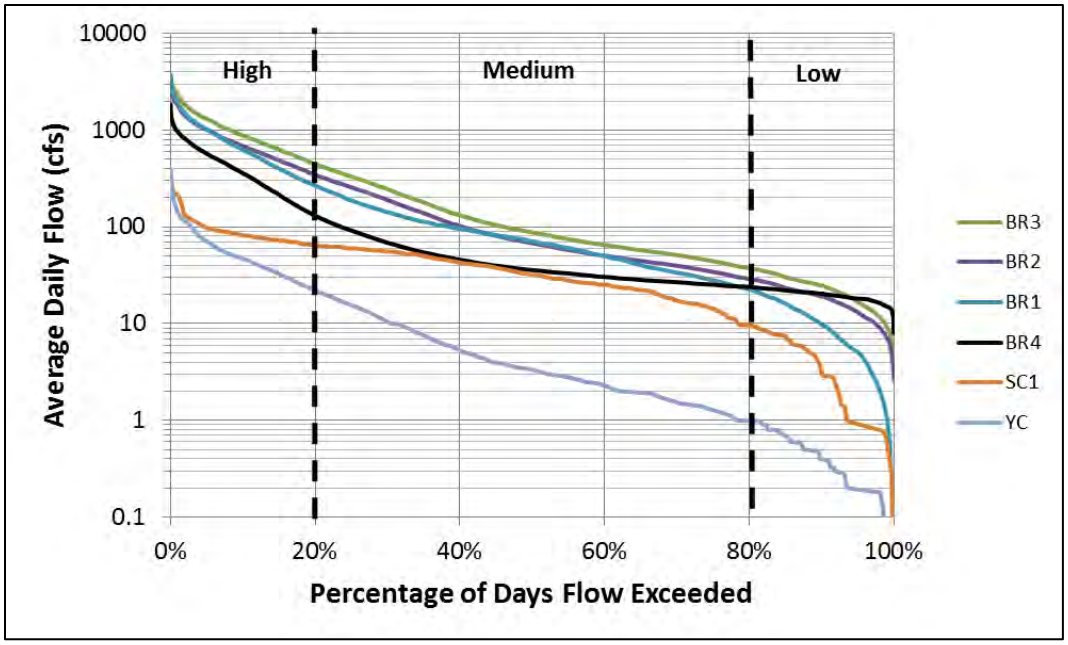
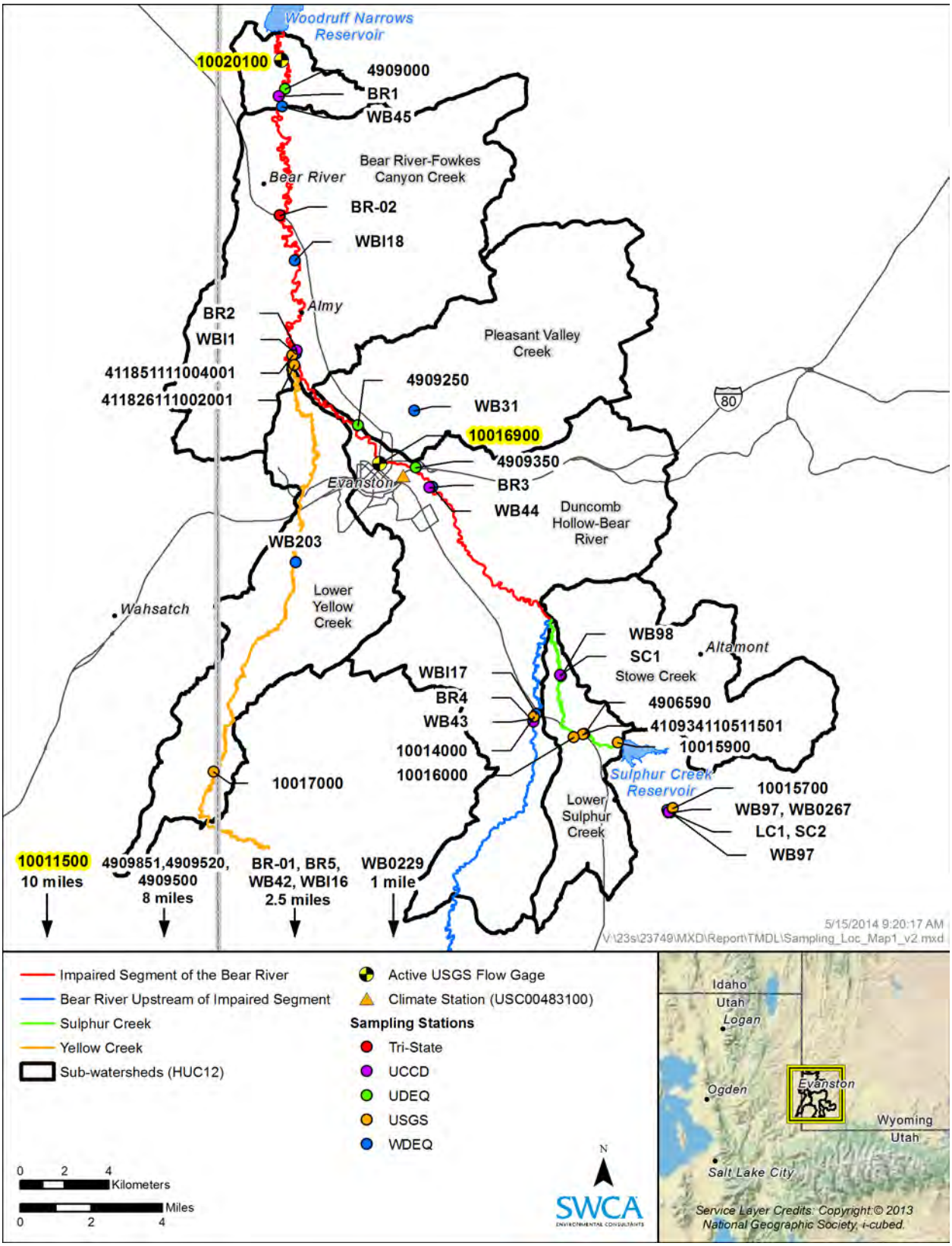


Figure 1.13. Flow duration curve summary.

1.4.5. Water Quality

Water quality data for this TMDL were available from UCCD, USGS, WDEQ, and the UDEQ. Parameters included flow, total suspended solids (TSS), turbidity, suspended sediment concentration (SSC), and other physical and chemical data. A summary of all sampling locations, agency source, period of record, and number of samples is provided in Appendix B as shown on Map 1.11.

As previously mentioned, TMDL load calculations rely on paired flow and pollutant data. For the Bear River TMDL, the pollutant data needs to be related to sediment. In the water quality database for the Bear River, these data include TSS, turbidity, and SSC. TSS and SSC data are the most representative for calculating sediment loads; however, measurements of TSS and SSC use different laboratory methods, and the results are not interchangeable. Therefore, the most useful and robust dataset for paired flow and sediment concentrations (TSS) is from the UCCD. A summary of these data pairs is provided in Table 1.17. Turbidity is included in this summary table because it was necessary for calculating background sediment concentrations (section 3.3.2). This summary table also includes flow estimates using the regression analysis described in section 1.4.4 and Table 1.15.



Map 1.11. USGS flow gages and sampling stations available for the Bear River TMDL.

Table 1.16. Water Quality Data Useful to the TMDL

UCCD Monitoring Station	Date	Flow (cfs)	Regressed Flows (cfs)	TSS (mg/L)	Turbidity Lab (NTU)
BR1	6/5/2007	Very deep	166.67	13	9.23
BR1	9/24/2007	29.021	–	11	11.1
BR1	6/2/2008	Too high	922.88	88	40.9
BR1	9/22/2008	45.539	–	6.8	6.68
BR1	6/1/2009	Too high	818.12	48	18.7
BR1	9/29/2009	29.247	–	4.4	4.54
BR1	6/1/2010	Too high	1,000.03	96	47.1
BR1	9/27/2010	10.549	–	2	3.38
BR1	7/25/2011	Too high	264.77	25	9.62
BR1	9/26/2011	39.100	–	1.6	1.92
BR1	6/4/2012	94.210	–	3.2	2.19
BR1	9/25/2012	14.660	–	7.8	5.32
BR2	6/5/2007	Very deep	205.29	10	7.31
BR2	9/24/2007	Rolling	63.80	38	29.5
BR2	6/2/2008	Too high	1,030.56	300	98.3
BR2	9/22/2008	58.248	–	3.2	3.32
BR2	6/1/2009	Too high	850.62	33	16
BR2	9/29/2009	42.322		4.5	3.39
BR2	6/1/2010	Too high	875.16	110	52
BR2	9/27/2010	30.299	–	2.4	2.33
BR2	7/25/2011	Too high	290.36	24	9.25
BR2	9/26/2011	81.830	–	1.9	2.57
BR2	6/4/2012	141.110	–	8.7	3.07
BR2	9/25/2012	27.780	–	8.2	4.90
BR3	6/5/2007	Fast and high	264.92	11	6.12
BR3	9/24/2007	86.805	–	29	23.2
BR3	6/2/2008	Flooding	1,329.88	160	97.6
BR3	9/22/2008	62.856	–	3.2	3.28
BR3	6/1/2009	Too high	1,097.68	32	12.6
BR3	9/29/2009	41.215	–	2.3	2.13
BR3	6/1/2010	Too high	1,129.34	98	38.1
BR3	9/27/2010	41.335	–	1.2	1.57
BR3	7/25/2011	Too high	374.69	9.1	6.74
BR3	9/26/2011	100.870	–	3.3	3.47
BR3	6/4/2012	Too high	191.04	6.3	2.37
BR3	9/25/2012	28.560	–	5.9	5.55
BR4	6/5/2007	Fast and high	284.42	9.5	5.22

Table 1.16. Water Quality Data Useful to the TMDL

UCCD Monitoring Station	Date	Flow (cfs)	Regressed Flows (cfs)	TSS (mg/L)	Turbidity Lab (NTU)
BR4	9/24/2007	Too swift	48.53	11	11.6
BR4	6/2/2008	Very high	669.60	98	44
BR4	9/22/2008	51.518	–	0.8	1.46
BR4	6/1/2009	Too high	600.79	17	8.98
BR4	9/29/2009	43.195	–	1	0.751
BR4	6/1/2010	Too high	512.33	55	25.6
BR4	9/27/2010	36.926	–	0.5	0.658
BR4	7/25/2011	Too high	295.48	4.5	4.74
BR4	9/26/2011	88.970	–	2	1.52
BR4	6/4/2012	Too high	240.81	10.2	2.01
BR4	9/25/2012	23.930		2	0.637
BR5	6/5/2007	Too high	337.82	9.1	4.78
BR5	9/24/2007	76.630	–	8.5	7.34
BR5	6/2/2008	High flow	795.31	79	17.4
BR5	9/22/2008	62.274	–	1.7	1.33
BR5	6/1/2009	Too high	713.59	21	5.98
BR5	9/29/2009	48.189	–	0.5	0.637
BR5	6/1/2010	Too high	608.52	25	10
BR5	9/27/2010	51.350	–	0.5	0.616
BR5	7/25/2011	Too high	350.96	8.3	4.57
BR5	9/26/2011	86.200	–	1.4	1.09
BR5	6/4/2012	Too high	286.02	7	1.86
BR5	9/25/2012	47.060	–	2	0.625
SC1	6/5/2007	13.845	–	2.7	16.2
SC1	9/24/2007	1.429	–	7.4	8.98
SC1	6/2/2008	73.006	–	44	15.2
SC1	9/22/2008	15.194	–	5.8	6.55
SC1	6/1/2009	29.123	–	5.9	5.52
SC1	9/29/2009	9.398	–	6.2	5.58
SC1	6/1/2010	Too high	122.03	29	14.5
SC1	9/27/2010	9.113	–	3.2	4.47
SC1	7/25/2011	16.860	–	2.6	3.23
SC1	9/26/2011	37.540	–	11	7.12
SC1	6/4/2012	29.710	–	10.6	2.45
SC1	9/25/2012	11.420	–	8.0	6.22

1.4.6. Fisheries

The fisheries of the Bear River watershed vary in diversity and productivity throughout the river network. There are many species of game and non-game fish in the Bear River, including Bonneville cutthroat trout, Utah sucker, mountain sucker, bluehead sucker, Utah chub, red-side shiner, leatherside chub, dace, and sculpins. As part of a monitoring assessment of the Bear River completed by the WQD in 1998 (WDEQ 2001a), the WDQ identified historical reports of fisheries in the Bear River watershed and found that as far back as 1850, Bonneville cutthroat trout were observed and caught by early travelers and scientists. This monitoring assessment also identified a comprehensive fisheries survey conducted by the WGFD that was initiated in 1966 and completed in the late 1970s. Based on an electrofishing study performed in 1972, this survey found a general trend of decreasing trout populations along the length of the river, beginning above the Sulphur Creek confluence, and ending at Woodruff Narrows Reservoir (Table 1.17). These findings are consistent with the monitoring assessment findings of decreasing habitat quality and macroinvertebrate diversity along the impaired segment of the Bear River (WDEQ 2001a).

Table 1.17. Wyoming Game and Fish Electrofishing Data, Bear River

Location	Date	Distance Sampled (feet)	Estimated Trout per Mile	Species and Number or Frequency	Source
Near BR5	August 1972	500	85	Bonneville cutthroat: 3 Snake River cutthroat: 5 Utah chub: present Red-side shiner: present Sculpins: present	Miller (n.d. [1977])
Near BR4	August 1972	300	106	Bonneville cutthroat: 6 Mountain whitefish: numerous Utah chub: 1 Red-side shiner: numerous Dace: present Mountain sucker: numerous Sculpins: present Leatherside shiner: present	Miller (n.d. [1977])
Near BR3	August 1972	1,200	48	Bonneville cutthroat: 11 Mountain whitefish: numerous Utah sucker: numerous Utah chub: numerous Bluehead sucker: present Red-side shiner: numerous Dace: present Mountain sucker: present Sculpins: present	Miller (n.d. [1977])

Table 1.17. Wyoming Game and Fish Electrofishing Data, Bear River

Location	Date	Distance Sampled (feet)	Estimated Trout per Mile	Species and Number or Frequency	Source
Near BR3	July 2005	12,144	6	Bonneville cutthroat: 12 Brown trout: 2 Bluehead sucker: 3 Mountain whitefish: 102 Leatherside chub: 2 Longnose dace: 33 Sculpins: 3 Mountain sucker: 12 Red-side shiner: 1 Speckled dace: 14 Utah sucker: 17	WGFD (2005)
Near BR3	July 2008	12,672	20	Bonneville cutthroat: 41 Brown trout: 4 Brook trout: 1 Rainbow trout: 2 Bluehead sucker: 50 Mountain whitefish: 209 Mountain sucker: 56 Mottled sculpin: 13 Longnose dace: 20 Speckled dace: 36 Red-side shiner: 14 Utah chub: 3 Utah sucker: 35	WGFD (2008)
Near BR2	August 1972	500	21	Bonneville cutthroat: 2 Utah sucker: numerous Utah chub: present Bluehead sucker: present Red-side shiner: present Dace: present Sculpins: present	Miller (n.d. [1977])
Near BR2	July 2005	13,147	10	Bonneville cutthroat: 22 Rainbow trout: 2 Mountain whitefish: 36 Longnose dace: 14 Sculpins: 3 Mountain sucker: 8 Red-side shiner: 15 Speckled dace: 31 Utah sucker: 60	WGFD (2005)
Near BR1	August 1972	500	0	Utah sucker: 4 Utah chub: common Redside shiner: numerous	Miller (n.d. [1977])

Table 1.17. Wyoming Game and Fish Electrofishing Data, Bear River

Location	Date	Distance Sampled (feet)	Estimated Trout per Mile	Species and Number or Frequency	Source
Near BR1	July 2006	13,728	0	Bonneville cutthroat: 1 Mountain whitefish: 1 Longnose dace: 7 Red-side shiner: 90 Speckled dace: 173 Utah sucker: 76	WGFD (2006)

The Miller survey report (n.d. [1977]) notes that non-game fish dominate the fish populations of the impaired segment of the Bear River, despite past stocking of Snake River cutthroat and brown, rainbow, and brook trout. This observation is vetted from recent electrofishing monitoring studies conducted throughout the Bear River Basin by the WGFD from 2004 to 2008. In 2005, within the Bear River State Park (near BR3), an electrofishing survey found that the fish assemblage was dominated by mountain whitefish (51% of all fish collected), though some Bonneville trout and leatherside chubs were found (see Table 1.17; WGFD 2005). In 2006, the reach just upstream of Woodruff Narrows Reservoir was sampled and was also found to be dominated by non-game fish, including speckled dace, red-side shiners, and young Utah suckers, with only one Bonneville trout identified (see Table 1.17; WGFD 2006). The report also finds that trout habitat was very poor in this reach due to low flows combined with very shallow, low velocity runs with few riffles or pools. A third survey performed in 2008 between Bear River State Park and the City of Evanston finds that most trout occupied the upper half of the reach through the state park where habitat is best, and very few trout were found north of Interstate 80 (I-80) (WGFD 2008). The 2008 report also concludes that the whitewater structures near I-80 do not appear to provide suitable trout habitat.

In addition to reduced habitat viability for game fish due to siltation and sediment (WDEQ 2001a), more recent studies have identified fish migration barriers as a potential impediment to fishery productivity. The Old City Diversion near the City of Evanston was found to be potentially limiting to fish movement in the high flow year of 2011, but in December 2013, the diversion was fitted with a rock and concrete block fish ladder to aid trout movement (Trout Unlimited 2014; Figure 1.14). It was also found that Mill Creek, a tributary to the Bear River, is likely an important migration pathway for trout during the spring, but some fish were found to use Sulphur Creek as well as the upper reaches of the Bear River (Trout Unlimited 2014). In the same report, a number of fish entrainment issues were identified due to trout movement into irrigation canals, where they could not escape and ultimately died.

Figure 1.14. Newly constructed rock fish ladder on the Old City Diversion. Photo credit: Trout Unlimited.

2 WATER QUALITY TARGETS

Many western states, including Wyoming, have narrative standards for sediment-based water quality parameters. These narrative standards provide guidance for preventing sediment from exceeding quantities that would impair designated uses, but lack the clarity that a numeric standard has for defining sediment-based water quality impairments. Wyoming has narrative standards for settleable solids and for floating and suspended solids, but it has numeric criteria for turbidity (see Table 1.2). Although the turbidity standard provides quantifiable targets, it refers to increases in turbidity above some background level. This is opposed to an exact target level, which is more desirable for a TMDL because it provides for direct comparison to field and laboratory measurements.

In this TMDL, the identification of an appropriate water quality target is derived from evaluation of reference conditions, review of available literature, other state standards, and precedent in other sediment TMDLs in comparable waterbodies. This approach uses the best available evidence to set an attainable target that, if not exceeded, will result in full support of all uses designated for the Bear River by the State of Wyoming for a Class 2AB waterbody.

Although there is more than one measure available to quantify stream sediment concentrations (e.g., turbidity and SSC), TSS is the most commonly used and measured. For this reason, TSS was chosen as the measure for the sediment water quality target used in this TMDL.

A review of literature, state standards, and TMDLs for similar waterbodies to the Bear River indicates that a TSS concentration in the range of 20–80 milligrams per liter (mg/L) is a reasonable sediment water quality target (Table 2.1).

Table 2.1. Sediment Targets in Literature and other TMDLs for Protection of Cold and Warm Water Fish

Source	Sediment Target (TSS)
Water Quality Criteria for European Freshwater Fish (European Inland Fisheries Advisory Commission 1964)	25–80 mg/L
Newcombe and Jensen (1996); review of 80 published reports on TSS in streams and estuaries	Reduced feeding and abundance at 18–35 mg/L Lethal effects in rainbow trout began 50–100 mg/L
South Dakota Administrative Rule 74:51:01:55	30-mg/L 30-day average for cold water fish 53-mg/L daily maximum for cold water fish 90-mg/L 30-day average for warm water fish 158-mg/L daily maximum for warm water fish
Nevada Administrative Code 445A	25–80 mg/L
Lower Bear River Water Quality Management Plan (UDEQ 1995)	35 mg/L for smaller streams 90 mg/L for larger streams
Bear River TMDL (IDEQ 2006)	60 mg/L during lower basin runoff 80 mg/L during upper basin runoff 35 mg/L during summer base flow 60 mg/L during winter base flow
Snake River-Hells Canyon TMDL (IDEQ 2004)	Less than 50 mg/L monthly average Less than 80 mg/L for no more than 14 days
Lower Boise River TMDL (IDEQ 1999)	Less than 50 mg/L for no more than 60 days 80 mg/L for no more than 14 days

Table 2.1. Sediment Targets in Literature and other TMDLs for Protection of Cold and Warm Water Fish

Source	Sediment Target (TSS)
Portneuf River TMDL (IDEQ 2001a)	Less than 50 mg/L monthly average Less than 80 mg/L maximum daily value
Blackfoot River TMDL (IDEQ 2001b)	50–80 mg/L
Yakima River TMDL (Joy and Patterson 1997)	56 mg/L

Based on this information, a sediment water quality target of 30 mg/L TSS for a 30-day average was chosen for the Bear River sediment TMDL. This sediment water quality target applies to flows across all seasons to support all Class 2AB uses designated by the State of Wyoming for the Bear River (in Wyoming) that include drinking water, game and non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value.

This target falls within the 25- to 80-mg/L TSS range recommended by the European Inland Fisheries Advisory Commission (1964) for maintaining good to moderate fisheries. Newcombe and Jensen's (1996) review of 80 published reports on TSS in streams and estuaries finds that health effects in rainbow trout began at as low as 18 mg/L, and lethal effects in rainbow trout began at observed concentrations of 50–100 mg/L when those concentrations were maintained for 14 to 60 days.

The TSS target of 30 mg/L is further justified through examination of measurements taken at the UCCD monitoring stations upstream of the impaired segment (BR4 and BR5). Because these stations are in a non-impaired segment of the Bear River, they represent a relatively good reference for comparison to the impaired segment. The average measured TSS at high flows at BR5 (near the Utah state line) is 25 mg/L, and the average measured TSS at high flows at BR4 (above the confluence with Sulphur Creek) is 32 mg/L (average of 29 mg/L for both stations at high flows). In comparison, the average measured TSS at high flows at the first UCCD monitoring station in the impaired segment (BR3) is 97 mg/L, roughly 3 times much than was measured at BR4. Therefore, it is reasonable to assume that a TSS target of 30 mg/L as a 30-day average represents an achievable and evidence-based water quality target. Furthermore, the monthly average TSS discharge limit for the City of Evanston Municipal Wastewater Treatment Plant is 30 mg/L (see Table 3.2).

Using this water quality target and the flow duration curves from section 1.4.4, load duration curves were developed for each UCCD monitoring station. These load duration curves were used to provide a visual examination of the sediment impairment by plotting the instantaneous TSS loads on the load duration curve for each monitoring station (Figures 2.1 through 2.5). Instantaneous loads that plot above the curve indicate an exceedance of the water quality target, whereas those below the load duration curve show compliance.

Examination of the load duration curves and instantaneous loads shows that most of the load exceedances occur during high flows associated with spring runoff. This provides evidence for the selection of high flows during spring runoff as the critical condition and season of sediment loading to the impaired segment of the Bear River (see section 4.3 for additional details on seasonality and critical conditions).

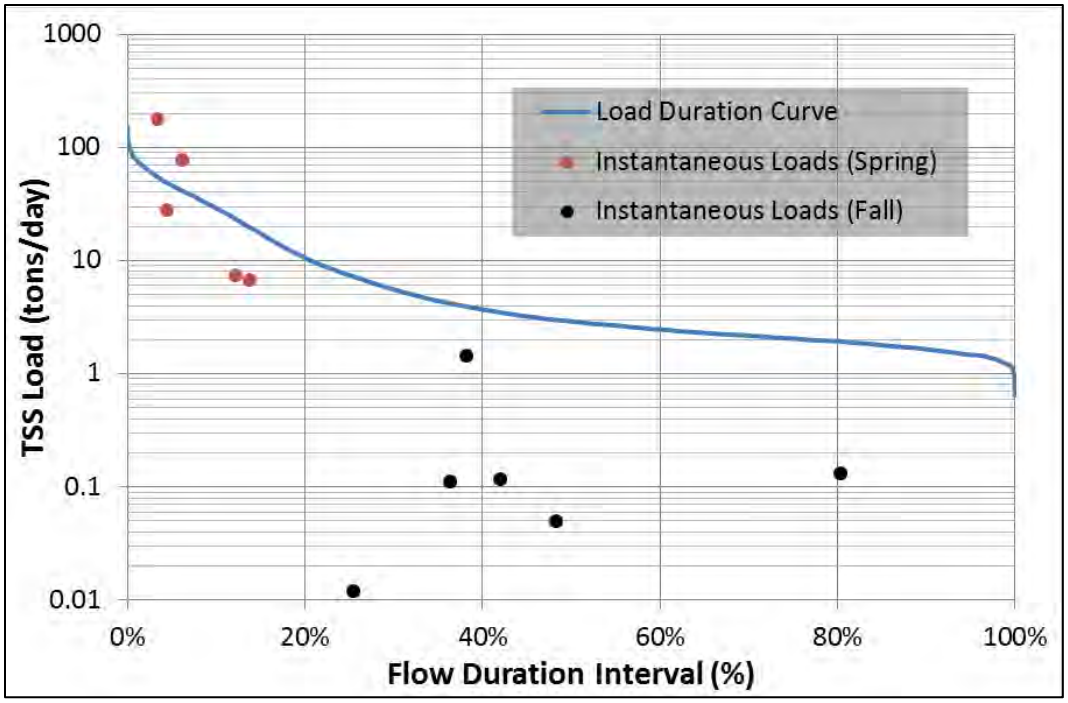


Figure 2.1. Load duration curve and instantaneous loads for BR4.

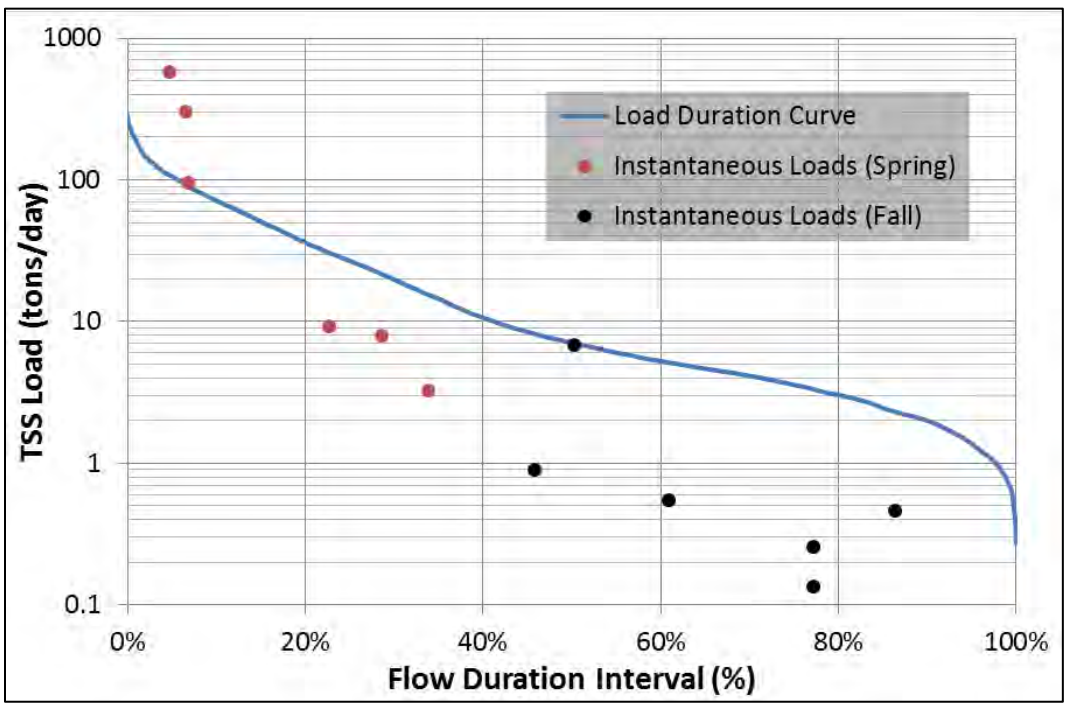


Figure 2.2. Load duration curve and instantaneous loads for BR3.

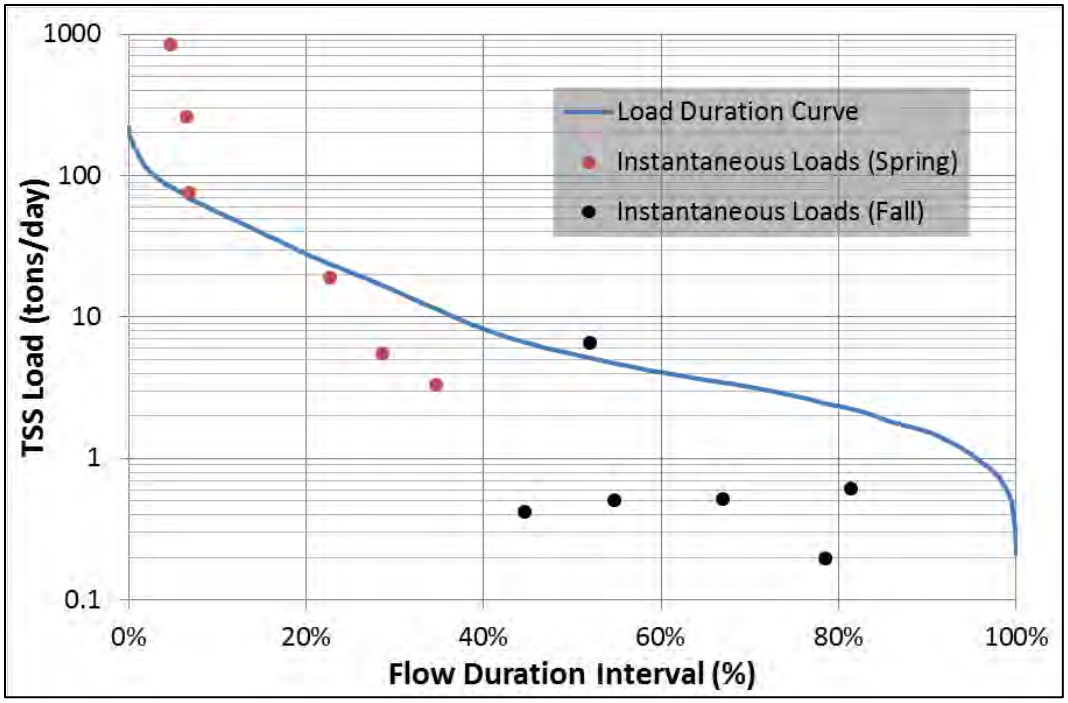


Figure 2.3. Load duration curve and instantaneous loads for BR2.

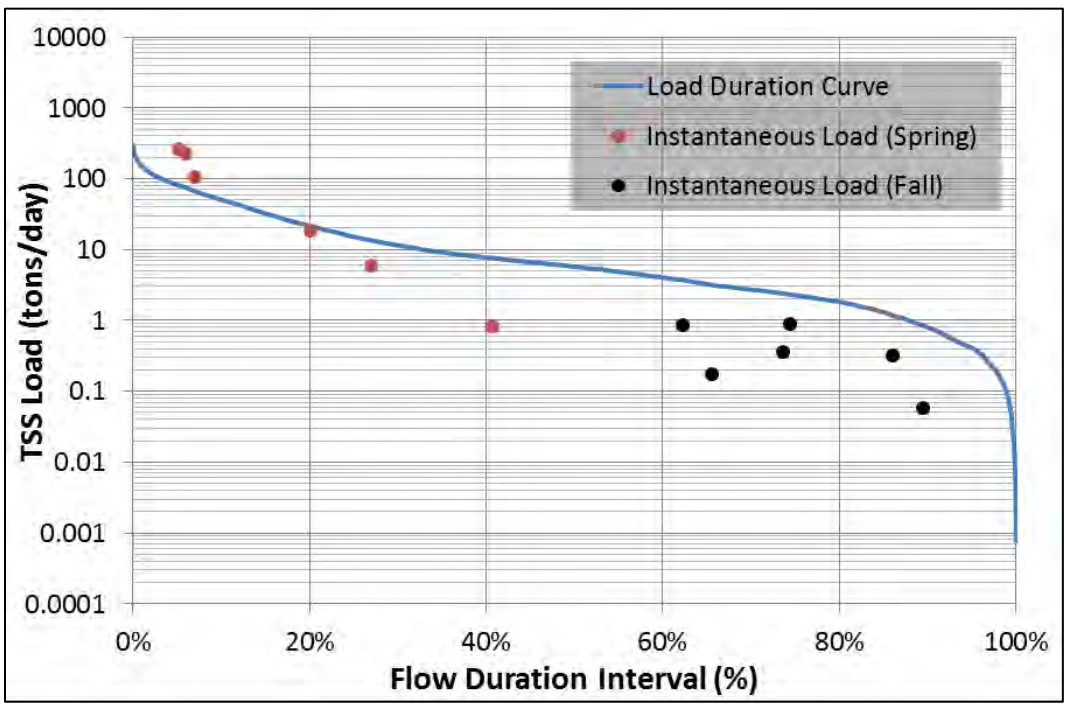


Figure 2.4. Load duration curve and instantaneous loads for BR1.

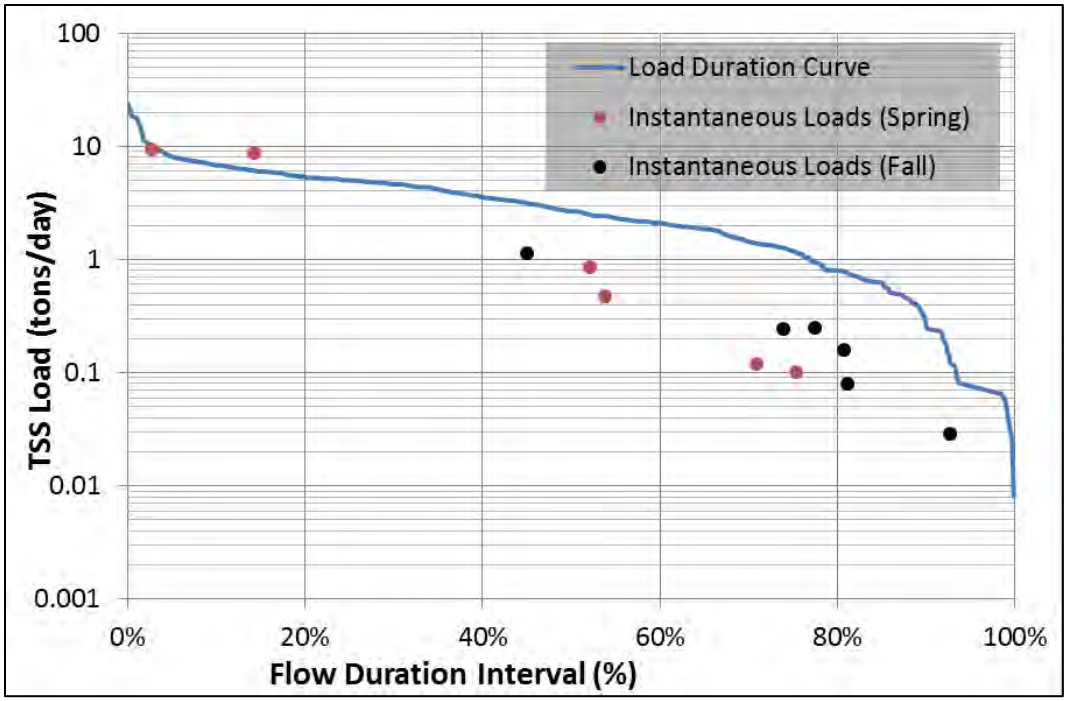


Figure 2.5. Load duration curve and instantaneous loads for SC1.

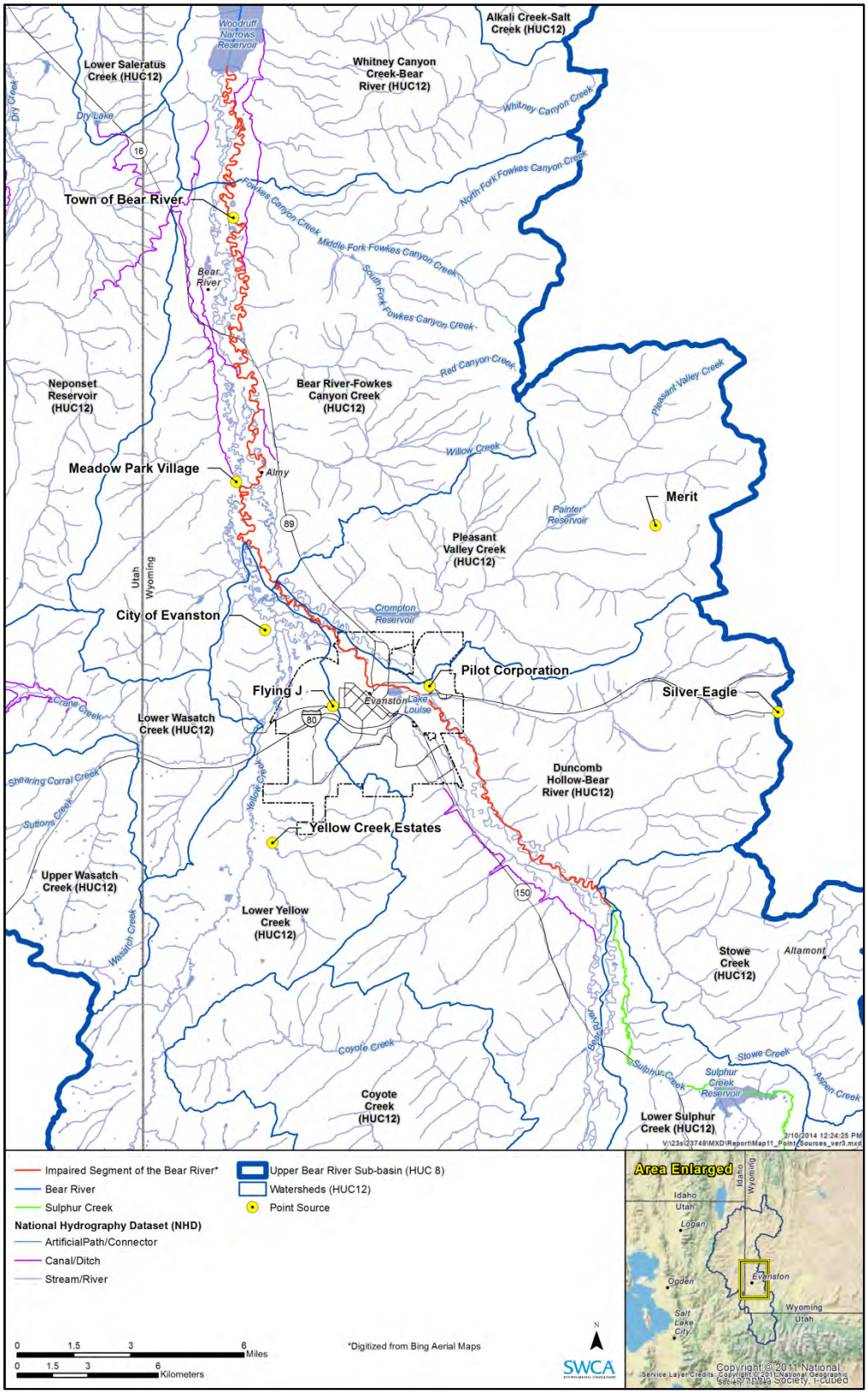
3 SOURCE ANALYSIS

This section identifies and discusses sediment sources that contribute to the habitat modification impairment of the Bear River. Sediment loads to the Bear River are categorized into point and nonpoint sources, where point sources are spatially discrete regulated sources of pollution (i.e., represented by a point in space) and nonpoint sources are generally spatially distributed and not regulated. There are eight point sources in the Bear River watershed. Nonpoint sources of sediment comprise stormwater, watershed erosion, and channel and bank erosion. Contributions from point and nonpoint sources vary throughout the year and by location within the watershed.

3.1. Point Sources

The CWA requires that discharge of any pollutant from a point source into a surface water of the United States must be regulated under the National Pollutant Discharge Elimination System (NPDES). For Wyoming, the NPDES permit program is administered through the Wyoming Pollutant Discharge Elimination System (WYPDES) Program (WDEQ 2013d). This program requires the operator of a point source discharge to obtain a WYPDES discharge permit, which places limits and conditions on discharge to assure that the state's surface water quality standards are protected.

There are eight point sources near the impaired segment of the Bear River (Map 3.1) The discharges of each of these eight point sources are covered under individual WYPDES discharge permits and listed in Table 3.1. Also listed in Table 3.1 are the permit numbers, permit use type, and the discharge receiving water.



Map 3.1. Locations of point sources in the Bear River watershed.

Table 3.1. Point Sources near the Impaired Segment of the Bear River

Permit Holder	Permit Number	Use Type	Receiving Waters	Source
City of Evanston	WY0020095	Municipal wastewater	Yellow Creek	WDEQ (2009a)
Town of Bear River	WY0031712	Municipal wastewater	Bear River	WDEQ (2012b)
Flying J, Inc.	WY0035700	Commercial wastewater	Yellow Creek via a City of Evanston storm drain	WDEQ (2009b)
Yellow Creek Estates	WY0028665	Municipal wastewater	Yellow Creek via an unnamed drainage. According to observations by WDEQ inspectors, when the facility discharges, the effluent does not reach Yellow Creek (WDEQ 2005a).	WDEQ (2005a)
Meadow Park Village Homeowners Association	WY0031348	Municipal wastewater	Chapman Ditch via Simms, Blight, and Turner Ditches. Simms, Blight, and Turner Ditches do not discharge to the Bear River.	Data from WDEQ (2005b)
Silver Eagle Refining, Inc.	WY0044199	Commercial wastewater	Albert Creek via an unnamed ditch. Albert Creek does not discharge to the Bear River.	WDEQ (2007)
Pilot Corporation	WY0041084	Commercial wastewater	Rocky Mountain and Blyth Ditches Rocky Mountain and Blyth Ditches do not discharge to the Bear River.	WDEQ (2005c)
Merit Energy	N/A	Commercial wastewater	N/A	No information available (personal communication, Leah Coleman, to John Christensen, SWCA, February 11, 2013).

Of the eight point sources listed in Table 3.1, only three are hydraulically connected to the Bear River (in other words, only three can contribute sediment to the Bear River). One of these point sources (Town of Bear River) discharges directly to the impaired segment, and two (City of Evanston and Flying J) discharge to Yellow Creek.

The Town of Bear River wastewater treatment facility is the only point source listed above that discharges sediment directly to the Bear River. The remaining point sources do not discharge directly to the Bear River; however, two of the point sources listed in Table 3.1 (City of Evanston and Flying J) do discharge to Yellow Creek, a tributary to the Bear River. No other point sources are known to contribute sediment to the impaired segment of the Bear River. Therefore, the City of Evanston, the Town of Bear River, and Flying J are discussed further. Data monitoring reports (DMRs) are available for these point sources (personal communication, Leah Coleman, to John Christensen, SWCA, February 11, 2013). A summary of these three point sources and their DMRs is provided in sections below.

The City of Evanston municipal wastewater treatment plant is approximately 2.6 miles northwest of downtown Evanston (southwest quarter of the southwest quarter of Section 7, Township 15 North, Range

120 West, Uinta County). The City of Evanston's treatment plant is a mechanical treatment plant that includes course screening, degritting, oxidation ditch, final clarification, and ultraviolet disinfection. The treated effluent is discharged to Yellow Creek approximately 3.5 stream miles above the confluence with the Bear River. The permit requires continuous monitoring of discharge as a daily total, and weekly composite samples for TSS analysis. During the irrigation season, much of the effluent (1.0–1.9 million gallons per day [MGD]) is diverted by a local farmer to irrigate alfalfa fields (WDEQ 2009a). The DMR data for this point source were provided by the WYPDES program, include data from 2002 to 2012, and are summarized in Table 3.2.

Table 3.2. Summary of DMR Data for the City of Evanston Municipal Wastewater Treatment Plant

Data Source	Monthly Average Discharge (MGD)	Daily Maximum TSS (mg/L)*	Weekly Average TSS (mg/L)*	Monthly Average TSS (mg/L)*
Permit limits	2.9	90	45	30
DMR sample value min.	0.9	1.3	0.6	0.5
DMR sample value max.	2.5	17.3	10.3	7.3
DMR sample value average	1.4	4.2	3.2	2.3

* DMR values revised by WDEQ (personal communication via email, Brianna Forrest on behalf of the WYPDES Program, to John Christensen, SWCA, November 21 and December 3, 2013).

None of the measured discharges or TSS results collected from 2002 to 2012 exceeded the permitted discharge limits.

The Town of Bear River municipal wastewater treatment plant (also referred to as the Whitney Mead treatment facility in the permit) is at the El Caballo Ranch approximately 10 miles north of Evanston, Wyoming (northeast quarter of the northwest quarter of Section 1, Township 16 North, Range 121 West, Uinta County). The Town of Bear River treatment plant consists of a three-cell, non-aerated lagoon system with no disinfection equipment. The facility discharges to the Bear River intermittently, approximately once every 3 months for 5–12 consecutive days. Effluent limits for TSS are based on a monthly average of 100 mg/l which is consistent with alternate National Secondary Treatment Standards. The permit requires monthly monitoring of flow and TSS via instantaneous and grab samples, respectively (WDEQ 2012b). The DMR data for this point source were provided by the WYPDES program, include data from 2002 to 2012, and are summarized in Table 3.3.

Table 3.3. Summary of DMR Data for the Bear River Municipal Wastewater Treatment Plant

Data Source	Monthly Average Discharge (MGD)	Daily Maximum TSS (mg/L)	Weekly Average TSS (mg/L)	Monthly Average TSS (mg/L)
Permit limits	0.175	300	150	100
DMR sample value min.	0.0	2	2	2
DMR sample value max.	3.0	150	150	149
DMR sample value average	0.2	23	23	21

None of the measured discharges or TSS results collected from 2002 to 2012 exceeded the permitted discharge limits.

The Flying J facility is at 192 Harrison Drive at the west end of Evanston, Wyoming (southwest quarter of the northwest quarter of Section 20, Township 15 North, Range 120 West, Uinta County). This facility

includes a truck stop, restaurant, and a gasoline service station. Wastewater consists of stormwater runoff and wash water from the fueling islands. The wastewater treatment system includes an oil/water separator to treat wastewater before discharge. Stormwater runoff and wash water will course through the oil/water separator, then discharge through the primary outfall located on the southwest corner of the property. This facility discharges intermittently and during non-freezing weather to the City of Evanston storm drain system to Yellow Creek. The permit requires weekly monitoring of flow for instantaneous values and monthly grab samples for TSS. The permit does not establish a flow limit (WDEQ 2009b). The DMR data for this point source were provided by the WYPDES program, include data from 2002 to 2011 (TSS from 2010 to 2011), and are summarized in Table 3.4.

Table 3.4. Summary of DMR data for the Flying J Commercial Wastewater Treatment.

Data Source	Monthly Average Discharge (MGD)	Monthly Average TSS (mg/L)
Permit limits	N/A	30
DMR sample value min.	0.0	7
DMR sample value max.	1.8	54
DMR sample value average	0.1	26

Note: N/A = not applicable. Only permits that establish water quality based effluent limits require a flow limit.

None of the measured discharges or TSS results collected from 2010 to 2011 exceeded the permitted discharge limits.

3.2. Natural Background

The Bear River is an alluvial river that has consistently shifted its course and pattern throughout history. This is evidenced by aerial/satellite photographs and by physical features visible during on-site inspections. These features include abandoned channels, meander cutoffs, meander scrolls, and vegetational growth patterns. Such activity indicates that, even in the absence of human influences, the Bear River is naturally subject to change and likely cannot be described by a single, stable channel configuration. This implies that there is a large natural background flux of sediment that moves through the Bear River.

3.3. Nonpoint Sources

Nonpoint sources of sediment include watershed erosion, stream bank and channel erosion, and urban stormwater runoff. The individual contribution from each of these sources is difficult to measure and tends to vary both spatially and temporally. However, the analysis presented here provides evidence that the greatest contributor to sediment loads in the impaired segment Bear River is stream bank and channel erosion. These nonpoint sediment sources are discussed further below

3.3.1. Watershed Erosion

For the Bear River TMDL, watershed erosion is defined as any overland process that transports sediment from the watershed directly to the Bear River. Watershed erosion is a continuous process and varies according to many factors, including sediment type and composition, wind velocity, rainfall volume, rainfall intensity (i.e., the rate of rainfall), and humidity. Direct transport of watershed sediment losses to

the Bear River occurs during overland sheet flow generated by rainfall, though the extent of this transport process in the Bear River watershed has not been quantified by any previous study.

To evaluate the contribution of sediment from watershed erosion to the impaired segment of the Bear River, methodologies developed by Rosgen (2009) were used. These methodologies included the Reconnaissance Level Assessment (RLA) of the Watershed Assessment of River Stability and Sediment Supply (WARSSS) methodology (see Appendix A for details of these methodologies). For the purposes of this TMDL, watershed erosion was assumed to be of negligible contribution to the total sediment load when compared to other sources. This lack of contribution was first identified in the watershed RLA of the WARSSS methodology (Rosgen 2009), where none of the sub-watersheds were promoted to a second-level analysis for watershed or surface erosion (see Appendix A for more detail). In other words, a sub-watershed-scale study of all available data (e.g., landscape history, land use and activities, soil, slope, lithology, vegetative cover) failed to indicate surface erosion as a significant source of sediment for any of the sub-watersheds contributing to the impaired segment of the Bear River.

Additionally, general hydrologic theory states that overland flow will not occur until the rainfall rate has exceeded the infiltration rate and depressional storage capacity (also collectively known as the initial abstraction) of the soil surface (Horton 1945). In fact, the widely used curve number method (USDA 1986) used for calculating the rainfall-runoff ratio of small watersheds is based on this principle. The infiltration capacity of the loamy soils surrounding the Bear River is on the order of 0.3–0.5 inch per hour (Tindall and Kunkel 1999). The average rainfall rate of a storm in Evanston, Wyoming, is approximately 0.12 inch per hour, with most (98%) rain events being less than or equal to 0.2 inch per hour (Figure 3.1). Therefore, most storm events do not exceed the predicted infiltration capacity of the soils surrounding the Bear River, further indicating that watershed erosion is minimal.

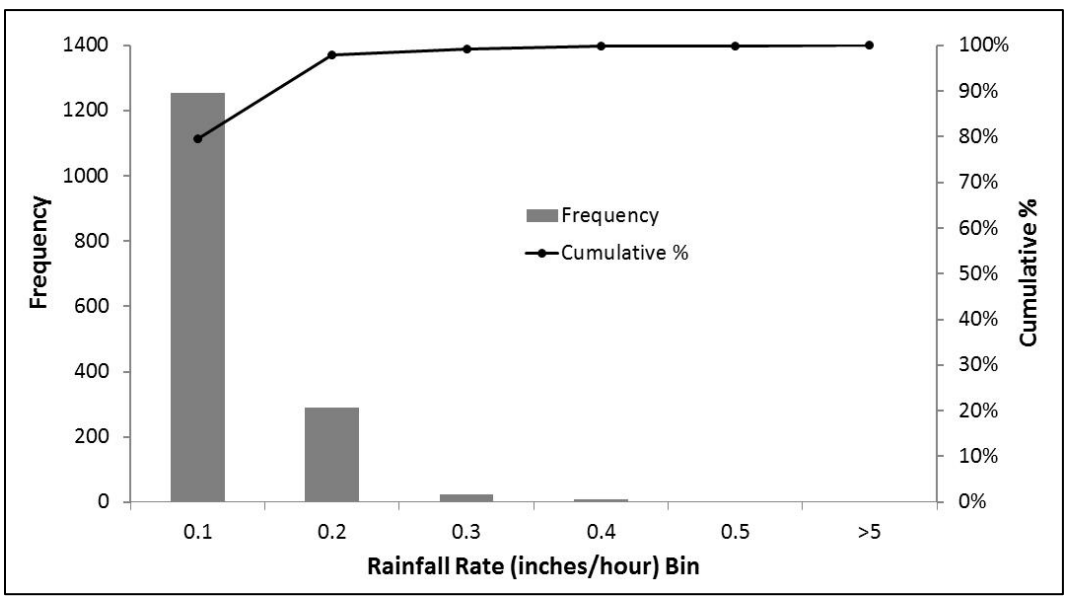


Figure 3.1. Hourly rainfall frequency and cumulative percentage for Evanston, Wyoming.[1]

[1] Data are hourly rainfall amounts from October 1, 1989, to September 30, 2013. Data from NCDC, station Evanston 1E.

3.3.2. Instream Erosion

Bank erosion is a natural process in the Bear River, and there is evidence that the Bear River has continually shifted its banks over time. However, human influences have increased this erosion and lateral channel movement significantly. These influences include land use changes such as agricultural expansion into riparian buffer zones; construction of seasonal push-up dams for irrigation (Figure 3.2); removal of wooded wetlands and riparian vegetation; high-pulse short-term releases of water from Sulphur Creek Reservoir; bridge, road, and railroad building in riparian zones; placement of concrete blocks along stream banks; urban developments; and channelization of the Bear River through the City of Evanston. All of these factors have contributed to increased stream bank erosion above what would be considered natural "background" levels.

Figure 3.2. A seasonal push-up dam in the impaired segment of the Bear River between downtown Evanston and the Yellow Creek confluence. Photograph taken on July 12, 2013.

Of these influences, the loss of riparian vegetation, seasonal push-up dams for irrigation diversion, and channelization have some of the most considerable consequences for bank erosion and sediment transport. A river meanders to adjust its slope toward a state of equilibrium for a given valley and flow configuration. By straightening and shortening the river's path, an excess energy is created that was previously dissipated through meandering. That excess energy is now directed toward downcutting of the channel bed, increasing local bed slopes, and removing sediment from the bottom of the river. In its path toward re-equilibration, the river will also naturally redevelop a meander pattern, causing bank erosion and lateral expansion. The sum of these effects is a substantial increase in sediment transport from the channelized section toward downstream sections. All of these consequences of channelization have been observed in the impaired segment of the Bear River since at least Smith and Maderak's geomorphic and hydraulic assessment of the river near Evanston in the late 1980s (USGS 1993).

To characterize and quantify bank erosion in the Bear River and its tributaries, the WARSSS model was used (Rosgen 2009). This method is detailed in Appendix A, but is referenced frequently here. Briefly, the WARSSS model comprises the following phases in order: 1) an RLA, 2) a Rapid Resource Inventory for Sediment and Stability Consequence (RRISSC), and 3) a Prediction Level Assessment (PLA). The PLA uses field survey data to estimate a BEHI and a NBS rating. These ratings are then used to quantify stream bank erosion rates with the Bank Assessment for Nonpoint Source Consequences of Sediment (BANCS) model. The results from the RLA and RRISSC are briefly summarized in the following sections. For a complete discussion of the RLA, RRISSC, PLA, and BANCS results see Appendix A.

3.3.2.1. IMPAIRED SEGMENT AND UPSTREAM REACH

Bank and channel erosion in the main stem of the Bear River has lowered the streambed up to 3 feet in the City of Evanston and probably is a direct result of channelization (USGS 1993). Advancement of this process farther upstream is being prevented by bedrock outcrops, where erosive processes are much slower than they are for alluvium soils. However, if erosion eventually destroys this control, it might be expected that degradation processes will continue to advance upstream and promote downcutting and channel instability in upstream reaches.

Bed/bank erosion of the channel throughout the main stem has led to individual efforts to stabilize channel banks with various forms of riprap (Figure 3.3). These stabilization measures have proved to be inadequate, as evidenced by deposition of dislodged riprap material downstream from the placement sites. Materials used to protect banks include cement bags, concrete slabs, boulders, and tires (USGS 1993). Other human influences include channel infilling for property enhancement, dredged cutoffs of meander loops by landowners for land management and farming, and artificial channel constrictions at bridge crossings. However, where no bank protection is in place, the channel banks are eroding actively and extensive areas of bank erosion are evident throughout the impaired reaches, where the river is trying to redevelop a more sinuous channel pattern.

Figure 3.3. Riprap used for bank stabilization located along the impaired segment of the Bear River between downtown Evanston and the Yellow Creek confluence. Photograph taken on July 12, 2013.

The RLA identified land use activities associated with erosion risk within the impaired segment of the Bear River (see Appendix A for more detail). These activities include urban development, agriculture, channelization, flood control, reservoir storage, diversions, grazing, roads, mining, energy development, and utility corridor development. The upstream reach has been influenced primarily by agriculture and irrigation, and diversions for the City of Evanston. Similarly, the impaired segment of the Bear River downstream has been influenced by agricultural development and irrigation diversions, but has also experienced significant flow alterations from Sulphur Creek Reservoir and more urban development.

Stream bank erosion was identified near irrigation diversions along the Bear River on both the impaired segment and the upstream reach. Review of aerial imagery indicates that multiple channel destabilization processes are occurring with very limited recovery. As an example, the Bear River has experienced aggradation, lateral accretion, and avulsion (i.e., rapid abandonment of a river channel and formation of a new one) downstream of the City of Evanston (41°17'57"N 110°59'56"W) between March 27, 2010, and October 2, 2011 (Figure 3.4).

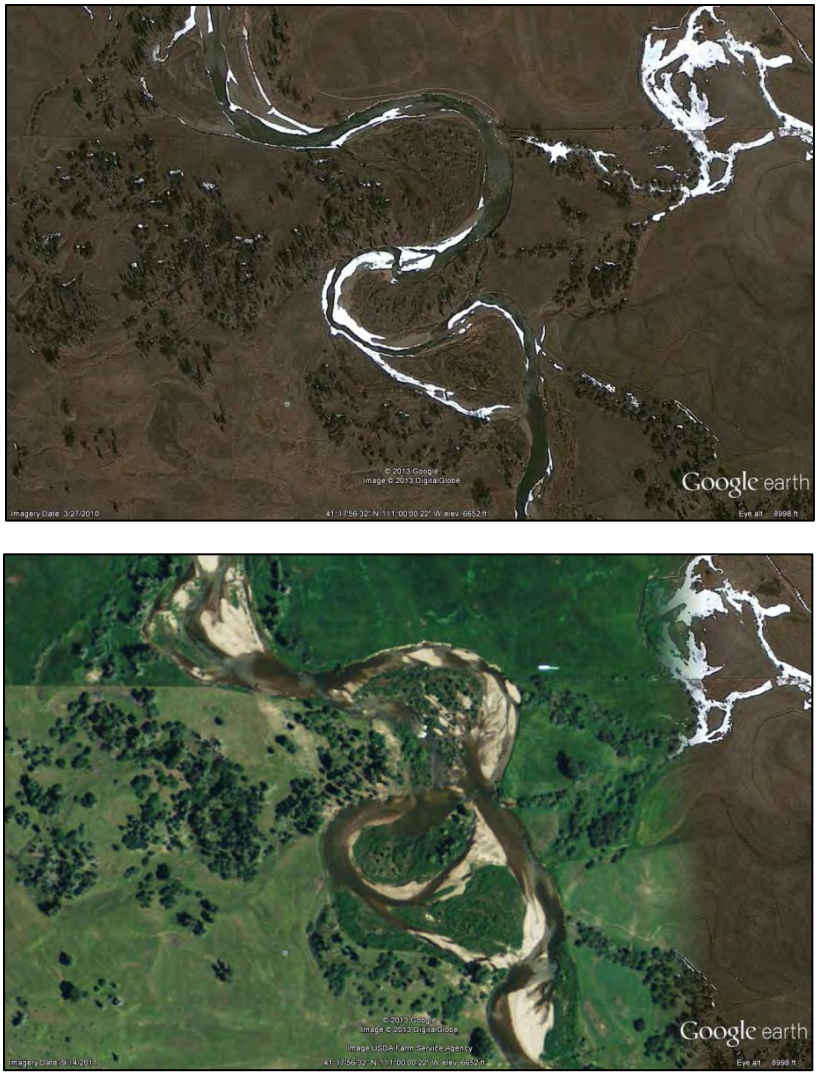


Figure 3.4. Aerial imagery showing avulsion, aggradation, and enlargement that occurred on the Bear River between 2010 (top photo) and 2011 (bottom photo).

Based on the results of the RLA, 13 sections of the Bear River (seven upstream of the impaired segment and six within the impaired segment) were promoted to a RRISSC analysis and subsequently to the PLA. The PLA consisted of BEHI and NBS field surveys. The results of these surveys were used to estimate the stream bank erosion rates along the impaired segment of the Bear River (see Appendix A).

3.3.2.2. SULPHUR CREEK

Bank erosion on Sulphur Creek is largely due to the hydrologic modification of the river from Sulphur Creek Reservoir and irrigation abstractions. The modified flow regime does not represent historical flow conditions, and therefore the historical structure and channel pattern of Sulphur Creek are in disequilibrium with the current flows. As the channel below the reservoir re-equilibrates with the new flow regime, a large amount of bank and channel sediment is scoured and transported downstream by releases from the reservoir.

Sulphur Creek Reservoir went under construction in 1958 and was completed in 1959, enlarged in 1989, and currently has a maximum storage of 19,775 acre-feet. It is filled with water from Sulphur Creek and water from the Bear River through the Evanston Pipeline, as well as return flow from three ditches that divert from the Bear River. According to the operational discussion from the *Bear River Basin Water Plan Technical Memoranda* (Wyoming Water Development Commission 2001), a minimum pool of 4,180 acre-feet in Sulphur Creek Reservoir and minimum releases to Sulphur Creek of 9 cfs must be maintained. Reservoir evaporation is on the order of 1,000 acre-feet per year (Water Development Office 2011).

The construction of reservoirs and dams can have complex and dynamic effects on downstream (and upstream) fluvial processes (Brandt 2000; Kondolf 1987; USGS 1984). Due to the complexity of the interactions between flow, sediment supply and transport, and ecosystem response, it is difficult to predict how a channel will respond to damming. However, some effects are easily measurable. For instance, examination of flow data from USGS gages before and after the construction of Sulphur Creek Reservoir indicates noticeable changes to the flow regime of Sulphur Creek (Figure 3.5). Generally speaking, the reservoir increased the “average” flows (the 20% to 80% interval of days flow exceeded) and decreased the magnitude of “low” flows (the 80% to 100% interval of days flow exceeded).

The reservoir also changed the timing of peak flows in Sulphur Creek (Figure 3.6). Before construction, flows peaked in Sulphur Creek on average near the middle of April, whereas post-construction flows are now peaking on average near the middle of May. Although the exact effects of this change are difficult to predict, it seems clear that this alteration has had consequences on the transport of sediment throughout the river system. Historically, flows in Sulphur Creek peaked about a month and a half before flows in the Bear River above the confluence of Sulphur Creek peaked (data from USGS gage 10014000 indicate that flows peaked around May 31). Now, Sulphur Creek peaks at about the same time as the peak in Bear River.

In addition to the change in timing of flows, there has more than likely also been a change in the distribution of sediment sizes transported by Sulphur Creek. As water is slowed down in the reservoir, larger particles drop out of suspension, shifting the suspended sediment distribution toward finer material, and reducing overall SSCs. Again, the exact effects that this settling process has on downstream erosion and transport rates are not clear, but literature suggests that the clearer water leaving the reservoir is “hungrier” for sediment, leading to more erosion downstream (Kondolf 1997).

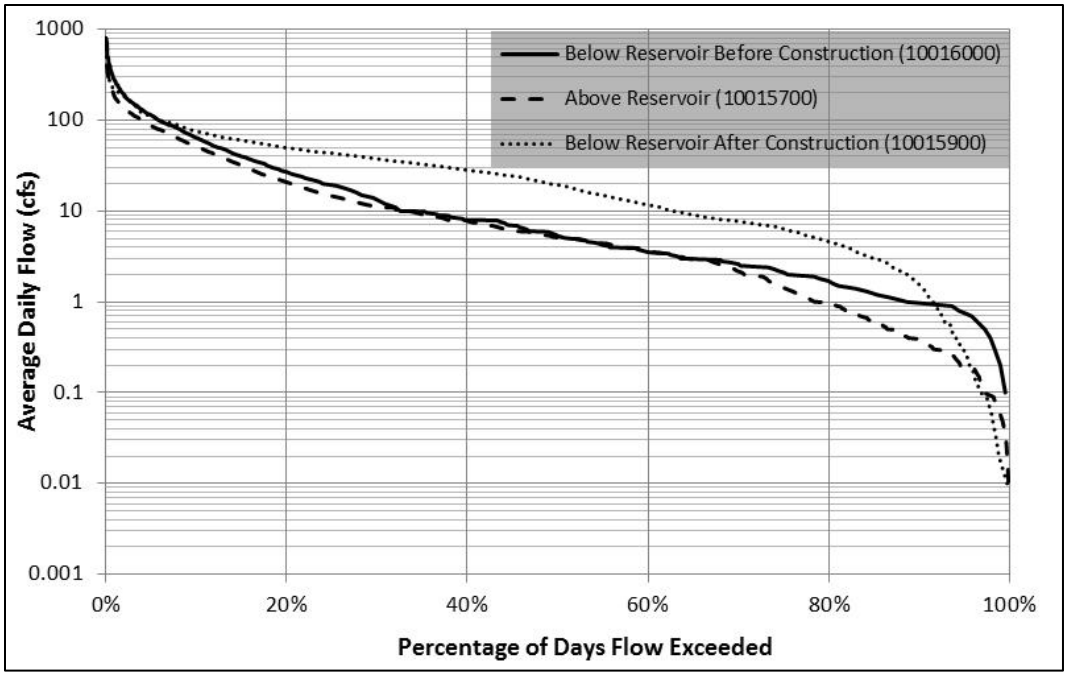


Figure 3.5. Flow duration curves for Sulphur Creek before and after construction of Sulphur Creek Reservoir.[2]

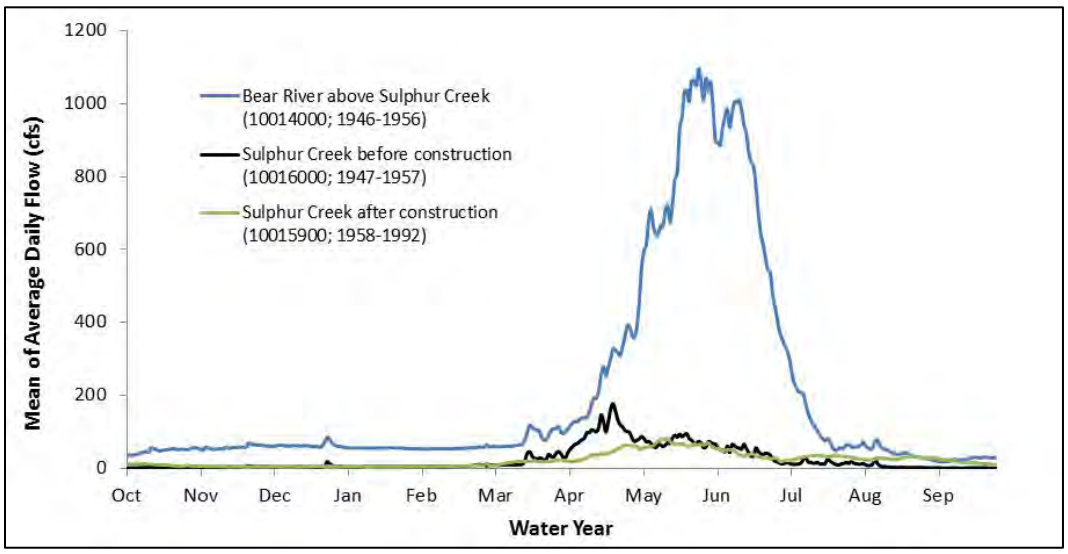


Figure 3.6. Mean annual hydrographs for selected stations.[3]

Land use also has an effect on bank and channel erosion in Sulphur Creek. Agriculture is the primary land use downstream of Sulphur Creek reservoir. Agricultural practices have both indirect (e.g., hydrologic modification through irrigation) and direct (e.g., removing riparian vegetation) effects on bank and

[2] USGS gage 10016000 uses data from 1947 to 1957, USGS gage 10015700 from 1957 to 1997, and USGS gage 10015900 from 1958 to 1992. Curves only for days with measured flow.

[3] To calculate mean average daily flow, for each day of the water year, flows were averaged over the period of record. Values in parentheses are USGS gage numbers and years of data.

channel erosion. Furthermore, Sulphur Creek downstream of Sulphur Creek Reservoir has stream stability impacts from road crossings, fill, and channelization. An example of this stream instability is shown in Figure 3.7 (located downstream of Sulphur Creek Reservoir at 41°09'14"N 110°50'20"W, flow direction is to the west). As shown in Figure 3.8, the Sulphur Creek channel also shows evidence of confinement and destabilization due to adjacent roads and changes in riparian vegetation from woody plants to a grass/forb community (imagery location: 41°11'20"N 110°51'59"W, flow direction is to the north).

Figure 3.7. Aerial imagery showing channel instability and headcuts (indicated by the red arrows) on Sulphur Creek.

Figure 3.8. Aerial imagery showing channel confinement and destabilization associated with roads and the conversion of riparian vegetation.

Based on the results of the RLA, four sections of Sulphur Creek (two upstream of the County Road 75 crossing and two upstream of the County Road 159 crossing) were promoted to the RRISSC analysis and subsequently to the PLA. The results of these surveys were used to estimate the stream bank erosion rates along Sulphur Creek below the reservoir (see Appendix A).

3.3.2.3. YELLOW CREEK

There is a large degree of channel and stream bank destabilization along Yellow Creek below Barker Reservoir. Most of the Yellow Creek drainage is composed of alluvial deposits that are particularly susceptible to stream bank erosion from changes in stream flow, land use, and land cover. Land use activities along Yellow Creek that have the potential to affect bank erosion and destabilization include reservoir management, agricultural development, stream channelization for interstate and road development, irrigation diversions, and grazing.

The magnitude, frequency, and location of releases from Barker Reservoir have an influence on stream flows and stream bank erosion along Yellow Creek. Excessive stream bank erosion occurs just below Barker Reservoir where the spillway directs flows directly along the base of unstable steep slopes (Figure 3.9, imagery located at 41°07'34"N 111°03'25"W, flow direction is to the west).

Figure 3.9. Erosion of unstable steep slopes below Barker Reservoir.

Significant changes in the stream flow of Yellow Creek have also occurred downstream of Barker Reservoir due to irrigation diversions. Changes in stream flow have altered the channel and stream bank conditions along Yellow Creek. These changes are evident in Figure 3.10 where irrigation diversions have altered downstream channel and bank conditions and reduced Yellow Creek flows (imagery from 41°08'52"N 111°03'03"W, flow direction is to the north).

Figure 3.10. Altered stream bank and channel conditions on Yellow Creek downstream of an irrigation diversion (indicated by the red arrow).

Other irrigation diversions along Yellow Creek, in addition to stream channelization due to the construction of I-80, are shown in Figure 3.11. Stream flows in Yellow Creek are significantly reduced downstream of these diversions (imagery at 41°15'56"N 111°00'01"W, flow direction is to the north).

Figure 3.11. Irrigation diversions (indicated by the red arrows) and channelization along Yellow Creek.

There is an abundance of channel destabilization processes occurring on Yellow Creek, including degradation (channel incision and floodplain abandonment), lateral accretion (excess bank erosion), and avulsion (abandonment of previous channels). Yellow Creek is clearly a location of high sediment supply due to stream bank and channel erosion; however, due to the lack of downstream flow data, the fraction of this supply that is delivered to the Bear River is unknown.

Based on the results of the RLA, seven sections of Yellow Creek were promoted to the RRISSC analysis and subsequently to the PLA. The results of these surveys were used to estimate the stream bank erosion rates along Yellow Creek below the reservoir (see Appendix A).

3.3.3. Stormwater

For this TMDL, stormwater is defined as urban runoff derived from rain events. Runoff from urban areas is several times greater than runoff from rural or undeveloped areas due to a larger percentage of impervious surfaces (e.g., pavement and concrete). The City of Evanston is the only urban area in the Bear River watershed, and stormwater loads from this source are included in this TMDL.

Urban stormwater management concentrates runoff generated from streets, parking areas, rooftops, and other impervious surfaces, and diverts it into canals, and eventually streams and rivers. As runoff flows over these surfaces, the water picks up sediment and other pollutants (e.g., oils, heavy metals, grease) and transports them to surface waterbodies, resulting in an associated stormwater pollutant load. Depending on the size of the urban area, the management of stormwater can be regulated or unregulated. The stormwater system in the City of Evanston is currently unregulated and therefore not permitted under EPA's permitted process for municipal separate storm sewer systems (MS4) (personal communication, Barb Sahl, to John Christensen, SWCA, March 12, 2013). Stormwater events in Evanston are generally small in magnitude, and depths rarely exceed 1 inch, with 75% of all events being less than 0.2 inch (Figure 3.12).

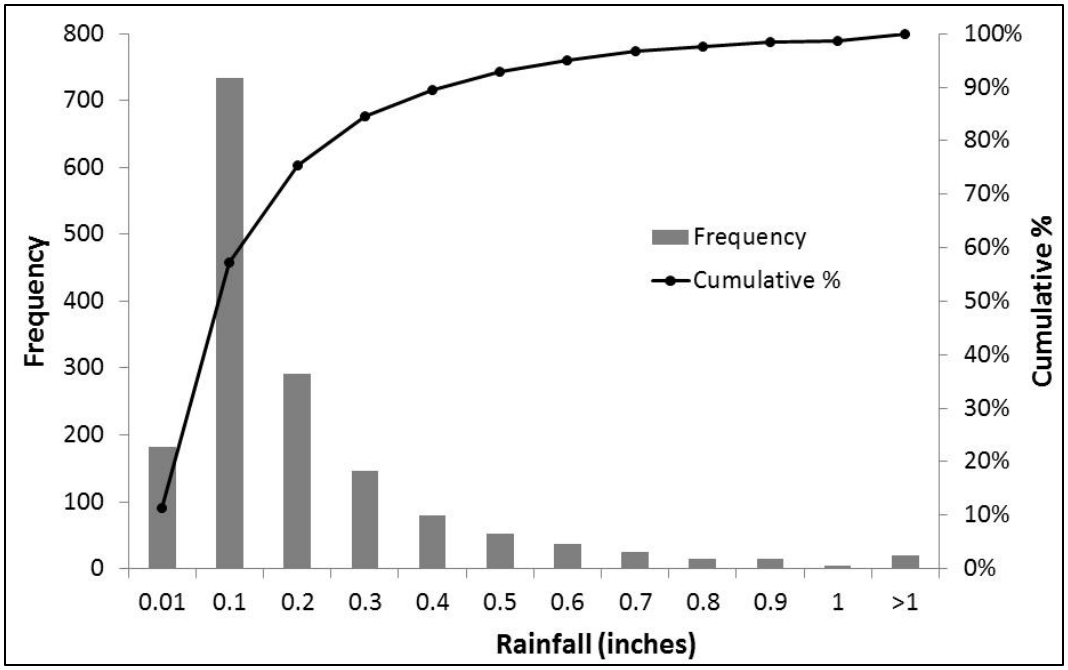
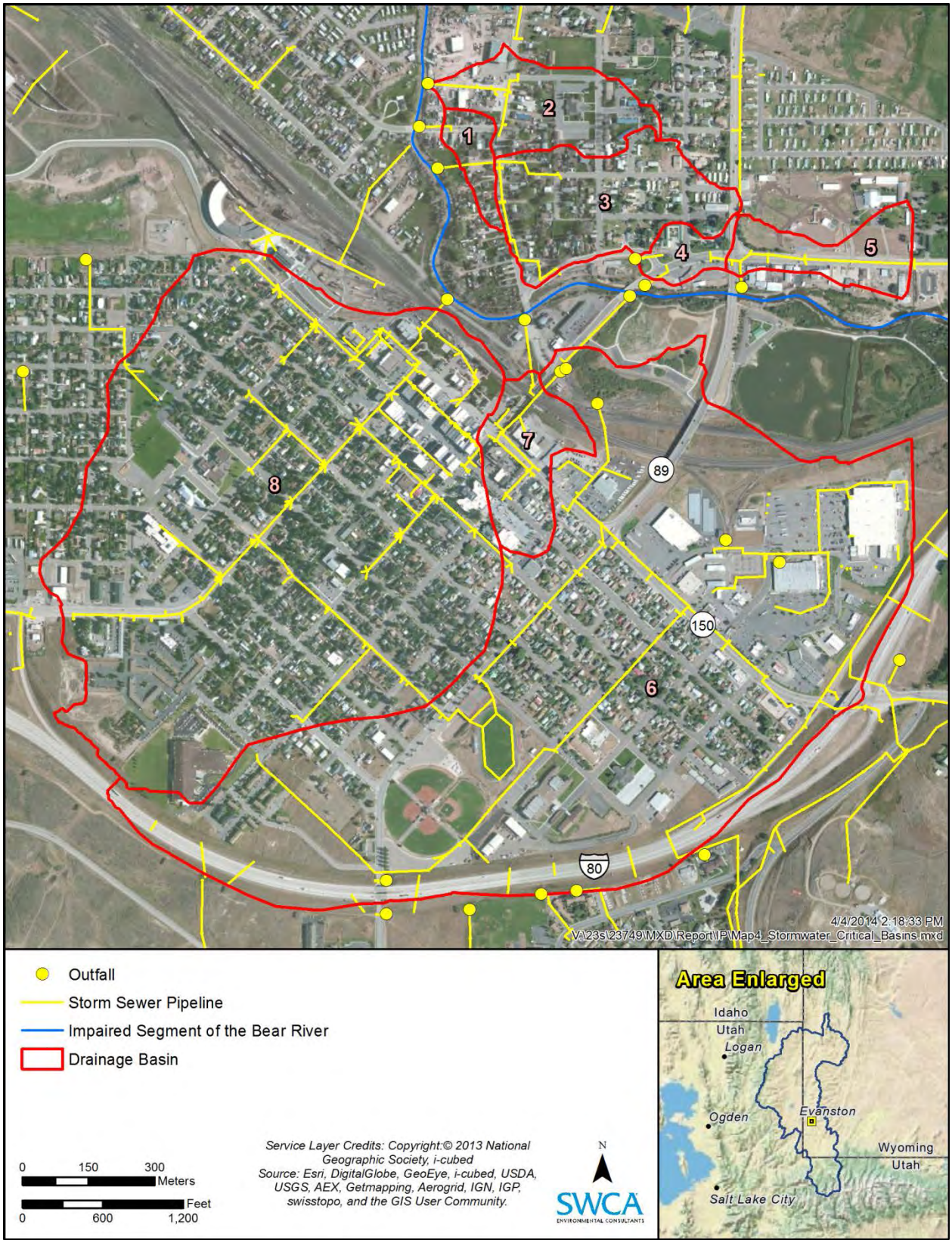


Figure 3.12. Daily rainfall frequency and cumulative percentage for Evanston, Wyoming.[4]

Stormwater in the City of Evanston is collected in numerous basins and discharged to 103 outfalls. Eight of these outfalls discharge directly to the Bear River (Map 3.2) and are the only outfalls considered for this TMDL. The collection basin areas associated with each of these eight outfalls were estimated using the stormwater infrastructure geographic information system layer provided by the City of Evanston. These collection basins drain a cumulative 592.6 acres.

[4] Data are daily rainfall amounts from October 1, 1989, to September 30, 2013. Data from NCDC, station Evanston 1E.



Map 3.2. Location of stormwater outfalls and drainage basins discharging to the Bear River.

3.4. Summary

The source analysis identified both point and nonpoint sources of sediment to the impaired segment of the Bear River. Three point sources with direct discharge to the Bear River or Yellow Creek were identified, as well as eight stormwater outfalls. Based on the results of the PLA, watershed erosion was determined to be an insignificant source of sediment to the impaired segment of the Bear River. Using the WARSSS model, instream erosion (i.e., bank erosion and channel bed erosion) was identified in all contributing sub-watersheds to the impaired segment. Causes of instream erosion and sediment transport were identified as channel straightening due to urbanization and land-use changes, loss of riparian vegetation and riparian buffer zones due to grazing and conversion to agriculture, alteration of hydrology through reservoir damming and irrigation withdrawals, and channel modification through riprap and push-up dams.

4 LOAD ANALYSIS

This load analysis quantifies the current sediment loads for all point and nonpoint sources identified in section 3. This analysis also includes a discussion of seasonality and critical conditions associated with these loads.

4.1. Point Sources

The Town of Bear River wastewater treatment facility is the only point source that discharges sediment-laden water directly to the Bear River. There are other point sources that indirectly discharge to the Bear River (via Yellow Creek), and these include the City of Evanston wastewater treatment facility and the Flying J commercial wastewater treatment system. No other point sources are known to contribute sediment directly to the Bear River. Average discharges, TSS concentrations, and sediment loads for these point sources are summarized in Table 4.1. The total current sediment load from the three point sources is 0.046 ton/day.

Table 4.1. Point Source Loads to the Impaired Segment of the Bear River

Permit Holder/ Permit Number	Receiving Waterbody	Monthly Average Discharge (MGD)	Monthly Average TSS (mg/L)	Current Sediment Load (tons/day)
Town of Bear River/ WY0031712	Bear River	0.25	20.8	0.021
City of Evanston/ WY0020095	Yellow Creek	1.41	2.3	0.014
Flying J, Inc./ WY0035700	Yellow Creek	0.10	25.5	0.011
Total				**0.046**

4.2. Nonpoint Sources

Current sediment loads for the impaired segment of the Bear River from nonpoint sources were calculated in two ways, depending on the source. For each source except bank erosion, sediment loads were calculated by multiplying TSS concentrations by flow. This included stormwater loads, upstream loads, and tributary loads. For bank erosion, the BANCS model was used for calculating sediment loads (see Appendix A).

Whereas it is relatively straightforward to calculate sediment loads to the impaired segment of the Bear River from stormwater, upstream, and tributary sources using TSS and flow data, it is close-to-impossible to calculate the sediment load generated from bank erosion along the impaired segment with available TSS and flow data. There are several reasons for this, including sparse sampling events, lack of paired data, and complex abstractions of flow (e.g., irrigation diversions and seasonal variation in groundwater recharge) that do not allow for a simple mass balance approach. On the other hand, the BANCS model provides a direct, evidence-based quantification of sediment supply generated within the impaired segment.

For loads determined from TSS and flow data, UCCD monitoring station data and USGS gage flow data were used. The UCCD monitors water quality at five stations on the Bear River (BR1 through BR5) in addition to one on LaChapelle Creek (not considered) and two on Sulphur Creek (only the station below

the reservoir, SC1, is considered here). Sampling is conducted twice per year, once in the spring and once in the fall. The UCCD monitoring provides the most complete TSS/flow dataset available for calculating sediment (TSS) loads to the impaired segment of the Bear River.

Additionally, all sediment loads derived from TSS and flow data were categorized into three different flow regimes: high, medium, and low. The high and low flow regimes represent the upper and lower 20% of observed flows, respectively. The medium flow regime represents the middle 60% of observed flows. On average, 94% (max = 97%, min = 84%) of the total sediment load occurs during the high flow regime.

4.2.1. Stream Bank Erosion

Bank erosion along the impaired segment of the Bear River is significant, but variable. A summary of average sediment loads as calculated using the BANCS model indicates that the area with the highest sediment loads is along the reach from the Sulphur Creek confluence to Bear River State Park (Reach 1), which has roughly twice the erosion rate as the other two reaches (Table 4.2). The total amount of sediment load generated from bank erosion along the impaired segment is 55.5 tons/day. Most of this load is generated in Reach 3, but that is entirely due to its length in comparison to Reaches 1 and 2. A better measure of bank erosion sediment load is the erosion rate, which as previously stated indicates that reach 1 has the highest rate of erosion.

Table 4.2. Summary of Current Bank Erosion Rates and Associated Sediment Loads Along the Impaired Segment of the Bear River

Reach of the Impaired Segment	Length of Stream (feet)	Erosion Rate (tons/year/feet)	Stream Bank Erosion Sediment Load (tons/day)
Reach 1: Sulphur Creek Confluence to Bear River State Park	20,446	0.215	12.0
Reach 2: Bear River State Park to Yellow Creek	60,118	0.085	14.0
Reach 3: Yellow Creek to Woodruff Narrows Reservoir	111,464	0.096	29.5
Total	**192,028**	**N/A**	**55.5**

Note: N/A = not applicable

Using the results from the BANCS analysis, the sediment load capacity for the Bear River and its tributaries is based on reduced bank erosion rating categories. Bank erosion rating categories are qualitative measures of the sediment supply loaded into a river, and they are delineated from the total distribution of erosion rates (in tons per year per foot of bank) (Table 4.3). The distribution of erosion rates from the BANCS model implied the categories listed in Table 4.3, which correlate to the 10th, 25th, 50th, 75th, and 90th quartiles of the distribution. These categories are useful for grouping long stretches of banks (i.e., reaches) by erosion rate. The erosion rates are discussed in detail in Appendix A, and briefly discussed here because they are used in determining the loading capacity presented in section 5.1.

Table 4.3. Erosion Rating Categories

Category	Range of Erosion Rates (tons/year/feet)
Very low	0.000–0.050
Low	0.051–0.100
Moderate	0.101–0.200
High	0.201–0.500
Very high	0.501–1.000
Extreme	> 1.000

4.2.1.1. UPSTREAM LOADS

The upstream sediment load to the impaired segment of the Bear River was calculated using flow and TSS data collected by UCCD at the BR4 monitoring station and its associated estimated flow duration curve (see section 1.4.4). The BR4 station is on the Bear River approximately 4.4 miles upstream of the Sulphur Creek confluence. The upstream sediment load was estimated from the average flow-regime flows and average flow-regime TSS measurements (Table 4.4). A weight was then applied to each sediment load based on the frequency of flows in each flow regime to scale the loads based on their frequency of occurrence (i.e., from the flow duration curve: high flow frequency = 20%, medium flow frequency = 60%, and low flow frequency = 20%). The resulting average daily upstream sediment load is 9.9 tons/day. As also shown in Table 4.4, most (97%) of the sediment load delivered to the impaired segment of the Bear River from upstream sources occurs during periods of high flow.

Table 4.4. Upstream Sediment Loads to the Impaired Segment of the Bear River

Flow Regime	Average Flow (cfs)	Average TSS (mg/L)	Average TSS (tons/day)	Weighted Average TSS Load (tons/day)	Percentage of Total Load
High	434	32	49.7	9.9	97.7%
Medium	54	3	0.3	0.2	2.0%
Low	24	2	0.1	0.03	0.3%
Total	**–**	**–**	**–**	**10.2**	**100%**

4.2.1.2. TRIBUTARY LOADS

The sediment load from Sulphur Creek to the impaired segment of the Bear River was calculated using flow and TSS data collected by UCCD at the SC1 monitoring station. The SC1 station is on Sulphur Creek approximately 6 miles upstream of its confluence with the Bear River. Using the same approach as above to calculate upstream loads, the resulting weighted average sediment load from Sulphur Creek is 1.8 tons/day (Table 4.5). As also shown in Table 4.5, most (86%) of the sediment load delivered to the impaired segment of the Bear River from Sulphur Creek occurs during periods of high flow.

Table 4.5. Sulphur Creek Sediment Loads to the Impaired Segment of the Bear River

Flow Regime	Average Flows (cfs)	Average TSS (mg/L)	Average TSS Load (tons/day)	Weighted Average TSS Load (tons/day)	Percentage of Total Load
High	96	37	9.0	1.8	86.3%
Medium	22	7	0.4	0.3	12.9%
Low	7	6	0.09	0.02	0.8%
Total	**–**	**–**	**–**	**2.3**	**100%**

Sediment loads from Yellow Creek were estimated using an assumed average high flow regime flow of 25 cfs (see section 1.4.4). TSS was estimated at the mouth of Yellow Creek from the only identified measurement, taken during a beneficial use reconnaissance project (BURP) report when the flow was reported as 0.058 cfs. These calculations yielded a TSS load of 3.9 tons/day, resulting in a weighted high flow average TSS load of 0.8 tons/day from Yellow Creek to the impaired segment.

4.2.2. Natural Background

Quantifying the natural background load to a system is an important component of the TMDL process. This is particularly true for the Bear River, which experiences sediment fluxes even without human influences. However, calculating the Bear River's natural background sediment load is not straightforward, because there is no ideal reference (i.e., non-human influenced) condition from which to compare current loads. Although the unimpaired reach upstream of the impaired segment is considered a "reference" reach for the BANCS model (see section 4.2), it has still experienced significant alteration from humans in its history (e.g., deforestation, channelization, land use change).

Therefore, a different method for calculating natural background sediment loads was used that is based on EPA recommendations (EPA 2000). Using water quality data from 58 rivers and streams in Nutrient Ecoregion III (xeric west), the EPA determined reference values for turbidity for each season based on the lower 25% value of all data (n = 279). A turbidity value of 3.70 NTUs was calculated by the EPA as a reference value for spring (EPA 2000). Though turbidity reference values were also calculated by the EPA for the other seasons, only the springtime value was used in the following calculations, because this is the critical sediment load season for the Bear River (i.e., the period of time where most of the sediment load occurs; see section 4.3).

To determine TSS reference values for the impaired segment of the Bear River, the upstream reach, Sulphur Creek, and Yellow Creek, turbidity and TSS measured at each UCCD monitoring station were correlated (both TSS and turbidity were measured at all stations). To be consistent with the EPA turbidity reference value for spring, only turbidity and TSS measurements collected by UCCD during the springtime were used in the correlations. The resulting TSS and turbidity correlations showed to be very robust, with coefficients of determination (R^2) ranging from 0.967 to 0.996 (Table 4.6). Because TSS proved to be a strong proxy for turbidity, linear regressions were developed to calculate best-fit slopes for TSS and turbidity at each UCCD monitoring station. A TSS reference value for each UCCD monitoring station was calculated by multiplying the best-fit slope by 3.70 NTUs (the EPA turbidity reference value). The resulting best-fit slopes and TSS reference values for each UCCD monitoring station are summarized in Table 4.6.

Because Yellow Creek does not have any measured TSS or turbidity data, SC1 data were used to estimate its TSS reference value. This is because Sulphur Creek represents the most similar conditions to Yellow Creek of any of the UCCD monitoring stations.

Table 4.6. Reference TSS Values

Reach	UCCD Monitoring Station	Best-Fit Slope for TSS vs. Turbidity*	TSS Reference Value (mg/L)
Upstream	BR4	2.19 (0.994)	8.1
Sulphur Creek	SC1	2.47 (0.968)	9.1
Yellow Creek	SC1	2.47 (0.968)	9.1
Impaired segment Reach 1	BR3	1.77 (0.967)	6.6
Impaired segment Reach 2	BR2	2.83 (0.981)	10.5
Impaired segment Reach 3	BR1	2.13 (0.996)	7.9

* Best-fit lines were developed through an x- and y-intercept of 0. Values in parentheses are R2 values of the best-fit line.

The TSS reference values listed in Table 4.6 were then multiplied by the average high flow for each UCCD monitoring station to calculate a high flow background sediment load at each station. Because only springtime high flows were considered for transport of background sediment loads, all high flow sediment loads were weighted by the percentage of time that the high flows occurred (i.e., 20%; see section 4.2 for more detail). In other words, sediment loads determined for high flows (i.e., loads that occur 20% of the time) were multiplied by 0.20 to get a weighted sediment load that represents the sediment load per day over the whole year. The average high flows, high flow sediment loads, and weighted sediment loads for each UCCD monitoring station are summarized in Table 4.7.

The calculation of natural background sediment loads for each reach of the impaired segment required additional calculations to account for the background sediment load entering that reach. To address the background sediment load entering each reach of the impaired segment, a mass balance approach was used. The mass balance approach subtracts the upgradient background sediment load entering each impaired segment. For example, the weighted sediment load calculated for Reach 1 of the impaired segment (4.2 tons/day) needed to account for (subtract) the sediment load entering from the upstream reach (1.9 tons/day) and Sulphur Creek (0.5 tons/day), resulting in a natural background sediment load of 1.8 tons/day. Similarly, the natural background sediment load for Reach 2 (0.9 tons/day) was calculated by subtracting out the sediment load delivered by Reach 1 (4.2 tons/day) and Yellow Creek (0.1 ton/day) from the weighted sediment load (5.2 tons/day). Results indicate that there is no associated background load generated in Reach 3 due to decreased flows, which presumably create a depositional environment for sediment. Natural background sediment loads are summarized in Table 4.7.

Table 4.7. Natural Background Sediment Loads

Reach	UCCD Monitoring Station	Average High Flow (cfs)	High Flow Sediment Load (tons/day)	Weighted Sediment Load (tons/day)	Natural Background Sediment Load (tons/day)
Upstream	BR4	434	9.9	1.9	1.9
Sulphur Creek	SC1	96	2.4	0.5	0.5
Yellow Creek	–	25	0.6	0.1	0.1
Impaired segment Reach 1	BR3	1,186	21.0	4.2	1.8 (= 4.2 - 1.9 - 0.5)
Impaired segment Reach 2	BR2	919	26.0	5.2	0.9 (= 5.2 - 0.1 - 4.2)
Impaired segment Reach 3	BR1	914	19.4	3.9	N/A (= 3.9 - 5.2)
Total	–	–	–	–	5.2

Notes: Loads derived from a reference TSS value of 3.7 NTUs.

Average high flows for Yellow Creek were estimated to be 25 cfs (see sections 1.4.4 and 4.2.2.2).

Parenthetical expressions show mass balance approach for impaired reaches.

N/A = not applicable; there is no background load from these reaches because the mass balance approach yields a negative value.

4.2.3. Stormwater

Stormwater runoff from the City of Evanston that discharges directly to the Bear River was estimated using the adjusted rainfall-runoff curve number method (Woodward et al. 2003) originally developed by the USDA (USDA 1986). The adjusted method uses a smaller value for the initial abstraction (5% of the storage) compared to the original method (20% of the storage); this has been shown to be a more accurate assumption, especially for urban areas.

The curve number method estimates the runoff expected for a rainfall event based on unique soil and land use combinations. Curve numbers are unitless and range from a low of 30 to a high of 100. Higher curve numbers indicate more runoff during a storm event and are influenced by slow draining soils and impervious cover (e.g., urban environments). The eight stormwater basins shown on Map 3.2 were classified by soil types and hydrologic group (A, B, C, or D), as defined in the SSURGO database (USDA 2013). Additionally, these basins were classified by land use cover based on the National Land Cover Database (NLCD) (Fry et al. 2006) (Table 4.8). Each soil and land use combination was assigned a representative curve number using tables provided in Technical Release 55, Urban Hydrology for Small Watersheds (USDA 1986), and an area-weighted curve number was calculated for each basin (see Table 4-8).

Sediment data are not available for stormwater in the City of Evanston; therefore, TSS from the National Stormwater Quality Database (NSQD) (Pitt et al. 2004) were used to estimate sediment values for the NLCD land use categories listed in Table 4.8. Land use categories from the NLCD and NSQD are different and required best professional judgment in assigning TSS values from NSQD categories to the NLCD data (Table 4.9). Area-weighted TSS concentrations were then calculated for each basin (Table 4.8).

Table 4.8. NSQD Land Use Categories Applied to NLCD Data for Stormwater TSS Concentrations

NLCD	NSQD	NSQD TSS Value (mg/L)
Developed, high intensity	Industrial	78
Developed, low intensity	Residential	49
Developed, medium intensity	Mixed Commercial	54
Developed, open space	Mixed Residential	68
Grassland/herbaceous	Open Space	48.5
Shrub/scrub	Open Space	48.5
Woody wetlands	Open Space	48.5

Table 4.9. Summary of Stormwater Basin Areas by NLCD land, SSURGO Hydrologic Soil Group, Weighted Curve Numbers, and Sediment TSS Values

Basin ID	Land Use	Soil Hydrologic Group	Curve Number	TSS (mg/L)	Acres
1	Developed, Low Intensity	B	85	49	2.26
	Developed, Medium Intensity	B	72	54	2.6
	Developed, Open Space	B	69	68	0.14
Basin 1 Weighted Value		–	*77.8*	*52.1*	–
2	Developed, Low Intensity	B	85	49	7.67
	Developed, Medium Intensity	B	72	54	10.61
	Developed, Open Space	B	69	68	0.58
Basin 2 Weighted Value		–	*77.2*	*52.4*	–
3	Developed, Low Intensity	B	85	49	14.05
	Developed, Medium Intensity	B	72	54	15.17
Basin 3 Weighted Value		–	*78.3*	*51.6*	–
4	Developed, High Intensity	B	92	78	0.27
	Developed, Low Intensity	B	85	49	1.2
	Developed, Medium Intensity	B	72	54	3.62
Basin 4 Weighted Value		–	*76.1*	*54.1*	–
5	Developed, High Intensity	B	92	78	0.45
	Developed, Low Intensity	B	85	49	6.24
	Developed, Medium Intensity	B	72	54	4.71
	Developed, Open Space	B	69	68	1
Basin 5 Weighted Value		–	*79*	*53.5*	–
6	Developed, High Intensity	D	95	78	26.35
	Developed, Low Intensity	B	85	49	1.7
	Developed, Low Intensity	D	92	49	113.15

Table 4.9. Summary of Stormwater Basin Areas by NLCD land, SSURGO Hydrologic Soil Group, Weighted Curve Numbers, and Sediment TSS Values

Basin ID	Land Use	Soil Hydrologic Group	Curve Number	TSS (mg/L)	Acres
	Developed, Medium Intensity	D	86	54	98.24
	Developed, Open Space	B	69	68	30.19
	Developed, Open Space	D	84	68	0.03
	Grassland/Herbaceous	D	77	48.5	1.11
	Shrub/Scrub	D	77	48.5	2.34
	Woody Wetlands	D	0	48.5	2.75
Basin 6 Weighted Value		–	*86.5*	*55.6*	–
7	Developed, High Intensity	D	95	78	5.47
	Developed, Low Intensity	D	92	49	2.98
	Developed, Medium Intensity	D	86	54	7.03
	Developed, Open Space	D	84	68	0.38
Basin 7 Weighted Value		–	*90.2*	*61.7*	–
8	Developed, High Intensity	D	95	78	11.65
	Developed, Low Intensity	D	92	49	102.4
	Developed, Medium Intensity	D	86	54	110.35
	Developed, Open Space	D	84	68	5.8
Basin 8 Weighted Value		–	*89.1*	*53.3*	–

Stormwater runoff was estimated using the curve number method according to the following equations:

$$Q = \frac{(P - I_a)^2}{(P + S_{0.05} - I_a)}, for\ P > I_a$$

$$Q = 0\ , for\ P \leq I_a$$

$$S_{0.20} = \frac{1000}{CN} - 10$$

$$S_{0.05} = 1.33{S_{0.20}}^{1.15}$$

Where:
Q = runoff depth [inches]
P = event rainfall depth [inches]
I_a = initial abstraction [inches]
S = site storage index [-]
CN = curve number [-]

To obtain the total volume of runoff for a storm, Q is multiplied by the basin area. Rainfall, or P in the equation, was determined from the average yearly distribution of daily rainfall depths. A runoff and load were calculated from each rainfall event depth, and then weighted based on their distribution (Table 4.10). Unweighted loads were calculated by summing the total load from each basin (derived from basin runoff and weighted TSS values).

Table 4.10. City of Evanston Stormwater Load by Rain Event

Rainfall (inches/day)	Load (tons/day)	Weight*	Weighted Load (tons/day)
0.1	0.00	0.57	0.00
0.2	0.02	0.18	0.00
0.3	0.06	0.09	0.01
0.4	0.14	0.05	0.01
0.5	0.23	0.03	0.01
0.6	0.35	0.03	0.01
0.7	0.48	0.01	0.01
0.8	0.64	0.01	0.01
0.9	0.80	0.01	0.01
1.0	0.98	0.00	0.00
2.0	3.26	0.01	0.04
Total			**0.09**

* Weight is based on the percentage of annual rainy days that are in each rainfall bin (e.g., 18% of rainy days are between 0.1 and 0.2 inches).

The total weighted load represents the average load from one rainy day in Evanston. This number is then multiplied by the average number of rainy days in Evanston per year (67) to get an average yearly load, and then divided by 365 to arrive at an average daily stormwater load. The resulting stormwater load is 0.02 tons/day.

4.3. Seasonality and Critical Conditions

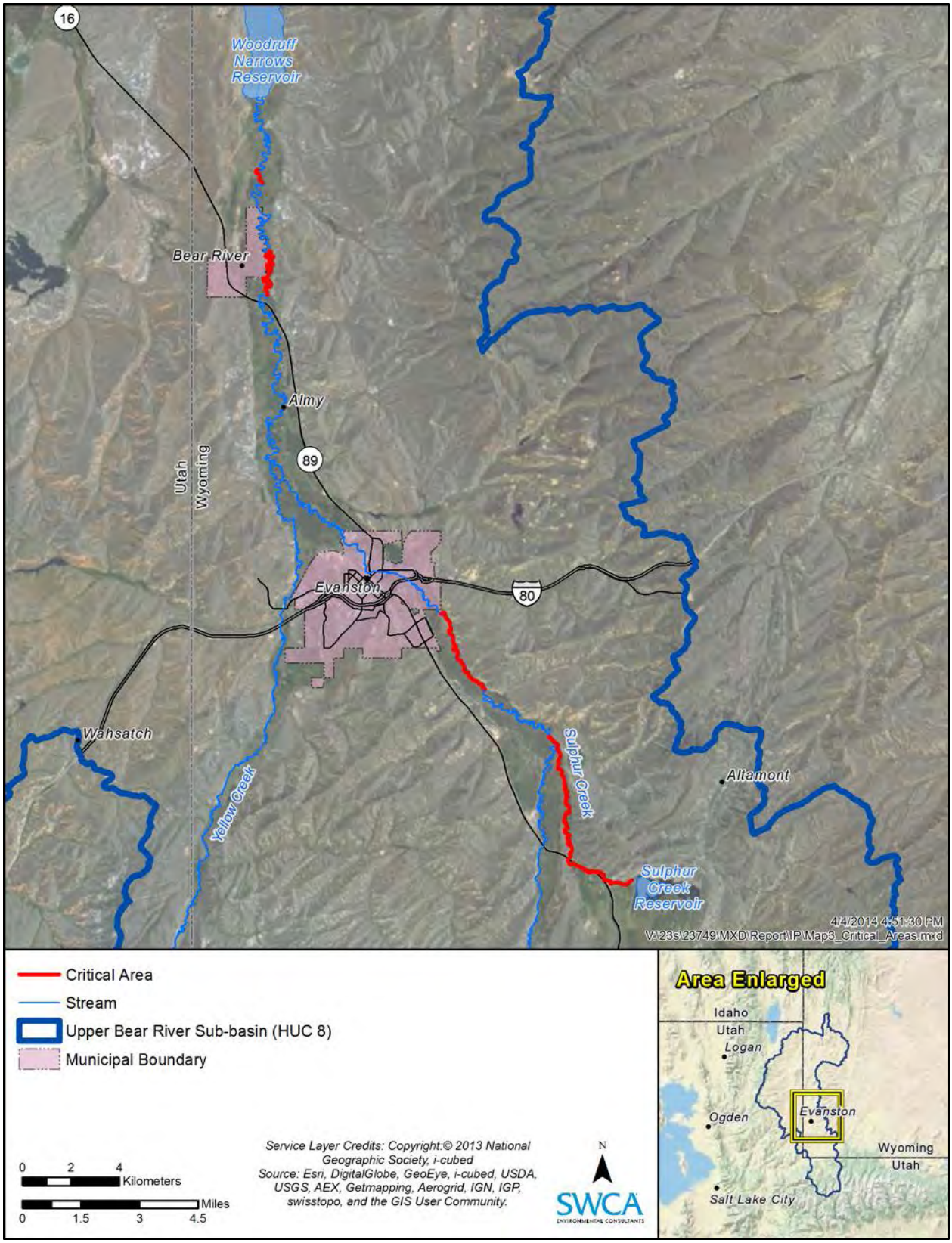
The most critical period for sediment loads to the impaired segment of the Bear River is during spring snowmelt. The high flows associated with this period are responsible for the majority of bank and channel erosion and subsequent sediment transport. This is supported by literature which suggests that the majority of sediment load occurs during the bankfull, or “effective” discharge (e.g., Wolman and Miller 1960; Andrews 1980; Petit and Pauquet 1997; Simon et al. 2004). The bankfull discharge concept was first proposed by Wolman and Miller (1960), and is often characterized by the peak discharge that occurs with a return frequency of 1–2 years. Bankfull discharges were not measured directly for any of the reaches of the impaired segment, but average measured high flows are well within the estimated 1- to 2-year recurrence interval bankfull discharges (Table 4.11). Based on these results, only the high flow loads for each UCCD station are used in the calculation of sediment loads for the Bear River TMDL.

Table 4.11. Comparison of Measured Average High Flows and Bankfull Discharges

UCCD Monitoring Station	Average High Flow (cfs)	Range of Likely Bankfull Discharges (cfs)
BR4	434	205–950
SC1	96	33–120
BR3	1,186	640–1,800
BR2	919	500–1,400
BR1	914	440–1,640

Note: The range of bankfull discharges equate to the 1- to 2- year return intervals.

Critical areas for bank erosion were identified through the BANCS model. The most critical area for bank erosion on the impaired segment is the length of stream just upstream of the Bear River State Park (Map 4.1). This area exhibited the highest bank erosion risk based on the results of BANCS model. Other critical areas include Sulphur Creek, a section of the river near the town of Bear River, and a section below the town of Bear River.



Map 4.1. Critical areas of bank erosion in the Bear River Watershed.

4.4. Load Summary

The total current sediment load to the impaired segment of the Bear River is 68.1 tons/day including natural background. Point sources contribute very little sediment load (0.05 ton/day) to the current load. Natural background from all sources equals 5.2 tons/day, leaving 62.8 tons/day from all nonpoint sources (Table 4.12). Stream bank and channel erosion along the impaired segment accounts for most (77%) of the total sediment load, where upstream loads (12%) and natural background loads (10%) make up most of the remaining sediment load (Figure 4.1).

Table 4.12. Current Load Summary

Sediment Source	Total Current Load (tons/day)	Natural Background (tons/day)	Point and Nonpoint Source Load (tons/day)
Bear River upstream of the impaired segment	9.9	1.9	8.0
Sulphur Creek	1.8	0.5	1.3
Stream bank and channel erosion of the impaired segment	55.5	2.7	52.8
City of Evanston stormwater	0.02	0	0.02
Yellow Creek	0.8	0.1	0.7
Point sources	0.05	0	0.05
Total	**68.1**	**5.2**	**62.8**

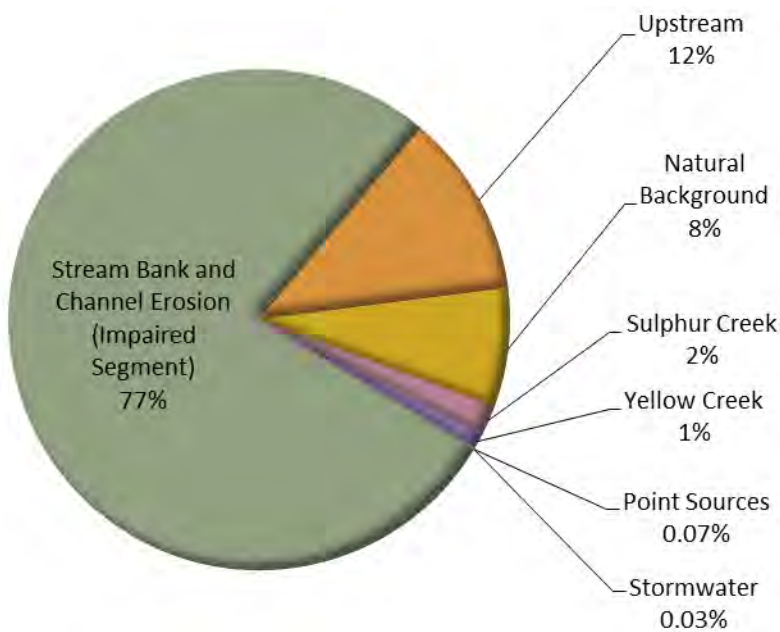


Figure 4.1. Sediment sources and percentages of load to the impaired segment of the Bear River.

5 TMDL CALCULATION AND DAILY LOADING EXPRESSION

This section provides a calculation of the loading capacity, waste load allocations (WLAs), load allocations (LAs), and margin of safety (MOS) for the impaired segment of the Bear River. A summary of the TMDL calculations and linkage analysis is also provided.

5.1. Loading Capacity

The loading capacity, or TMDL, is the greatest amount of sediment that the impaired segment of the Bear River can assimilate and still meet its water quality targets. It is the sum of all elements on the right hand side of the following equation:

$$TMDL = WLA + LA + MOS$$

where:
- TMDL = total maximum daily load (tons/day)
- WLA = waste load allocation (tons/day)
- LA = load allocation (tons/day)
- MOS = margin of safety (tons/day)

The Bear River sediment TMDL is based on the results of the BANCS model. The rationale behind this is that bank and channel erosion along the impaired segment (which BANCS directly quantifies) represents most (77%) of the total sediment load. Furthermore, most of the sediment delivered to the impaired segment originates from bank and channel erosion processes occurring upstream and in tributaries (15% of the total sediment load). Therefore, the sediment load percentage reduction is based on the results of the BANCS model. In general, the process used for calculating the sediment TMDL for the Bear River is as follows: 1) develop a percentage reduction required for the impaired segment based on BANCS, and 2) apply that percentage reduction to the current load. The result of this calculation equals the load capacity, or TMDL.

A sediment load capacity was developed for each reach of the impaired segment. This reach-based loading capacity was determined by calculating what the sediment load would be if each reach had a bank erosion rating category of “Moderate” or lower (see Appendix A for detail on these ratings). A “Moderate” erosion rating was used because it is the highest erosion rating observed along the upstream unimpaired reach of the Bear River. Therefore, each section within the impaired reaches with bank erosion ratings of “High” or greater were lowered to “Moderate”, and a subsequent reach-based load capacity was calculated (Table 5.1). Reach 2 had no banks with an erosion rating category of “High” or greater, so no load reduction was calculated for this reach. The total reach-based load capacity of the impaired segment is 44.8 tons/day (a 19% reduction from BANCS current loads; Table 5.1).

Table 5.1. Sediment Load Capacity Based on BANCS and Percentage Reductions

Reach or Tributary	Current Load (tons/day)	Reach-Based Load Capacity (tons/day)	Percentage Reduction Required
Reach 1: Sulphur Creek confluence to Bear River State Park	12.0	5.5	54.2%
Reach 2: Bear River State Park to Yellow Creek	14.0	14.0	0.0%
Reach 3: Yellow Creek to Woodruff Narrows Reservoir	29.5	25.3	14.0%
Total	**55.5**	**44.8**	**19%**

This 19% reduction in load was then applied to the total current load (68.1 tons/day) to achieve a total load capacity of 55.0 tons/day for the impaired segment. Therefore, the sediment TMDL for the impaired segment of the Bear River is 55.0 tons/day.

5.2. Waste Load Allocations

WLAs (i.e., point source allocations) are the only sediment LAs that are regulated and enforced. For this TMDL, WLAs are calculated from the permitted monthly average discharge and permitted monthly average TSS. A summary of WLAs for point sources that discharge to the impaired segment of the Bear River and Yellow Creek is presented in Table 5.2.

Table 5.2. Point Source Waste Load Allocations

Permit Holder	Permitted Monthly Average Discharge (MGD)	Permitted Monthly Average TSS (mg/L)	Waste Load Allocations (tons/day)	Current Sediment Load (tons/day)
Town of Bear River	0.18	100	0.073	0.021
City of Evanston	2.90	30	0.363	0.014
Flying J, Inc.	0.10	30	0.012	0.011
Total			**0.448**	**0.046**

The total sediment WLA for the three point sources is 0.448 ton/day. The current point source sediment loads are at or below their respective WLAs, and no further action or sediment load reduction is necessary.

5.3. Margin of Safety

This TMDL uses an explicit MOS of 10% of the loading capacity to account for uncertainty in measurements and uncertainty in predicting how well pollutant reductions will result in meeting water quality standards. The MOS effectively increases the amount of reduction required for nonpoint sources by lowering the magnitude of LAs (assuming natural background and WLAs remain constant). An explicit 10% MOS was chosen based on best professional judgment of the uncertainties involved in the TMDL analysis and to ensure compliance with all designated uses. These uncertainties include measurement error for TSS concentrations and flow rates, potential underestimation of sediment load due to lack of paired flow and concentration measurements in Yellow Creek, and potential underestimation of sediment loads from stormwater and watershed erosion. The MOS load is calculated by multiplying the TMDL by the MOS percentage; in this case, 10% of 55 tons/day, or 5.5 tons/day.

5.4. Load Allocations

LAs (i.e., nonpoint source allocations) are calculated based on the remainder of the TMDL left for allocation after the MOS, WLAs, and natural background load are accounted for. The load allocation for nonpoint sources in this sediment TMDL is 43.9 tons/day (TMDL [55.0 tons/day] - MOS [5.5 tons/day] - WLA [0.45 tons/day] - natural background [5.2 tons/day] = 43.9 tons/day).

Because the current nonpoint source load is 62.8 tons/day, this LA represents a 30% reduction in nonpoint source sediment loads to the impaired segment of the Bear River (note that the 19% load reduction referred to in section 5.1 for calculating the load capacity is based on BANCS calculations). This 30% reduction is then applied equally over all nonpoint sources (Table 5.3). This required reduction is practicable and achievable through implementation of management measures, which comprise best management practices (BMPs) as well as stream restoration projects. Some of these management measures include the following:

Agricultural management: Typical BMPs include adding riparian buffer zones, replacing seasonal push-up dams with more permanent structures, fencing livestock away from river banks, and using off-site watering to avoid livestock movement into the river channel.

Stream restoration: Typical BMPs include restoring oxbows, un-straightening channels, and using j-hooks, cross vanes, and engineered stream design. Engineered stream design has the highest probability of long-term improvement in stream stability and sediment supply for the Bear River.

Construction and stormwater management: Typical BMPs include mesh fencing around construction projects, sediment traps in stormwater drains, and stormwater wetlands.

Table 5.3. Load Allocations for Nonpoint Sources of Sediment to the Bear River

Source	Load Allocation (tons/day)
Stream bank and channel erosion (impaired segment)	36.8
Natural background	5.2
Upstream	5.6
Sulphur Creek	0.9
Yellow Creek	0.5
Stormwater	0.01
Total	**49.0 (43.9)**

Note: Value in parentheses has natural background subtracted.

5.5. TMDL Summary

In summary, the TMDL represents a 19% reduction in sediment loads from the current load. This percentage reduction is determined from the percentage of banks on the impaired segment that require improved bank erosion ratings. Only the impaired segment was considered in the determination of the percentage reduction because it is the only waterbody that is listed on the 303(d) list (i.e., although Sulphur Creek and Yellow Creek have significant bank erosion, they are not listed and thus cannot be used to determine a percentage reduction on the impaired segment). After accounting for the WLAs, natural background, and MOS, a 30% reduction in nonpoint sources was calculated (Table 5.4). This is because the natural background and MOS cannot be “reduced” and because the point sources are currently meeting their discharge permits (and thus do not require reduction). Therefore, with a load

capacity of 55.0 tons/day, 11.1 tons/day are reserved for the following: natural background (5.2 tons/day), MOS (5.5 tons/day), and point sources (0.4 tons/day). This leaves 43.9 tons/day (55.0-11.1 tons/day) to be allocated to all nonpoint sources. The current nonpoint source load is 62.8 tons/day, and this must be reduced to 43.9 tons/day, or a 30% reduction. This percentage reduction is applied equally to all nonpoint sources. In summary, a 19% overall reduction in sediment load is required by this TMDL (68.1 tons/day to 55.0 tons/day), which equates to a 30% reduction in all nonpoint sources (62.8 tons/day to 43.9 tons/day) after point sources, natural background, and the MOS are accounted for.

Table 5.4. TMDL Summary

Sediment Source	Current Load (tons/day)	Allocation (tons/day)	Percentage Reduction Required
Upstream	8.0	5.6	30%
Sulphur Creek	1.3	0.9	30%
Stream bank and channel erosion (impaired segment)	52.8	36.8	30%
Stormwater	0.02	0.01	30%
Yellow Creek	0.7	0.5	30%
Nonpoint sources	62.8	43.9	30%
Point sources	0.05	0.4	0%
Natural background	5.2	5.2	0%
MOS	–	5.5	0%
Total	**68.1**	**55.0**	**19%**

5.6. Linkage Analysis

The linkage analysis is an important component of the TMDL process because it provides a clear connection between measured data, impairments, pollutant sources, and water quality targets. Here, a link must be created between the impaired fisheries habitat and the nonpoint source water quality targets for sediment load. Through WDEQ's BURP studies and weight-of-evidence approach, it was determined that the Bear River from the Sulphur Creek confluence to Woodruff Narrows Reservoir was in partial support of its "protection and propagation of fish and wildlife" designated use for the following primary reasons (WDEQ 2001a):

- Quantitative biological data that show a significant departure from reference condition
- Macroinvertebrate and biological data that confirm that core metrics change from clean-water taxa and functional feeding groups upstream to functional feeding groups that are sediment tolerant and respond to nutrient enrichment downstream
- Semi-quantitative physical data (weighted embeddedness) that show increased sedimentation on sample riffles
- Quantitative water quality monitoring data (USGS) that show significant sediment transport in the system during high flows
- Historic quantitative water quality data that show nutrient and sediment loading in the system
- Historic quantitative fisheries data that show declining cold water game fish density and composition from upstream to downstream

The BURP report also found that although water quality measurements did not significantly change along the impaired segment, overall suspended sediment increased in the downstream direction (WDEQ 2001a). This fact, in combination with the evidence of degraded physical habitat related to sedimentation, would

indicate that sediment is the primary stressor of fisheries habitat in this section of the Bear River. Furthermore, peaks in turbidity and TSS are seen just downstream of the Sulphur Creek confluence, implying that Sulphur Creek is a major source of sediment to the Bear River. This is vetted by an additional BURP study done on Sulphur Creek, which identified the system as impaired due to sediment and nutrients (WDEQ 2001b). Note that although Sulphur Creek was found to be impaired through the BURP report, it was not put onto the 303(d) list for impaired waterbodies because it is a hydrologically modified via Sulphur Creek Reservoir (WDEQ 2013a).

In addition to the evidence provided by the BURPs, literature suggests that an increase in turbidity and TSS has been shown to decrease the production and abundance of plant material, decrease abundance of fish food organisms, and decrease production and abundance of fish (Lloyd 1987; Newcombe and Jensen 1996). Lloyd's (1987) literature review of the effects of turbidity on salmonids suggests that turbidity in the 10- to 25-NTU range and TSS concentrations near 35 mg/L can have deleterious effects on fish. Newcombe and Jensen's (1996) literature review suggests TSS values between 18 and 35 mg/L can result in reduced feeding and abundance, and TSS values in the range of 50–66 mg/L can result in reduced rates of weight gain and avoidance behavior in adult rainbow and cutthroat trout. Average TSS measurements in the impaired segment during high flows range from 96.7 to 147.7 mg/L (36.5 mg/L in Sulphur Creek).

Based on the available data and literature, evidence strongly suggests that the fisheries habitat impairment is directly linked to increased sedimentation in the Bear River. WDEQ's BURPs suggest that one of the primary causes of this increase in sediment loads to the Bear River is increased sediment loads from Sulphur Creek, which are a result of bank and channel erosion. Large-scale bank and channel erosion is also evident in many of the reaches of the impaired segment of the Bear River (see section 3.3.2). Thus, reducing bank and channel erosion is fundamental to improving water and habitat quality of the Bear River. This is the primary linkage between using BANCS to assign percentage reductions in the impaired segment. To further determine if the BANCS approach for assigning a percentage reduction to the impaired segment is appropriate, resultant TSS concentrations were derived for each monitoring station based on reduced BANCS erosion rating categories. This links the BANCS methodology to the water quality target set out in section 2.

Using the reach-based load capacities in Table 5.1 (see section 5.1) and an average value for high flows, an equivalent TSS value was calculated for each reach. Reach-based load capacities BR4 and SC1 were determined in the same way as the capacities for BR1–3 (i.e., all bank erosion ratings above moderate reduced to moderate), though these were not used in determining the percentage reduction of the impaired segment. It was first assumed that most of the sediment is transported during periods of high flow, a reasonable assumption given available data and theory from the literature (see section 4.3). Therefore, the TSS numbers calculated here are only valid for high (spring snowmelt) flows.

Each reach-based load capacity was divided by flows from the average flow of the high flow regime for each UCCD monitoring station, resulting in a TSS concentration value in milligrams per liter for each station (Table 5.5). For the BR3, BR2, and BR1 stations, a mass balance approach was used where the total mass was summed through TSS loads from upstream sources, and from the load capacity for each reach. This mass was then divided by the total average high flow at each monitoring station to arrive at a TSS value.

Table 5.5. TSS Values Based on Reduced BANCS Ratings

UCCD Monitoring Station	Average High Flow (cfs)	Load Capacity (tons/day)	TSS (mg/L)
BR4	434	14.1	12
SC1	96	9.5	37
BR3	1,186	5.5	9
BR2	919	14.0	18
BR1	914	25.3	29
Average			21

The results of the above analysis (see Table 5.5) suggest that the reductions in bank erosion called for by this TMDL will result in TSS values very close to or less than the water quality target of 30 mg/L set forth in section 2. Though the results presented here identify that one of the stations (SC1) is above this TSS target value, it is still within a reasonable range of the target given the assumptions involved in the calculations. Therefore it is concluded that the reductions called for in this TMDL are directly linked to the TSS target value which itself is directly linked to the health of cold water fisheries. Thus, if the proposed reductions are achieved, the impaired segment will be brought back into compliance with its designated uses. This water quality target was written to be protective of the health of cold water fisheries, which is considered to be the most sensitive to excess sediment out of all the designated uses. By doing so, this sediment water quality target is protective of all designated uses, which could be affected by excess sediment.

6 EFFECTIVENESS MONITORING

The effectiveness monitoring goals of this project are to document progress in achieving improved water quality conditions in the impaired segment of the Bear River as nonpoint source control management strategies are implemented. Specifically, the objectives are as follows:

- Obtain information necessary to ensure that progress is being made toward meeting water quality targets for sediment.
- Obtain a detailed record of water quality data to assess whether the established target levels and threshold values are protective of designated uses.
- Evaluate BMP effectiveness and load reductions that result from implementation efforts.

Successful development and implementation of the effectiveness monitoring plan will provide flexibility for adapting to new information and changes in the watershed. To document this progress, an effectiveness monitoring program is needed to examine and report on the performance of each management strategy. Effectiveness monitoring is used to check if the selected strategies are effectively reducing sediment loading. The following discussion presents effectiveness monitoring methods proposed for organizations that will be involved in execution of this TMDL.

Effectiveness monitoring is used to check if the selected strategies are reducing pollutant loading. Effectiveness monitoring may be quantitative (e.g., laboratory analysis of TSS concentrations in water from specific monitoring stations) or qualitative (e.g., visual observation of sediment reduction in the water passing through an irrigation diversion structure), depending on the BMP implemented and the overall scope of the project. Although quantitative monitoring methods will document progress toward improved conditions, qualitative methods can also provide an effective measurement of implementation progress. Other examples of qualitative effectiveness monitoring include photograph documentation of improvement in streambank vegetation and cover. This involves establishing photo points that can be found in subsequent years. First, find a reference point that can be located in subsequent years such as a rock, tree, fencepost, or other relatively permanent feature. Photographs taken over the years using the same reference point can be compared for changes in stream and riparian conditions. As with all monitoring procedures, pretreatment photographs are essential to determine effectiveness of treatments. It is important to take the photographs at the same time every year to avoid a seasonal bias in vegetation features.

Qualitative monitoring could also include documentation of relative sediment volume (i.e., high, medium, or low) collected from stormwater outfalls. Although these methods do not provide quantitative information on the effectiveness of the projects, they do illustrate progress and can be combined with other monitoring efforts to show success of implementation activities.

Quantitative effectiveness monitoring is required to document actual progress toward improved water quality conditions and can only be achieved through water quality assessments. Therefore, the success in reducing the load of sediment will be measured by contributions monitored at or near the mouths of major tributary points (e.g., Sulphur and Yellow Creeks), and above and below major changes in land use (e.g., the City of Evanston).

Instream monitoring is scheduled to occur periodically throughout the year by UCCD and includes physical and chemical parameters. The following section outlines the proposed procedures for quantitatively monitoring the effectiveness of the proposed management strategies. While not all the proposed monitoring procedures outlined below need to be implemented, it is important to design an effectiveness monitoring protocol to monitor progress toward achieving the TMDL water quality sediment target.

6.1. Quantitative Monitoring

The quantitative monitoring plan requires water quality monitoring of sites throughout the watershed that contribute directly to the annual sediment load. To assist in achieving the water quality goals, the initial monitoring plan should include the following:

- Conduct seasonal monitoring throughout the year at established sites. The addition of sampling sites at the mouth of major tributaries, above and below major changes in land use and at reach boundaries defined in this document for TSS and discharge is recommended. Load analysis of discharge and TSS should be performed yearly to test whether the sediment load is meeting the TMDL target.
- Continue to monitor changes in the benthic macroinvertebrate communities, habitat conditions, substrate composition, and silt cover (embeddedness) through periodic targeted assessments by WDEQ's Surface Water Quality Monitoring Program.
- Periodically review new data against historic data to illustrate restoration effectiveness.
- Periodically monitor fish species and density. Changes in fish species and density should be collected in a database to monitor the effectiveness of restoration treatments.
- Provide technical and financial support for the conversion of temporary diversion dams (particularly seasonal push-up dams) to permanent structures that will allow fish passage and reduce sediment loads.
- A general monitoring tool for riparian condition assessments that can be applied by landowners along the Bear River is the riparian monitoring questionnaire developed by the Montana Riparian Wetland Association (2004). This questionnaire addresses conditions and changes in stream banks, riparian vegetation community, fish habitat parameters, and stream substrate composition. This tool is recommended for implementation by landowners along the Bear River, regardless of restoration activities that occur on their property, to assess the effects of land management on riparian and stream conditions and troubleshoot problems such as excessive soil erosion.
- Monitor above and below large BMP installation projects to determine the effectiveness of individual projects.
- Monitor instream erosion. Measurements of instream erosion and channel morphology changes comprise another potential monitoring tool. This involves establishing survey sections and transects along reaches that have undergone restoration treatment. Rosgen (2009) provides good guidance for establishing survey sections and transects to measure bank erosion and cross-sectional channel changes. The bank erodibility field estimation tools developed by Rosgen (2009), BEHI, and NBS could be used in conjunction with BANCS to document instream erosion changes over time. The flow data should be taken in conjunction with these data.

7 PUBLIC PARTICIPATION SUMMARY

Local involvement and public participation were highly encouraged throughout the Bear River TMDL process. Interactions and exchanges with local stakeholders provided SWCA with invaluable information and perspective about the Bear River watershed and aided in the development of sediment reduction strategies. Successful outcomes from the TMDL process rely largely on local stakeholder interest and local implementation and facilitation of BMPs. Therefore, public involvement was viewed as a critical component of the Bear River TMDL.

The Bear River TMDL was conducted in a publicly transparent manner that encouraged local feedback and participation. Transparency and incorporation of public feedback were the primary goals of the public involvement plan (PIP). The PIP acts as a blueprint for public participation and stakeholder involvement, and outlines the process by which the public and stakeholders will be kept informed of TMDL activities in the Bear River Basin. The Bear River TMDL PIP identifies important stakeholders and participants and defines their roles, develops public outreach activities including maintaining a project website, and provides a schedule of all important reporting and meeting dates. A project website was developed and updated throughout the life of the project to keep public members informed of the project's progress. The website address for this content during the project is http://upperbearrivertmdl.com. The PIP is available on the project website. After this project is finalized, the website content will be transferred and maintained on the WDEQ TMDL program's webpages. Major features of the website include a comment area, reviews of important meeting minutes, and important documents (Figure 7.1).

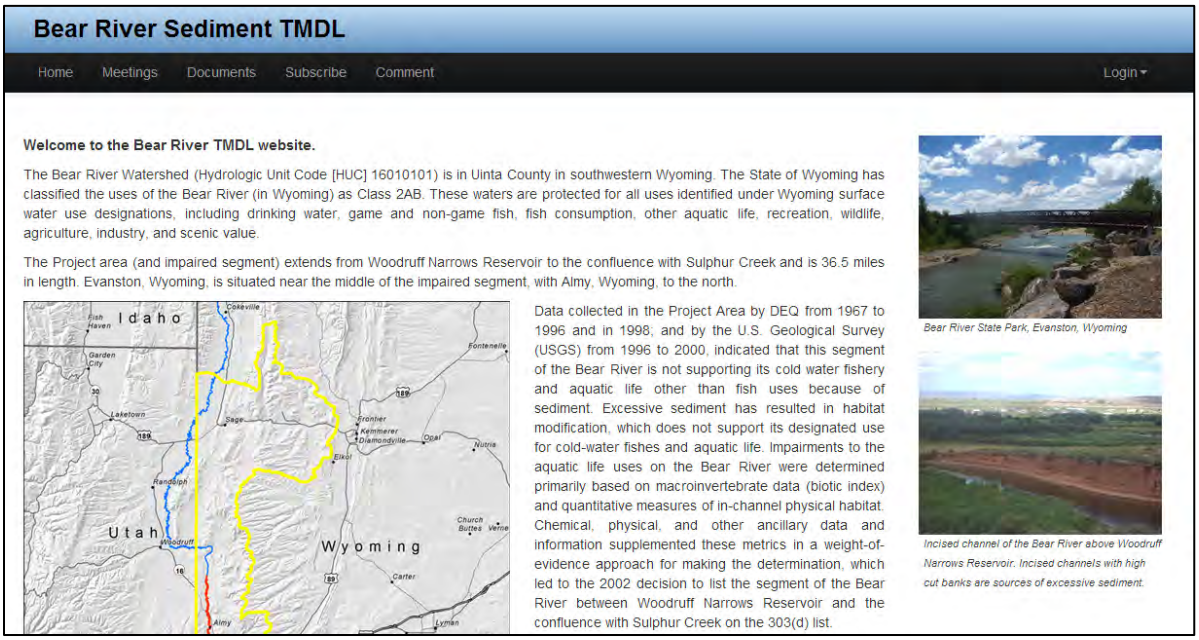


Figure 7.1. Screenshot of the Bear River TMDL website.

Public participation was encouraged throughout the TMDL process through public meetings, technical advisory committee (TAC) meetings, radio announcements, newspaper articles, and website updates. A list of all TAC members and their organizations is presented in Table 7.1. Announcement of public meetings was also made through email, where approximately 50 invitations were sent out to public participants. During public meetings, information was presented during the meetings in an understandable format for the general public, yet with enough technical depth for the scientific community. Notices and announcements of public meetings and requests for comments were provided in the local newspaper (*The Uinta County Herald*), on local radio broadcasts (KEVA), and on the UCCD, WDEQ, and Bear River

Commission websites. Three public meetings were held at the Evanston Public Library in Evanston, Wyoming, and included brochures, comment cards, and a discussion-based presentation style. The dates and discussion topics for each public meeting are summarized as follows:

- The first public meeting was held on January 23, 2013, and focused on an overview of the general TMDL process, the work plan and schedule, a discussion of the problem identification, and a presentation of the public involvement plan. The next phases (data acquisition, watershed characterization, identification of water quality standards and targets, and pollution source identification) were also discussed and presented.
- The second public meeting was held on September 21, 2013, and presented the findings of the data summary and watershed characterization, a discussion of water quality targets and impairments, and results from the pollution source identification. The next phases (TMDL analysis and implementation and monitoring plan) were also presented and discussed.
- The third public meeting was held on February 19, 2014, and presented results from the TMDL analysis, the draft implementation plan, and draft effectiveness monitoring plan. A presentation of the effectiveness and requirements for river restoration BMPs was delivered by the engineering firm Stantec out of Fort Collins, Colorado. A future schedule for the draft TMDL release and incorporation of public comments were also discussed.

Table 7.1. Technical Advisory Committee Members, Titles, and Organizations

Name	Title	Organization
Mike Allred	Environmental Scientist	UDEQ, TMDL Program
Don Barnett	Manager	Bear River Commission
Jeremy Caldwell	Field Manager	BLM, Kemmer Field Office
Leah Coleman	Permitting Supervisor	WDEQ, WYPDES Program
Dave Dasher	Public Works Supervisor	Town of Bear River
Dennis Doncaster	Hydrologist	BLM
Tavis Eddy	Environmental Analyst	WDEQ, Watershed Monitoring
Brianna Forrest	Natural Resources Analyst	WDEQ, TMDL Program
Brian Honey	Director of Public Works	City of Evanston
Kevin Hyatt	Program Principle	WDEQ, TMDL Program
Robert Keith	Supervisor	WGFD, Green River Fisheries
Dave Kimble	Biologist	U.S. Fish and Wildlife Service
Jeff Lewis	District Conservationist	Natural Resources Conservation Service
Sue Lowry	Administrator	State Engineer's Office, Interstate Streams
David Mott	Director	USGS, Wyoming Science Center
Troy Nolan	Mayor	Town of Bear River
Gilbert Olson	Chairman	Bear River Steering Committee
Roland Peterson	Senior Environmental Analyst	WDEQ, WYPDES Program
Thomas Pointon	Hydrologic Technician	USGS, Wyoming Science Center
Mitch Poulsen	Secretary	Bear River Water Quality Task Force
Jodee Pring	Water Planning Coordinator	State Engineer’s Office, Interstate Streams

Table 7.1. Technical Advisory Committee Members, Titles, and Organizations

Name	Title	Organization
Jean Stramel	NRCS Watershed Coordinator	Wyoming NRCS
Kerri Sabey	District Manager	UCCD
Rick Schuler	District Ranger	USFS, Uinta-Wasatch-Cache
Don Shoemaker	Water Commissioner	State Engineer's Office
Jean Stramel	Watershed Coordinator	Natural Resources Conservation Service

Stakeholder comments were documented and individually addressed throughout the TMDL process. Most of the comments and concerns were centered on the implementation plan's recommended BMPs. These comments and concerns were addressed through TAC calls, at a public meeting, through personal communication, and by responding to written comments. The implementation plan was revised in accordance with these concerns to provide stakeholders with a usable and understandable document.

Numerous institutions contributed data, documents, valuable input, and extensive comments during the Bear River TMDL process and on the initial draft document. Representatives from the following institutions contributed to the completion of the Bear River TMDL:

- EPA
- WDEQ
- UCCD
- Wyoming Association of Conservation Districts
- Bear River Water Quality Steering Committee
- Bear River Water Quality Task Force
- Wyoming Game and Fish Department
- Wyoming State Engineer's Office
- Trout Unlimited
- City of Evanston
- Town of Bear River
- Natural Resources Conservation Service
- BLM
- UDEQ
- WGFD

[Placeholder for future completion] The Bear River TMDL public draft was completed on Month Day, 2014, and made available for public review on Month Day, 2014. A 30-day public comment period from Month Day, 2014 to Month Day, 2014, was advertised in the local newspapers (*Uinta County Herald*), and posted on the WDEQ and UCCD websites. The public draft TMDL was available in hard copy at the Evanston Public Library and the UCCD office. The pubic draft TMDL was also available for electronic download from SWCA's client space and the WDEQ website. The only comments received during the 30-day comment period were from EPA. These EPA comments are addressed in this final document. A copy of EPA comments is provided in Appendix C.

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Appendix A.

Watershed Assessment of River Stability and Sediment Supply

(submitted separately due to size)

Appendix B.

Water Quality Sampling Locations, Agency Source, Period of Record, and Number of Samples

Table B.1. Water Quality Sampling Locations, Agency Source, Period of Record, and Number of Samples

Station ID	Station Name	Agency	Flow	TSS	SSC	Turbidity	Comments
			(period of record/number of samples)				
10011500	Bear River near UT-WY State Line	USGS	1942–present/ ~daily	–	2001/2		–
4909851	Bear River at Utah Highway 150 south of Evanston, WY	UDEQ	2009/1	–	–		–
4909500	Bear River at UT/WY state line west of Highway 150	UDEQ	1976–2001/~130	1976–2001/~130	–	1976–2001/~130	–
4909520	Mill Creek at UT/WY state line	UDEQ	1978/1	1977–1979/4	–	1976–1978/4	–
WBI16	Bear River 1 - Upper	WDEQ	1994/1 1995/1 1996/1	1994/1 1995/1 1996/1	–	1994/1 1995/1 1996/1	–
WB42	Bear River - Burton	WDEQ	1998/1	1998/1	–	1998/1	–
BR-01	Above Evanston west of Highway 150 where Highway 150 crosses Mill Creek	Tri-state	Q	2006–2012/22	–	2006–2012/22	Flow from USGS 10011500
BR5		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	–
WBO229	Mill Creek - State (Bear River)	WDEQ	2004/1	2004/1	–	2004/1	–
BR4		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	–
WB43	Bear River - Field	WDEQ	1998/1	1998/1	–	1998/1	–
WBI17	Bear River 1 - Lower	WDEQ	1994/1	1994/1	–	1994/1	–
10015700	Sulphur Creak above reservoir, below La Chapelle Creak, near Evanston, WY	USGS	1957–1997/~daily		–	–	Above Sulphur Creek Reservoir
WB0267		WDEQ	–	2006/1	–	–	Above Sulphur Creek Reservoir
SC2		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	Above Sulphur Creek Reservoir
LC1		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	Above Sulphur Creek Reservoir

Table B.1. Water Quality Sampling Locations, Agency Source, Period of Record, and Number of Samples

Station ID	Station Name	Agency	Flow	TSS	SSC	Turbidity	Comments
			(period of record/number of samples)				
WB97		WDEQ	1999/1 2002/1	1999/1 2002/1 2006/1	–	1999/1 2002/1 2006/1	Above Sulphur Creek Reservoir
4906590		UDEQ	–	2001/4	–	2001/4	On Sulphur Creek
410934110511501	Sulphur Creek at mouth, near Evanston, WY	USGS	–	–	2001/2	–	–
10015900	Sulphur Creek below reservoir, near Evanston WY	USGS	1958–1992/~daily	–	–	–	–
WB98	Sulphur Creek Highway 159 Bridge	WDEQ	1999/1 2002/1	1999/1 2002/1 2006/1	–	1999/1 2002/1 2006/1	On Sulphur Creek
SC1		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	On Sulphur Creek
10014000	Bear River above Sulphur Creek, near Evanston WY	USGS	1946–1956/~daily	–	–	–	–
10016000	Sulphur Creek, near Evanston, WY	USGS	1947–1957/~daily	–	–	–	–
WB44	Bear River - State Park	WDEQ	1998/1	1998/1	–	1998/1	–
BR3		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	–
4909350		UDEQ	–	1981–1987/72 2001/1	–	1981–1987/26 2001/1	–
10016900	Bear River at Evanston, WY	USGS	1984–present/~daily	–	1986–1989/17	–	–
4909250	Bear River below Evanston, WY	UDEQ	–	1981–1987/72 2001/1	–	1981–1987/25 2001/1	–
WB31	Pleasant Valley Creek - Crompton	WDEQ	1998/1	1998/1		1998/1	Above Compton Reservoir
411826111002001	Bear River above Yellow Creek, near Evanston, WY	USGS	1988–1989/13	–	1988–1989/13	–	–

Table B.1. Water Quality Sampling Locations, Agency Source, Period of Record, and Number of Samples

Station ID	Station Name	Agency	Flow	TSS	SSC	Turbidity	Comments
			(period of record/number of samples)				
411851111004001	Bear River below Yellow Creek, near Evanston, WY	USGS	–	–	2001/2	–	–
WBI1	Bear River 2 - Upper (Nixon)	WDEQ	1994/1 1998/1	1994/1 1998/1	–	1994/1 1998/1	–
BR2		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	–
10017000	Yellow Creek near Evanston, WY	USGS	1943–1978/~daily		–		–
WB203	Yellow Creek-Sulphur Hollow	WDEQ	2003/1	2003/1	–	2003/1	–
WBI18	Bear River 2 - Lower	WDEQ	1994/1	1994/1	–	1994/1	–
BR-02	Above Woodruff Narrows below Evanston at Highway 89 road crossing	Tri-State	Q	2006–2012/24	–	2006–2012/24	Flow from USGS 10016900
WB45	Bear River - Martin Ranch	WDEQ	1998/1	1998/1	–	1998/1	–
BR1		UCCD	2007–2012/12	2007–2012/12	–	2007–2012/12	–
4909000	Bear River above Woodruff Narrows Reservoir	UDEQ	–	1981–1982/26 2001/2	–	1981–1982/26 2001/2	–
10020100	Bear River above Reservoir, near Woodruff, UT	USGS	1961–present/ ~daily	–	1989–2006/70	–	–

Note: ~ = approximately

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Appendix C.

EPA Comments

(placeholder for EPA comments yet to be received)