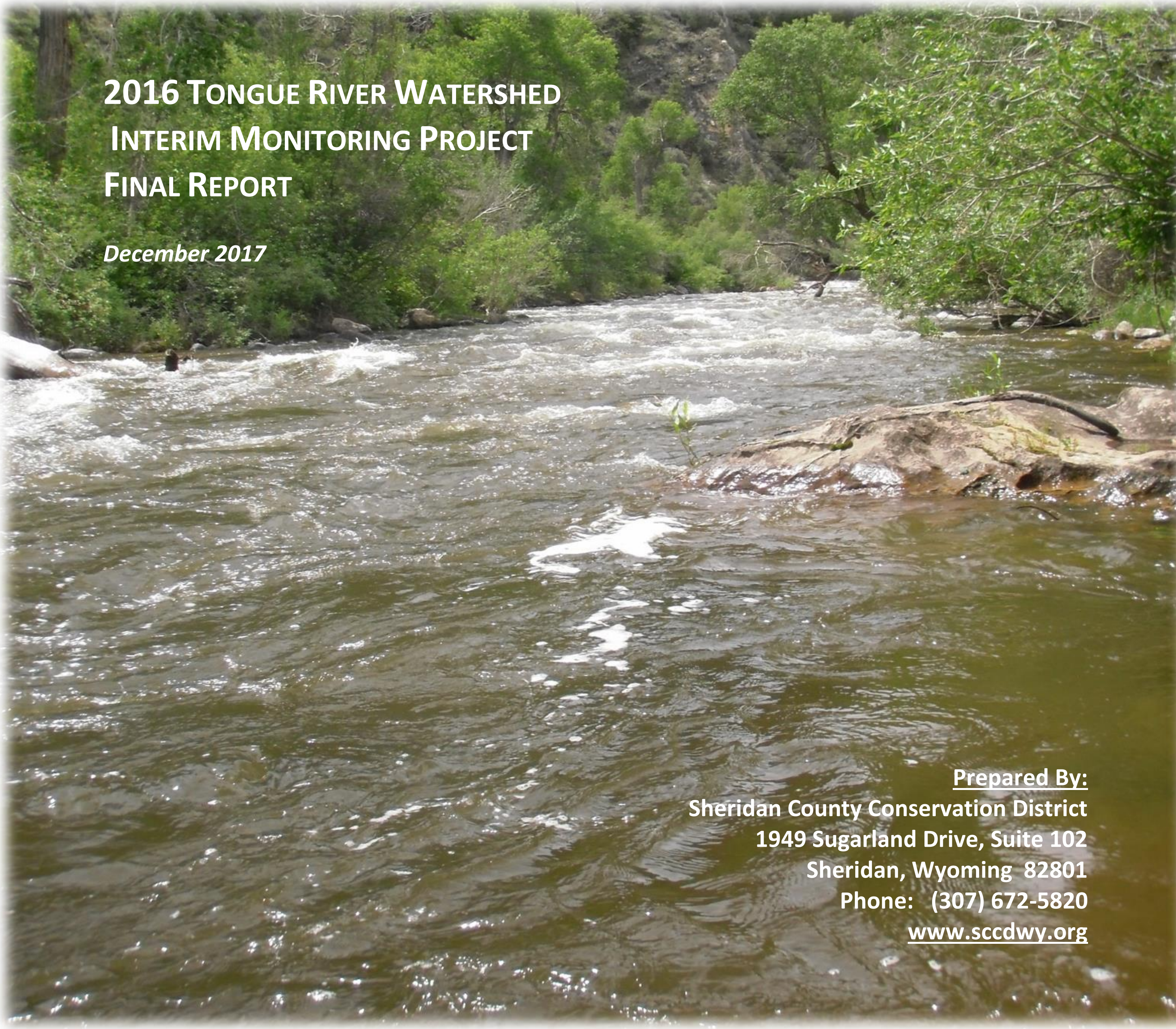

2016 Tongue River Watershed Interim Monitoring Project Final Report

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EXECUTIVE SUMMARY

The Tongue River originates in Wyoming on the eastern side of the Big Horn Mountains and flows through the Towns of Dayton and Ranchester east and north into Montana. The project area, which begins at the Wyoming-Montana state line, consists of approximately 463,990 acres. Annual precipitation ranges from 32 inches in the headwaters to 12 inches near the state line. Major tributaries of the Tongue River above the Town of Ranchester include Little Tongue River, Smith Creek, Columbus Creek, Five Mile Creek, and Wolf Creek. Goose Creek and Prairie Dog Creek are the primary perennial tributaries in the lower portion of the project area, however intermittent draws may contribute stormwater run-off during precipitation or snowmelt events. Tributaries provide irrigation water and make up a portion of the water supply to rural residents in the watershed. The project area includes a combination of private, State, and Federal lands, with private lands dominating the portion of the watershed downstream of the Bighorn National Forest (BNF). Land uses include irrigated and non-irrigated hay and crop lands, pasture, livestock grazing, energy development, recreation, the Towns of Dayton and Ranchester, and wildlife habitat. The Tongue River and major tributaries are perennial waterbodies expected to support drinking water supplies (when treated), fish and aquatic life, recreation, wildlife, industry and agriculture uses. Five Mile Creek and other draws are not expected to support fish populations or drinking water supplies. The State of Wyoming has identified the Tongue River and several tributaries as impaired for recreational use because of bacteria concentrations. Some lower Tongue River segments have also been identified as impaired for Cold Water fisheries because of high water temperatures.

The Sheridan County Conservation District (SCCD) initiated water quality monitoring on the Tongue River Watershed in 1996. The original 1996 Tongue River project area consisted of eight sites in approximately 313,121 acres upstream of the Town of Ranchester. The 1996-1999 Tongue River Watershed Assessment Final Report was completed in September 2000 and resulted in the development of the Tongue River Watershed Plan. The Plan outlined the goals, objectives, and action items for addressing bacteria concerns within the watershed.

The project boundary was expanded twice since the Tongue River Watershed Assessment, but still includes the initial eight sites. The first expansion, in 2006, included two new sites on the Tongue River between the Town of Ranchester and the confluence with Goose Creek. The section from Goose Creek to the Montana State Line was added in 2013 to tie into existing efforts on adjacent watersheds. In the 2013 expansion, four sites on the Tongue River were added, along with the lowermost sites on Goose Creek and Prairie Dog Creek.

There have been five rounds of interim water quality monitoring since 1999; one in 2003, 2006, 2010, 2013, and the most recent in 2016. Interim monitoring includes water quality monitoring along with benthic macroinvertebrates and habitat assessments at a limited number of stations. Interim monitoring evaluates trends in bacteria and other water quality parameters. Benthic macroinvertebrate populations and habitat assessments are evaluated at a limited number of stations. The water quality parameters include: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli* bacteria.

Implementation of the Tongue River Watershed Plan resulted in the development and administration of a water resources improvement program, which included cost-share funding for projects with the potential to benefit water quality. Despite improvement efforts, bacteria concerns continued to exist and the initial watershed plan was updated in 2007. In 2012, the plan was updated again to meet the nine essential elements of a Watershed Based Plan, required by the U.S. Environmental Protection Agency. Ongoing interim water quality monitoring influenced the decisions, priority areas, and action items within the plan.

Water quality monitoring for 2016 was performed at 13 stations; six sites on the mainstem of the Tongue River, and seven sites on the major tributaries that flow into the Tongue River. These seven tributaries included Smith Creek, Little Tongue River, Columbus Creek, Five Mile Creek, Wolf Creek, Goose Creek, and Prairie Dog Creek. Stations were equipped with a SCCD calibrated staff gauge or located at USGS gauging stations. Grab samples for bacteria and turbidity were collected five times in the early season from May-July and five times in the late season from July-September. Instantaneous temperature, pH, conductivity, dissolved oxygen (% and mg/L), and gauge height were measured on-site during sampling events. Continuous temperature loggers were used to monitor water temperature at the seven mainstem stations. Macroinvertebrate collections and habitat assessments were conducted on five mainstem sites of the Tongue River during the month of September. All monitoring methods, standard operating procedures, and QA/QC protocols used for this project were described in the 2016 Quality Assurance Project Plan 2015 Update and the 2016 Tongue River Watershed Interim Monitoring Sampling and Analysis Plan.

Data Quality Objectives (DQOs) were established for each monitoring parameter for precision, accuracy, and completeness at levels sufficient to allow SCCD to recognize project goals and objectives. With few exceptions, all parameters met the DQO's and data were accepted. Meter malfunction resulted in discarding all dissolved oxygen measurements for one sample day. In addition, one-set of *E. coli* and turbidity samples on Five Mile Creek were discarded because of non-representative sample conditions.

Summary statistics and geometric mean values were calculated for instantaneous monitoring parameters on accepted data. Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at 12 of the 13 sites on at least one occasion; the uppermost station (TR09) did not have any temperature measurements above 20°C. Continuous temperature loggers reported temperatures above 20°C at all but the uppermost station in Tongue River Canyon. Conductivity and pH were within the expected ranges during 2016. Turbidity values were considered normal for the watershed with occasional high values occurring during late-spring, early summer precipitation and run-off events. All sites met the minimum instantaneous dissolved oxygen concentration for early and other life stages. Four tributary stations and four mainstem stations had one or more samples that were below the 8.0 mg/L water column concentration recommended to achieve the inter-gravel concentrations for early life stages.

Bacteria geometric mean concentrations in the early season were typically higher than in the late season on tributary sites. In contrast, mainstem sites had higher bacteria concentrations in the late season except on TR03 and TR09. While some mainstem sites did not meet Wyoming Water Quality Standards, the highest bacteria concentration observed at a mainstem site was 169 cfu/100 mL or 25% above the standard. Bacteria concentrations at tributary stations appeared to contribute to bacteria increases on the Tongue River at adjacent downstream stations in the upper portion of the watershed during the early season. Except for Wolf Creek during the late season, bacteria concentrations at all tributary stations exceeded Wyoming Water Quality standards in both the early season and the late season.

For the most part, bacteria concentrations decreased from 2003-2016 and from 2013-2016 at all mainstem sites in the early season but increased in the late season. In contrast, bacteria concentrations at TR09 in the early season increased since 2003, but were still well below Wyoming Water Quality standards.

The collection and analysis of stream benthic macroinvertebrate samples during 2016 revealed similar trends in biological condition observed during previous monitoring at Tongue River mainstem stations. No Tongue River tributary stations were sampled during this 2016 report period. Biological condition scores at reference station TR09 varied little over the years. With the exception of 1995 and 2007, the biological condition scores indicated full support for aquatic life use. The slightly positive trendline indicating improvement in biological condition at station TR09 over the years indicated stability in the biological community and confirmed that station TR09 was a representative reference station. The biological condition of the benthic macroinvertebrate community at Tongue River TR07 station varied little from the period of 1996 through 1999 and indicated indeterminate or full support for aquatic life use each year. However, a negative trendline indicated a general decline in biological condition since sampling began in 1996. The biological condition scores at station TR05 in from 1995 to 2004 indicated full support for aquatic life use. Sampling from 2006 to 2016 indicated indeterminate support for aquatic life use. The negative trendline for biological condition at TR05 indicated a gradual downward trend in biological condition since sampling in 1995. Biological condition scores at the most downstream station TR01 located near the Montana border indicated full support for aquatic life use during each year since 1998. However, a graph of biological condition scores indicated that biological condition has declined over time. Full support for aquatic life use may change should the decline in biological condition continue. No threatened or endangered benthic macroinvertebrate taxa or fish species have been identified since sampling began in the Tongue River watershed in 1993. The generally widespread occurrence of indicator taxa indicated that water contained no toxic substances in sufficient concentration to prevent the establishment and survival of these taxa. The disappearance of stoneflies since the latter 1990's noted at some mainstem Tongue River stations continued. The general disappearance of stoneflies at Tongue River stations downstream of TR09 since the 1990's indicates that water quality and habitat change have negatively affected this pollution intolerant group of aquatic insects. Monitoring of aquatic benthic macroinvertebrate communities in the Tongue River watershed have not identified the presence of aquatic invasive species of concern to the Wyoming Game and Fish Department. No zebra mussel (*Dreissena polymorpha)*, quagga mussel (*Dreissena rostriformis bugensis),* New Zealand Mudsnail (*Potamopyrgus antipodarum)* and the Asian Clam (*Corbicula fluminea*) have been identified in the Tongue River watershed. Recommended future benthic macroinvertebrate monitoring by SCCD will be attentive to the presence of aquatic invasive species.

Tubifex tubifex, a species of aquatic worm*,* involved in the whirling disease life cycle that may decimate trout populations, have not been collected at Tongue River stations since monitoring began indicating a low probability for the occurrence of whirling disease. However, the presence of the genus *Tubifex* and immature Tubificid worms in samples collected in the Tongue River watershed suggest the future potential occurrence of *T. tubifex*. Whirling disease has not been detected in the Tongue River watershed or nearby Little Goose Creek and Big Goose Creek watersheds.

Attempts to determine if improvements in overall water quality have been achieved are often difficult, especially when comparing water quality data that has been collected during seasons with different hydrological and meteorological conditions. Although normal flow conditions cannot be anticipated nor expected during monitoring, these varying conditions do make water quality comparisons more difficult. Bacteria concentrations, in particular, are known to vary in response to a number of different water quality and water quantity factors, including changes in water temperature, water quantity, and suspended sediment loads. Higher *E. coli* bacteria concentrations in May can be associated with precipitation events in the spring, including run-off from snowmelt, that contribute surface contaminants. Increased stream discharge can also disturb bed sediment containing high concentrations of bacteria. From 2000 through 2006, the local area was in a prolonged drought and below average stream discharge conditions were experienced. Years 2001 and 2002 lacked adequate peak flows during May and June which normally “flush” stream channel sediment accumulated during the previous year. During 2003 and 2010, the Tongue River experienced higher than normal peak flows, which may have had the ability to “flush” streambed sediment that had accumulated during previous drought years. Flows in 2013 and 2016 were generally below normal at most stations, especially during the early season.

The positive effects that improvement projects have on water quality may not be immediately determined due to factors such as the bacteria storage capacity of bed sediment, which is normally suspended during bankfull flows. Bacteria “storage” in bed sediments and their annual release during high flows may cause a delay in observing quantifiable changes in bacteria currently entering the system. The data provided by the 1996 – 1999 watershed assessment and subsequent interim monitoring indicate the need for additional improvement projects as well as additional future monitoring to create and measure positive water quality changes. The SCCD anticipates that voluntary, incentive based watershed planning and implementation will be successful; however, it may require several years to measure these achievements. Nonetheless, each improvement project that has been implemented or is currently being implemented on the watershed certainly induces positive water quality changes, whether they are immediately apparent or not.

SCCD will continue to monitor water quality in the Tongue River Watershed on a three-year rotation, pending available funding sources. Planning and implementation of remedial measures to restore full aquatic life use support in the streams in the Tongue River watershed should continue. Continued benthic macroinvertebrate sampling should be conducted at stations in the watershed to track potential changes in biological condition.

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Chapter 1 Project Area Description

1.1 Watershed Description

The Tongue River originates in the Bighorn National Forest (BNF) on the eastern side of the Big Horn Mountains, flows east and north through the towns of Dayton and Ranchester, and eventually into the Yellowstone River in Montana. The project area, which begins at the Wyoming-Montana state line, consists of approximately 463,990 acres in northern Sheridan County, in north-central Wyoming and Big Horn County in south-east Montana (Appendix A-1). Of the 463,990 acres, 81,207 acres (17.5 %) are located in Montana adjacent to smaller, ephemeral tributaries and draws and are not included in the following project area description. This area did not include the entire Goose Creek and Prairie Dog Creek Watershed areas, which have separate monitoring and improvement efforts. The designated project area, including the project area description, includes only a small area above the sampling site at those stations.

Elevation of the Tongue River within the project area starts at 4,160 feet in the Tongue River canyon (TR09) and drops to 3,420 feet just below the confluence with Prairie Dog Creek at TR01. Total elevation difference is 740 feet over a distance of approximately 53.01 miles (13.96 ft/mile or 0.07% slope). The annual precipitation is 28 to 32 inches at the headwaters in the BNF. At the uppermost monitoring station in Tongue River Canyon (TR09), the annual precipitation is 16 to 18 inches. Downstream of the Town of Ranchester, the watershed transitions to a drier precipitation zone; near the Wyoming-Montana state line, at TR01, the precipitation is only 12 to 14 inches (Appendix A-2). The watershed is comprised of three ecological site groups (Appendix A-3). Sites within the lower watershed, below the Town of Ranchester to the State Line, are in the 10-14" Northern Plains Ecological Site Group. The middle to upper portion of the watershed, including Tongue River Sites TR07 and TR08, are within the 15-19" Northern Plains Ecological Site Group. The 20+" Mountains Ecological Site Group, encompasses the remaining portion of the watershed, including all of the area within the BNF and the uppermost sample station (TR09).

Major tributaries of the Tongue River above the Town of Ranchester include Little Tongue River, Smith Creek, Columbus Creek, Five Mile Creek, and Wolf Creek. Goose Creek and Prairie Dog Creek are the primary perennial tributaries below the Town of Ranchester, however intermittent draws may contribute stormwater run-off during precipitation or snowmelt events. The largest of these draws include Six-mile Creek, Earley Creek, North Dry Creek, Slater Creek, South Dry Creek, and Hidden Water Creek. Tributaries provide irrigation water to ranches and make up a portion of the water supply to rural residents in the watershed. Diversions result in the transferring and mixing of waters from different areas of the watershed.

1.2 Land Ownership and Uses

Descriptions of land ownership and uses are limited to the 382,783 acres within the State of Wyoming. The project area includes a combination of private, State, and Federal lands with private lands dominating the portion of the watershed downstream of the BNF (Appendix A-4).

Nearly 177,127 acres (46%) are privately owned. State lands comprise approximately 24,664 acres (6%) and include the Amsden Creek Big Game Winter Range. Federal lands constitute approximately 180,993 (47%) of the total acres, including:

- 174,111 acres managed by the BNF,
- 5207 acres managed by the Bureau of Land Management (BLM),
- 1150 managed by the Department of Defense, and
- 525 acres managed by the United States Fish and Wildlife Service (USFWS).

Land uses within the watershed include irrigated and non-irrigated hay and crop lands, dry land pasture, livestock grazing, energy development, various types of recreation, the urban areas of Dayton and Ranchester, and prime wildlife habitat that is concentrated along stream bottoms and brushy draws where riparian zones are intact (Appendix A-5). Sensitive species including warm water game and non-game fish, sage grouse and prairie dog populations occur within the project area. The headwaters, located in the BNF, supports wildlife habitat, livestock grazing, logging, recreation, including angling, camping, hiking, ATV trails, and other uses. The historic coal mining community of Monarch, as well as others, has been almost entirely removed, with some remnant homesites, a church (converted into a residence), and a water tower remaining. A railroad, local highway, and the interstate run parallel to the Tongue River between the Town of Ranchester and Acme. The lower portion of the project area has more coal bed methane, mining, and other energy development than other areas of the watershed.

There are five permitted point source discharges (not including storm drains) within the upper portion of the project area; four are from sanitary wastewater facilities (including the Towns of Dayton and Ranchester), and one from a Concentrated Animal Feeding Operation (CAFO). The lower portion of the project area contains point source discharges from coal bed methane production, although some of these are inactive. The City of Sheridan Wastewater Treatment Plant discharges into Goose Creek approximately 7 miles upstream of the GC01 site. Approximately 5 miles upstream of the GC 01 site, the KOA campground also had a permitted discharge from a small wastewater facility; however, that system is being replaced with a connection to the City of Sheridan sanitary sewer system in 2017.

The mainstem of the Tongue River and major tributaries contain numerous small to very large ranches. Status for domestic wastewater treatment at ranches and rural subdivisions is unknown. Agriculture related land use dominates the watershed. Agricultural operations center on cattle and hay production enhanced by irrigation water from the Tongue River and its tributaries during the summer growing season. Livestock tend to be fed and wintered along the creek bottoms since these areas provide the necessary shelter and water. A more comprehensive, detailed description of the project area has been previously provided in the 1996-1999 Tongue River Watershed Assessment Final Report (SCCD, 2000), which includes narrative descriptions of water uses, land uses, surface geology, soil types, and other factors.

1.3 STREAM CLASSIFICATIONS AND BENEFICIAL USES

The Wyoming Department of Environmental Quality (WDEQ) is charged with implementing the policies of the Clean Water Act and providing for the "highest possible water quality" for activities on a waterbody (WDEQ, 2013). Depending upon its classification, a waterbody is expected to be suitable for certain uses (Table 1-1).

Table 1-1. Wyoming surface water classes and use designations (WDEQ, 2013)

Class	Drinking Water[2]	Game Fish[3]	Non-Game Fish[3]	Fish Consumption[4]	Other Aquatic Life[5]	Recreation[6]	Wildlife[7]	Agriculture[8]	Industry[9]	Scenic Value[10]
1[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
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

[1] 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, etc.).

[2]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.

[3]The fisheries use includes water quality, habitat conditions, spawning and nursery areas, and food sources necessary to sustain populations of game and non-game fish. This does not include the protection of exotic species which are designated "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.

[4]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.

[5]Aquatic life other than fish includes water quality and habitat necessary to sustain populations of organisms other than fish in proportions which make up diverse aquatic communities common to waters of the state. This does not include the protection of insect pests or exotic species which are designated "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service with their appropriate jurisdictions.

[6]Recreational use protection involves maintaining a level of water quality that is safe for human contact. It does not guarantee the availability of water for any recreational purpose. Both primary and secondary contact recreation are protected in Class 2AB waters.

[7]The wildlife use designation involves protection of water quality to a level that is safe for contact and consumption by avian and terrestrial wildlife species.

[8]For purposes of water pollution control, agricultural uses include irrigation or stock watering.

[9]Industrial use protection involves maintaining a level of water quality useful for industrial purposes.

[10]Scenic value 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.

Stream classifications are assigned by WDEQ and identified on the Wyoming Surface Water Classification List (WDEQ, 2013a) or in subsequent reports. Chapter 1 of the Wyoming Water Quality Rules and Regulations (WDEQ, 2013) describes the surface water classes, and designated uses, and the water quality standards that must be achieved for a Wyoming waterbody to support its designated uses (WDEQ, 2013).

Streams within the Tongue River Watershed project area are classified as either 2AB or 3B (Table 1-2). Class 2AB waters are perennial waterbodies expected to support drinking water supplies (when treated), fish and aquatic life, recreation, wildlife, industry, and agriculture uses (WDEQ, 2013). Five Mile Creek and other draws, which are Class 3B surface waters, are not expected to support fish populations or drinking water supplies.

Table 1-2. Stream classifications of waterbodies in the Tongue River watershed

Stream Classifications	
Class 2AB	**Class 3B**
Tongue River (below BNF boundary)	Ash Creek
Amsden Creek	Earley Creek
Columbus Creek	Five Mile Creek
Little Tongue River	Six Mile Creek
Sheep Creek	Slater Creek
Smith Creek	South Dry Creek
Wolf Creek	Squirrel Creek
Goose Creek	Youngs Creek
Prairie Dog Creek	

1.4 Stream Impairments and Listings

States are required to summarize water quality conditions in the state through section 305(b) of the Clean Water Act; this report is commonly known as the 305(b) report and is published every two years. If a waterbody exceeds narrative or numeric water quality standards, it is considered "impaired" or not meeting its designated uses. Section 303(d) of the Clean Water Act requires states to identify waters that are not supporting their designated uses and/or need to have a Total Maximum Daily Load (TMDL) established to support the designated uses. A TMDL describes the amount of a given pollutant a waterbody can receive and still meet water quality standards. Currently, impaired waterbodies are first included on the Wyoming 303(d) list of Waters Requiring TMDLS under Category 5 (WDEQ, 2016). Once a TMDL is completed, a waterbody is moved from Category 5 to Category 4, which includes the list of waterbodies with TMDLs.

Some streams within Tongue River Watershed were listed as early as 1996, but were removed or included in the list of waterbodies requiring further monitoring in the 1998 list. Subsequent monitoring by SCCD, USGS, WDEQ, and others resulted in impairment designations on the Tongue River and several tributaries (Table 1-3). These waterbodies were assigned a low priority for TMDL development because of local watershed improvement efforts.

Table 1-3. Impaired stream segments within the Tongue River watershed (WDEQ, 2016)

Name	Class	Location	Miles	Uses	Impairment	List Date
Tongue River	2AB	From Monarch Road upstream to Wolf Creek Road	13.5	Recreation	*E. coli*	2010
Tongue River	2AB	From Goose Creek downstream to the Montana border	22.1	Cold Water Fishery	Temperature	2002
Prairie Dog Creek	2AB	From I-90 to a point 47.2 miles downstream	47.2	Recreation	Fecal Coliform	2004
Prairie Dog Creek	2AB	From I-90 to a point 47.2 miles downstream	47.2	Drinking Water	Manganese	2012
Prairie Dog Creek	2AB	From I-90 to a point 47.2 miles downstream	47.2	Cold Water Fishery	Temperature	2012
Prairie Dog Creek	2AB	From Tongue River to a point 6.7 miles upstream	6.7	Recreation	Fecal Coliform	2004
Prairie Dog Creek	2AB	From Tongue River a point 6.7 miles upstream	6.7	Drinking Water	Manganese	2002
Prairie Dog Creek	2AB	From Tongue River a point 6.7 miles upstream	6.7	Cold Water Fishery	Temperature	2012
Goose Creek	2AB	From Little Goose Creek downstream to the Tongue River	12.7	Aquatic life, Cold Water Fishery	Habitat Alterations, Sediment	2006
Goose Creek	2AB	From Little Goose Creek downstream to the Tongue River	12.7	Recreation	Fecal Coliform	2000
Wolf Creek	2AB	From Tongue River upstream to East Wolf Creek	10.6	Recreation	Fecal Coliform	2002
Five Mile Creek	3B	From Tongue River upstream to Hanover Ditch	2.1	Recreation	Fecal Coliform	2002
Columbus Creek	2AB	From Tongue River to a point 3.1 miles upstream	3.1	Recreation	Fecal Coliform	2002
Little Tongue River	2AB	From Tongue River upstream to Frisbee Ditch	4.8	Recreation	*E. coli*	2002
Smith Creek	2AB	From Tongue River to a point 5.8 miles upstream	5.8	Recreation	Fecal Coliform	2002
North Tongue River (Bighorn National Forest)	1	From Road 171 upstream to Pole Creek	11.1	Recreation	Fecal Coliform	2004

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Chapter 2 Project Background

2.1 Previous SCCD Monitoring Efforts

The Sheridan County Conservation District (SCCD) initiated water quality monitoring in the Tongue River Watershed in 1996, in partnership with the USDA Natural Resources Conservation Service (NRCS) and the Tongue River Watershed steering committee. The original 1996 project area consisted of approximately 313,121 acres and contained eight water quality monitoring sites; three mainstem sites and five tributary sites. The 1996-1999 Tongue River Watershed Assessment Final Report was completed in September 2000 and identified fecal coliform impairments on Five Mile Creek, Columbus Creek, Smith Creek, Little Tongue River, and Wolf Creek (SCCD, 2000). The Lower Tongue River station, near the Ranchester Water Treatment Plant intake, also exceeded the fecal coliform standard on some occasions. Other water quality parameters monitored during this assessment (including nutrients and pesticides) were found at low or non-detectable levels, suggesting fertilizers and pesticides appeared well managed within the watershed.

Previous interim water quality monitoring was conducted in 2003, 2006, 2010, and 2013 utilizing many of the same monitoring sites, water quality parameters, and sampling periods (SCCD, 2004; SCCD, 2007; SCCD, 2012; and SCCD, 2015). Interim monitoring includes water quality monitoring along with benthic macroinvertebrates and habitat assessments at a limited number of stations. In 2003 and 2006, SCCD collected fecal coliform and *E. coli* samples to correspond with changes in WDEQ water quality standards. The water quality parameters include: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli* bacteria. Upper tributary stations were not monitored in subsequent years because no water quality impairments were identified at these stations during the initial assessment. In addition, SCCD did not collect nutrient, pesticide, or herbicide data because these parameters were found at low or non-detectable levels during the initial assessment.

The project boundary was expanded in 2006 and again in 2013. The 2006 expansion included two new sites on the Tongue River between the Town of Ranchester and the confluence with Goose Creek. The section from Goose Creek to the Montana State Line was added in 2013 to tie into existing efforts on adjacent watersheds. SCCD added four new Tongue River sites, along with sites on Goose Creek (GC01) and Prairie Dog Creek (PD01), which are the primary tributaries in the lower watershed. Two of the Tongue River sites were retained for monitoring in 2016; the other two were discontinued due to limited staff and funding resources.

The general trend in bacteria concentrations on Tongue River stations were typically higher in the early season than in the late season; while tributaries are much more variable. Relatively high bacteria concentrations in May of 2010 were followed by sharp decreases in 2013 at most stations, which may have resulted from higher than normal precipitation and early season flows in 2010. Extremes in short and long-term weather conditions have produced bacteria data that are not directly comparable among years. Nonetheless, values that exceed bacteria standards were observed on essentially the same stream reaches year after year and indicate water quality impairments continue to exist, regardless of hydrologic conditions.

Biological condition trends are relatively stable for most years through 2013 at the uppermost station in Tongue River Canyon (TR09) and stations below the Town of Ranchester, including, the station near Kleenburn (TR05) and near Decker Highway (TR03). While the lowermost station (TR01) continued to show full support for aquatic life use, biological condition declined from 2004-2013. The site within the Town of Ranchester downstream of the confluences with Wolf Creek and Five Mile Creek (TR07) declined from full support of aquatic life use from 1996-1999 to partial or non-support in 2010 and 2013.

2.2 WATERSHED PLANNING AND IMPLEMENTATION

The 1996-1999 Tongue River assessment served as the foundation of a local watershed planning and improvement effort. The Tongue River Watershed steering committee, which consisted of stakeholders representing rural, urban, and other local interests, recognized bacteria levels as a major concern. Wildlife, livestock and other domestic animals, and humans were identified as possible bacteria sources. The Tongue River Watershed Plan was developed to address these concerns and was approved by WDEQ in 2000 (SCCD, 2000a). The plan outlined the goals, objectives, and action items for improving water quality with the Tongue River Watershed, along with prioritizing best management practices, and providing future recommendations. This initial plan included recommendations for continued monitoring, information and education, and improvement projects.

Since the completion of the original *Tongue River Watershed Management Plan*, there have been two updates. The *Tongue River Watershed Management Plan, Revision 1* (SCCD, 2007a) recommended continuation of improvement efforts and monitoring. Although excess sediment was not identified as a source of impairment in the Tongue River watershed, it was a concern for watershed residents. As a result, sediment contributions related to unstable channels and irrigation diversions were included in the 2007 Plan. In 2012, the SCCD and steering committee developed the *Tongue River Watershed Plan, Revision 2* (SCCD, 2012a) to include the nine essential elements required by the USEPA. The 2012 Plan identifies impaired waters; designates and characterizes distinct subwatersheds; quantifies existing pollutant loads from previous monitoring efforts; develops estimates of the load reductions required to meet water quality standards; and develops effective management action items to reduce pollutant loads. Ongoing interim water quality monitoring influenced the decisions, priority areas, and action items within the *Tongue River Watershed Plan, Revision 2* (SCCD, 2012a). As part of the *Tongue River Watershed Plan, Revision 2*, SCCD/NRCS will implement the following recommendations:

- Continue a watershed improvement effort by providing leadership and project oversight;
- Reduce bacteria contributions by an average of 18% by 2017;
- Continue mitigation efforts in the highest priority reaches, which include Smith Creek, Little Tongue River, Columbus Creek, and Five Mile Creek, along with their tributaries.
- Reduce water quality impacts, other than bacteria, such as nutrient concentrations, organic matter, temperature, and sediment loads***;***
- Increase awareness and encourage participation in the watershed improvement efforts***;*** and
- Increase awareness and understanding about water quality impacts and relationships among water quality parameters.

As of December 2016, there have been several improvement projects completed within the Tongue River Watershed, including: 10 septic system replacements; 3 riparian fencing/stockwater developments, 7 corral relocation projects; 6 irrigation diversion replacements; 10 stinger/tree cutting sites; and 9 stream/channel stabilization projects. In addition, riparian buffers on four tributaries and a reservoir restoration project have been done without financial assistance from the SCCD. Some of the buffers included contracts under USDA programs while others were completed by the landowner without assistance from SCCD or USDA. These and other watershed improvement projects are documented on a progress register map for the watershed (Appendix A-6).

The Tongue River Watershed improvement effort has helped to increase awareness about several important resource issues and has led to more public interest in the watershed. The SCCD anticipates that voluntary, incentive based watershed planning and implementation efforts will eventually be successful; however, it may require several years to measure these achievements. Continued monitoring can provide information on water quality changes over the long-term.

2.3 Project Purpose and Objectives

The purpose of this project was to complete the 2016 interim milestone in the *Tongue River Watershed Plan, Revision 2* (SCCD, 2012a). The 2015 monitoring is within a three-year monitoring rotation currently conducted by SCCD on the Tongue River, Goose Creek, and Prairie Dog Creek watersheds and is funded through the Sheridan County Watershed Improvements #4 Project funded by WDEQ through Section 319 of the Clean Water Act.

The project was consistent with the goals and overarching principles outlined in the Wyoming Nonpoint Source Management Plan Update (WDEQ, 2013b). The monitoring is part of a locally-led collaborative process that includes information and education programs and project implementation through the organization and facilitation of local stakeholder groups.
The specific objectives of this project were to use water quality monitoring information/trends:

- to identify and prioritize areas affected by nonpoint source pollution and
- to evaluate effectiveness of implementation of improvement projects and other activities.

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CHAPTER 3 HISTORICAL AND CURRENT DATA

Historical data, for the purposes of this project, are defined as data greater than five years old from the start of the 1996-1999 Assessment. The 1996-1999 Tongue River Watershed Assessment Final Report included a comprehensive compilation of known water quality data for the watershed and contained historical and current data through 1999 (SCCD, 2000). Data collected by SCCD, government agencies, and various other sources were provided in tabular form and are not repeated in this document.

Summaries of current water quality data collected after the 1996-1999 Assessment were provided in the reports for the 2003, 2006, 2010, and 2013 interim monitoring (SCCD, 2004, 2007, 2012, and 2015). USGS collected water quality and/or discharge data from seven stations within the expanded watershed boundary through 2016 (Table 3-1). Among other things, the USGS collected temperature, pH, dissolved oxygen, specific conductivity, and flow throughout the period (Appendix Tables C-17 through C-20). USGS did collect water quality samples for other parameters, but they are not included here. It was not the purpose of the interim monitoring to conduct a comprehensive review of data from other sources.

Table 3-1. Active USGS stations in the Tongue River watershed project area during 2016.

Site ID	Drainage Area (miles^2)	"Real-time: Current Observations	Field Lab Water Quality Samples	Daily/Monthly/Annual Statistics
06306300 Tongue River, at State Line Near Decker, MT	1451	10/1994-Cirremt Discharge Conductivity	10/16/1985- Current	7/1960-Current Discharge Conductance SAR
06306250 Prairie Dog Creek, Near Acme, WY	358	6/15/2000-6/30/2016 Discharge Conductivity SAR	6/23/1986-6/24/2016 Field Discharge 5/15/2000-7/7/2016	10/1970-6/2016 Temperature Discharge Conductance SAR
06305700 Goose Creek Near Acme	413	10/01/1990-Current Discharge	10/1983-8/2008 Field Discharge 5/1984-10/2017	5/1984-Current Discharge
06299980 Tongue River, at Monarch, WY	478	5/1/2004-Current Discharge Conductivity	4/3/1974-Current	5/2004-Current Discharge Conductance SAR
06306020 Tongue River BL Youngs Creek, NR Acme	Not identified		3/26/2009- 6/24/2016	
06298000 Tongue River Near Dayton, WY	206	9/1987-Current Discharge	10/10/1966- 08/14/2002	11/1918-Current Discharge
06297500 Highline Ditch near Dayton	NA	10/1996-Current Discharge	Field Discharge 9/1979-Current	6/1920-Current Discharge

USGS has not reported any field/laboratory data from Station No. 06298000 (Tongue River Near Dayton) since August 2002; discharge information from this station is included in this report. USGS Station 06297500 Highline Ditch near Dayton, which collected discharge information, is not located on one of the contributing tributaries or mainstem of the Tongue River. Therefore, no information from this station is included in this report. Station 06305700 (Goose Creek near Acme) has intermittently collected hydrologic information since 1983; “real-time” flow observations began again in June 2015.

CHAPTER 4 MONITORING DESIGN

4.1 KEY PROJECT PERSONNEL AND RESPONSIBILITIES

This project involved various individuals from the SCCD, NRCS, WDEQ, and others (Table 4-1). The District Manager served as the Project Coordinator and Field Supervisor and was responsible for the implementation of the Quality Assurance/Quality Control (QA/QC) procedures. The Program Specialist was responsible for data entry and initial QA/QC procedures through mid-July 2016. These duties were assumed by the Program Assistant after that time. Other SCCD Supervisors and NRCS personnel assisted with the project as needed. WDEQ provided assistance and oversight as well as administration of the funds provided through Section 319 of the Clean Water Act. Progress updates were provided to the SCCD Board of Supervisors, steering committee, and cooperating stakeholders and landowners who provided site access for sampling and other information.

Table 4-1. Key personnel and organizations involved in the project

Personnel/Organization	Project Role
Carrie Rogaczewski, District Manager	Project management/oversight; field monitoring; QA/QC protocol and oversight; data validation; reporting
Amy Doke, Program Specialist	Assistance with field data collection, data management, QA/QC protocols, and reporting through July 2016
Theresa Shaw, Program Assistant	Assistance with field data collection, data management, QA/QC protocols, and reporting after July 2016
SCCD Board of Supervisors	Project review; field monitoring assistance
NRCS Sheridan Field Office Staff	Field monitoring assistance
Wyoming Department of Environmental Quality	Project review; QA/QC review; report review, funding administration
Inter-Mountain Laboratories	Laboratory analyses of water quality samples
Aquatic Assessments, Inc.	Macroinvertebrate sample sorting and midge identification; macroinvertebrate data interpretation
Aquatic Biology Associates	Macroinvertebrate sample identification and analyses
Landowners/ Steering Committee	Project and data review; sampling access

4.2 MONITORING PARAMETERS

Water quality parameters monitored in 2016 included: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli* bacteria. Monitoring was performed at 13 stations; six sites on the mainstem of the Tongue River and seven sites on the major tributaries (Appendix A-1). Samples were collected 5 times in May-July and 5 times in July-September. Continuous data loggers recorded water temperature at five stations at 15-minute intervals from May through November. Macroinvertebrate sampling and habitat assessments were performed at five mainstem stations in September-October.

4.3 SITE DESCRIPTIONS

Sites were selected based on a review of the historical data, historical SCCD sampling sites, availability, and access (Table 4-2). During the initial site reconnaissance and site set-up SCCD identified land uses and other site characteristics. Considerations for site selection included the ability to reveal types and regions of non-point source pollution at a level that would optimize landowner participation in the watershed planning process and would allow SCCD to direct remediation assistance in the most cost-effective and environmentally sound ways.

All of the sites used in this project were previously monitored in the 1996-1999 assessment and/or subsequent monitoring years. In total, there were 13 water quality sampling stations; six sites on the mainstem of the Tongue River and seven tributary stations. These seven tributaries include Smith Creek, Little Tongue River, Columbus Creek, Five Mile Creek, Wolf Creek, Goose Creek and Prairie Dog Creek. Macroinvertebrates were collected from five Tongue River stations. Detailed site and watershed descriptions were provided in the 1996-1999 Tongue River Assessment Final Report (SCCD, 2000) and/or subsequent SAPs and Reports.

Historically, SCCD requested and documented verbal permission to collect water quality samples and publish the data in a report. On July 1, 2012, changes to the Wyoming Public Records Act (W.S. 16-4-291 through 16-4-205) required written permission to release any information collected on agricultural operations. In addition, Wyoming Statute W.S. 6-3-414 through the 2015 Enrolled Act #61 (The Trespass Bill), requires written permission to access for the purpose of collecting data. Signed consent forms were maintained for all sample sites; all sites were accessed using public highways/roads or private driveways/parking areas where consent forms had been received.

Table 4-2. Tongue River watershed 2016 sample site descriptions

Site ID	1996-2010 Site Name	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (ft)	Land use(s)
Water Quality Stations							
TR01	____	On Tongue River, approximately 200 meters downstream of river bend off of well pad road from County Road 1211	4983391N 0356301E	44.989417N 106.822851W	100901010407 Beatty Gulch-Tongue River	3,435	Cattle grazing, irrigated haylands, and wildlife habitat.
PD01	____	On Prairie Dog Creek approximately 150 meters downstream USGS station 06306250.	4982905N 0354974E	44.984773N 106.839612W	100901010307 Lwr Prairie Dog Creek	3,484	Cattle grazing, irrigated haylands, and wildlife habitat.
TR03	____	On Tongue River, approximately 20 meters downstream of Hwy 338 bridge crossing	4978645N 0346783E	44.944777N 106.941805W	100901010407 Beatty Gulch-Tongue River	3,544	Primarily wildlife habitat. Winter cattle grazing only.
GC01	____	On Goose Creek between USGS Station No. 06305700 and HWY 339 bridge crossing.	4971855N 0343017E	44.882964N 106.987587W	100901010109 Soldier Creek-Goose Creek	3,630	Cattle grazing, irrigated hayland, and wildlife habitat. Parallel to railroad.
TR05	TR1	On Tongue River at Kleenburn Road Recreational Picnic Area approximately 0.7 miles downstream of USGS Station 06306250	4974512N 0341266E	44.906308N 107.010622W	100901010211 Slater Creek-Tongue River	3,595	Primarily wildlife habitat. Reclaimed mining lands made into recreational picnic area.
TR07	TRL	On Tongue River, approximately 3 meters downstream of the Ranchester Water Treatment Plant intake	4974826N 0329210E	44.9063314N 107.163592W	100901010210 Five Mile Creek-Tongue River	3747	Urban: Ranchester City limits. Site of City water intake.
WC01	WCL	On Wolf Creek, upstream of the County Road 67 bridge crossing	4973980N 0328613E	44.898278N 107.172225W	100901010209 Lower Wolf Creek	3763	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
FMC01	FMCL	On Five Mile Creek upstream of the Hwy 14 Bridge in Ranchester	4975024N 0328635E	44.908068N 107.170918W	100901010210 Five Mile Creek-Tongue River	3748	Urban, Ranchester City limits. Rural residential livestock.
TR08	TRM	On Tongue River, downstream of the Halfway Lane County Road bridge	4973244N 0325508E	44.891483N 107.209832W	100901010210 Five Mile Creek-Tongue River	3778	Cattle grazing, irrigated haylands, and wildlife habitat. Some rural residential.
CC01	CCL	On Columbus Creek downstream of the Hwy 14 bridge crossing	4973511N 0323346E	44.892859N 107.237026W	100901010207 Columbus Creek-Tongue River	3707	Cattle grazing, feedlot, irrigated hay and wildlife.

Table 4-2 (continued). Tongue River Watershed 2016 Monitoring Sample Site Descriptions

Site ID	1996-2010 Site Name	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (ft)	Land use(s)
LTR01	LTRL	On Little Tongue River, approximately 300 meters upstream of Tongue River confluence	4971707N 0321031E	44.877175N 107.265394W	100901010206 Little Tongue River	3726	Urban: Dayton city limits. Occasional wildlife habitat.
SC01	SCL	On Smith Creek downstream of County Road 92 bridge crossing	4971970N 0321164E	44.878043N 107.268177W	100901010207 Columbus Creek-Tongue River	3885	Urban: Dayton city limits.
TR09	TRU	At the USGS Station No. 06298000	4968747N 0317895E	44.849105N 107.304038W	100901010205 Sheep Creek-Tongue River	4060	Primarily wildlife habitat. Recreational camping. Parallel to County Road.
Macroinvertebrate Stations							
TR01	____	On Tongue River, approximately 50 meters downstream of river bend off of well pad road from County Road 1211	4983391N 0356301E	44.989417N 106.822851W	100901010407 Beatty Gulch-Tongue River	3,435	Cattle grazing, irrigated haylands, and wildlife habitat.
TR03	____	On Tongue River, approximately 500 meters upstream of Hwy 338 bridge crossing	4978650N 0346809E	44.944778N 106.941806W	100901010407 Beatty Gulch-Tongue River	3,530	Primarily wildlife habitat. Winter cattle grazing only. BLM recreation area.
TR05	TR1	On Tongue River at Kleenburn Road Recreational Picnic Area approximately 0.7 miles downstream of USGS Station 06306250	4974512N 0341266E	44.906308N 107.010622W	100901010211 Slater Creek-Tongue River	3,595	Primarily wildlife habitat. Reclaimed mining lands made into recreational area.
TR07	TRL	On Tongue River upstream County Road bridge crossing	4974822N 0329198E	44.9063314N 107.163592W	100901010210 Five Mile Creek-Tongue River	3750	Wildlife habitat, irrigated haylands, rural residential.
TR09	TRU	On Tongue River at USGS Station No. 06298000	4968747N 0317895E	44.849105N 107.304038W	100901010205 Sheep Creek-Tongue River	4060	Primarily wildlife habitat. Recreational camping. Parallel to County Road.

4.4 Sampling and Analysis Methods

Water quality sample collection, discharge measurements, macroinvertebrate sampling, and habitat assessments were performed according to the methods described in the project Sampling Analysis Plan (SCCD, 2016) and the SCCD Water Quality Monitoring Program Quality Assurance Project Plan, 2015 Update (SCCD, 2015a), according to the WDEQ Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ, 2015) and accepted analytical methods (Table 4-3). Samples were obtained from representative riffles.

Table 4-3. Standard field and laboratory methods applicable to 2016 monitoring

Parameter	Units	Method / Reference[1,2]	Location of Analyses	Preservative	Holding Time
Temperature	ºC	grab/USEPA 170.1 SM2550	On-site	n/a	n/a
Temperature	ºC	continuous recorder	On-site	n/a	n/a
pH	SU	grab/USEPA 150.2	On-site	n/a	n/a
Conductivity	µS/cm	grab/USEPA 120.1	On-site	n/a	n/a
Dissolved Oxygen-Probe	mg/l	grab/USEPA 360.1	On-site	n/a	n/a
E. coli	col/100 ml	grab/SM9223B, CFR136[3]	IML[4]	Cool to 10°C	8 hours
Turbidity	NTU	grab/ SM2130	IML[4]	Cool to 6°C	48 hours
Stage Height	cfs	Calibrated staff gauge	On-site	n/a	n/a
Discharge	cfs	Mid-Section Method	On-site	n/a	n/a
Macroinvertebrates	Metrics	King 1993	AA[5] ABA[6]	99% ethyl alcohol or isopropanol	n/a
Habitat (Reach level)	n/a	King 1993	On-site	n/a	n/a

[1]USEPA Method references from Methods for Chemical Analysis of Water and Wastes (USEPA, 1983)
[2] SM Method references from Standard Methods for the examination of water and wastewater (APHA, 1998 & 2005).
[3] CFR reference from 40 CFR Part 136. Guidelines Establishing Test Procedures (Federal Register, 2012)
[4]IML refers to Inter-Mountain Laboratories in Sheridan, Wyoming.
[5]AA refers to Aquatic Assessments, Inc. in Sheridan, Wyoming.
[6]ABA refers to Aquatic Biology Associates, Inc. in Corvallis, Oregon.

Sample sites were equipped with a staff gauge for flow measurements. Initially, two sample sites were already equipped with USGS gauges (station 06298000 in Tongue River Canyon and 06306250 on Prairie Dog Creek). The USGS gauge on Prairie Dog Creek was scheduled to be discontinued in July 2016 and a staff gauge was installed. During site reconnaissance, staff gauges were inspected, surveyed, and replaced if needed. Upon installation and/or inspection, gauges were surveyed and compared with a permanent bench mark; this confirmed the stability of the gauge to ensure consistent measurement. Staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter using the mid-section method (WDEQ, 2015). The resulting stage-discharge relationships were used to estimate flow during sampling events.

Grab samples for *E. coli* and turbidity were collected within two separate 60-day periods in May-July and July-September. Gauge height, pH, conductivity, dissolved oxygen, and instantaneous water temperature were also measured during these sampling events. Continuous temperature data were collected by anchoring data loggers to the bottom of the staff gauges and downloading the recorded information. Benthic macroinvertebrates were collected and habitat assessments were performed at five stations in September.

Sample containers for bacteria and turbidity were provided by the contract laboratory and left unopened until sample collection. Bacteria containers were sealed, clear, cylindrical, IDEXX bottles that contained the sample preservative. The turbidity containers were 125 mL plastic, opaque bottles. All containers had blank labels, which were completed in the field. Containers for macroinvertebrate samples were 32 oz, pre-cleaned, HDPE wide mouth bottles. Labels were completed and affixed in the field with packing tape.

Turbidity and *E. coli* samples were hand delivered to Inter-Mountain Laboratories (IML) in Sheridan, Wyoming for analysis. Macroinvertebrate samples were sorted by Aquatic Assessments, Inc. (AA) in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon.

4.5 Monitoring Schedule

The 2016 monitoring schedule included sampling to determine the geometric means of *E. coli*, based on 5 samples collected within a 60-day period in May-July and 5 samples collected within a 60-day period in July-September (Table 4-4). Other field water chemistry parameters were also measured. A total of ten water quality samples were collected at each site.

Sample dates were based on random numbers generated for Monday-Thursday due to lab availability and sampling holding times. Continuous temperature data loggers were deployed to measure instream temperatures from May 18th through October 3rd. Macroinvertebrate collections and habitat assessments were completed in September-October.

Table 4-4. Sample schedule for 2016 Tongue River watershed monitoring

<table>
<tr><th>Date(s)</th><th>Sites</th><th>Parameters</th></tr>
<tr><td>May 18th – October 3rd</td><td>TR01, TR03, TR05, TR07, TR09</td><td>Continuous Temperature</td></tr>
<tr><td>May 18th</td><td rowspan="5">TR01, TR03, TR05, TR07, TR08, TR09, PD01, GC01, WC01, FMC01, CC01, SC01, LTR01</td><td rowspan="5">Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/Discharge, Turbidity, and E. coli.

*Early Season upstream and downstream photos were taken on 6/13/16</td></tr>
<tr><td>May 31st</td></tr>
<tr><td>*June 13th</td></tr>
<tr><td>June 27th</td></tr>
<tr><td>July 13th</td></tr>
<tr><td>July 28th</td><td rowspan="5">TR01, TR03, TR05, TR07, TR08, TR09, PD01, GC01, WC01, FMC01, CC01, SC01, LTR01</td><td rowspan="5">Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/Discharge, Turbidity, and E. coli.

*Late Season upstream and downstream photos were taken on 8/10/16</td></tr>
<tr><td>*August 10th</td></tr>
<tr><td>August 22nd</td></tr>
<tr><td>September 7th</td></tr>
<tr><td>September 20th</td></tr>
<tr><td>September 22nd – October 4th</td><td>TR01, TR03, TR05, TR07, TR09</td><td>Macroinvertebrates, Habitat, Photo</td></tr>
</table>

CHAPTER 5 QUALITY ASSURANCE/QUALITY CONTROL

5.1 FUNCTION OF QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance (QA) may be defined as an integrated system of management procedures designed to evaluate the quality of data and to verify that the quality control system is operating within acceptable limits (Friedman and Erdmann, 1982; USEPA, 1995). Quality control (QC) may be defined as the system of technical procedures designed to ensure the integrity of data by adhering to proper field sample collection methods, operation and maintenance of equipment and instruments. Together, QA/QC functions to ensure that all data generated are consistent, valid and of known quality (USEPA, 1980). QA/QC should not be viewed as an obscure notion to be tolerated by monitoring and assessment personnel, but as a critical, deeply ingrained concept followed through each step of the monitoring process. Data quality must be assured before the results can be accepted with any scientific study. Project QA/QC is fully described in the SCCD QAPP (SCCD, 2015a) and the Project SAP (SCCD, 2016).

5.2 SAMPLING PERSONNEL QUALIFICATIONS

Water quality monitoring, data management, and reporting were performed by SCCD personnel, which had the appropriate training and qualifications to implement the project (Table 5-1). SCCD Supervisors and NRCS Field office staff assisted with site set-up, surveys, discharge measurements, water quality monitoring, and macroinvertebrate collection. During monitoring activities, SCCD personnel collected the samples/measurements, while the other staff recorded the information on the appropriate data sheets. Assisting personnel were under the direct supervision of SCCD staff. The SAP defined all necessary field protocols and was available to the sampling team for every sampling event.

Table 5-1. SCCD sampling personnel and qualifications

Personnel	Qualifications
Carrie Rogaczewski District Manager	M.S. University of Wyoming in Rangeland Ecology and Watershed Management with an emphasis in Water Resources; BKS Environmental; 17+ years of experience with the SCCD; WACD Water Quality training
Amy Doke Program Specialist	B.A. University of Wyoming in Environment and Natural Resources with an emphasis in international studies and ecology; 10+ years of experience with SCCD, assisting in other watershed efforts
Theresa Shaw Program Assistant	B.S. Montana State University in Sociology, Social and Criminal Justice; United States Air Force Special Investigations Officer and Special Agent; joined SCCD in August 2016 and under supervision of District Manager

5.3 SAMPLE COLLECTION, PRESERVATION, ANALYSIS, AND CUSTODY

Accepted referenced methods for the collection, preservation and analysis of samples were adhered to as described in the SAP. In addition to field data sheets, samplers carried a field log book to document conditions, weather, and other information for each sample day and/or site. Calibration logs were completed for each instrument every time a calibration was performed.

Project field measurements were recorded on field data sheets. Water samples requiring laboratory analysis were immediately preserved (if required), placed on ice, and hand delivered to the laboratory. A Chain of Custody (COC) form was prepared and signed by the sampler before samples entered laboratory custody. A laboratory employee would then sign and date the COC form after receiving custody of the samples. After samples changed custody, laboratory internal procedures were implemented according to their Quality Assurance Plans.

Benthic macroinvertebrate samples were preserved in the field, placed in a cooler, and transported to the SCCD office in Sheridan. A project specific macroinvertebrate COC form was completed. After all macroinvertebrate samples were collected, samples and COC forms were hand delivered to the contractor for initial sorting. COC forms were signed by SCCD and the contractor receiving the samples. Sorted samples, COC forms, and lab bench sheets were hand delivered to SCCD and then shipped to the contract laboratory for identification. Upon receipt, the contract laboratory performed a visual check for the number and general condition of samples, and signed the COC form. The completed COC form was returned to SCCD.

5.4 Calibration and Operation of Field Equipment

The project SAP outlined requirements for calibration and maintenance of field equipment; calibration instructions and manuals were carried on sampling days. On every sampling day, before leaving the office, the pH meter, conductivity meter, and dissolved oxygen meter were calibrated according to the manufacturer's instructions. The Hanna 9025 pH meter was calibrated using a two-point calibration method with pH 7.01 and pH 10.01 buffer solutions. The Hanna 9033 conductivity meter was calibrated using a 1413 µS/cm calibration standard. All calibration solutions were discarded after each use. The YSI Pro20 dissolved oxygen meter did not require a calibration solution; the meter was calibrated by inserting the probe into the moist calibration chamber. The barometric pressure on the meter was cross referenced to the barometric pressure at the Sheridan County airport to check calibration accuracy. Calibration of each meter was documented on the corresponding calibration logbook.

The Marsh-McBirney flow meter was factory calibrated and did not require field calibration; however, SCCD conducted a "zero check" prior to the beginning of the field season using a five-gallon plastic bucket of water. However, the meter began to malfunction and provide erratic readings in September. Another Marsh McBirney flow meter was obtained from the Sheridan WDEQ field office for some of the final discharge calibrations and velocity measurements during macroinvertebrate sample collection. Factory calibration of Onset HOBO data loggers, used for continuous temperature monitoring, was checked by performing a crushed-ice test at the beginning and end of the season to validate the loggers' accuracy.

Equipment used for benthic macroinvertebrate sample collection and reach level habitat assessments did not require calibration; however, surber sampler nets and other equipment were checked for damage prior to entering the field. Equipment maintenance, to include replacement of the dissolved oxygen meter membrane cap before each sampling day and battery replacement as needed, was performed according to the SAP and manufacturer's instructions. All maintenance activities were documented on the maintenance log.

5.5 SUMMARY OF QA/QC RESULTS

Data Quality Objectives (DQO's) are qualitative and quantitative specifications used by water quality monitoring programs to limit data uncertainty to an acceptable level. DQO's were established for each monitoring parameter for precision, accuracy, and completeness at levels sufficient to allow SCCD to realize project goals and objectives (Table 5-2). SCCD evaluated collected data according to the DQOs in the SAP (SCCD, 2016) and WDEQ protocols (WDEQ, 2015).

Table 5-2. Data Quality Objectives for 2016 Tongue River watershed monitoring (SCCD, 2016)

Parameter	Precision (%)		Accuracy** (%)	Completeness (%)	Minimum Detection Limit
	SCCD*	WDEQ*			
Temperature	10	10	10	95	0.2 ^{O}C
pH	5	±0.3 SU	5	95	0.01 S.U.
Conductivity	10	10	10	95	1 µS/cm
Dissolved Oxygen	20	10	20	95	0.2 mg/L
Turbidity	20	20	10	95	0.1 NTU
E. coli	50	50 if >100 NA if <100	NA	95	1 CFU/100 mL
Macroinvertebrates	NA		NA	95	NA
Total Taxa	15		NA	95	NA
Total Abundance	50		NA	95	NA
Habitat Assessment	NA		NA	95	NA
Intra-Crew	15		NA	10	NA
Discharge	NA		NA	95	NA
Stage-Discharge Relationships	NA		NA	95	Minimum r^2 = 0.95

** SCCD Precision DQOs were from the Tongue River 2016 Sampling Analysis Plan and the SCCD Quality Assurance Project Plan, 2015 update; WDEQ precision DQOs were from the 2015 Manual of Standard Operating Procedures.*
*** Accuracy values shown are acceptable departures from 100% accuracy. A 10 percent accuracy value means accuracy values of 90 to 110 percent are acceptable.*

5.5.1 *COMPARABILITY*

Comparability refers to the degree to which data collected during this Project were comparable to data collected during other past or present studies. This was an important factor because future water quality monitoring will occur within the watershed and current project data must be comparable to future data in order to detect water quality change with confidence. Recognizing that periodic adjustments to locations, parameters, and/or sampling methods are needed, several steps were taken to assure data comparability including:

- Collection of samples at previously used monitoring stations;
- Collection of samples during the same time of year;
- Collection of samples using the same field sampling methods and sampling gear;
- Analysis of samples using the same laboratory analytical methods and equipment;
- Use of the same reporting units and significant figures;
- Use of the same data handling and reduction methods (rounding and censoring); and
- Use of similar QA/QC processes.

Chemical, physical, biological, and habitat data collected during this project were highly comparable because of close coordination prior to initiation of sampling. Where possible, each step identified above was implemented to assure comparability.

Prior to 2014, *E. coli* standards were based on a geometric mean of 5 samples collected within a 30-day period. SCCD collected water quality parameters on the same schedule as the *E. coli* samples; 5-sample geometric means were calculated for all water quality parameters for the 30-day periods. During revisions to water quality standards and methods in 2014, WDEQ changed the basis for the *E. coli* standard to a geometric mean of 5 of more samples collected within a 60-day period (WDEQ, 2014). As a result, SCCD incorporated 60-day geometric means into the 2016 schedule. Comparisons among years are still valuable for evaluating water quality trends; both the 30-day geometric means and the 60-day geometric means capture samples collected during early season (May-June/July) and late season (July-August/September) conditions.

5.5.2 Continuous Temperature Data Loggers

The continuous temperature data loggers, Onset's HOBO Pendent Temperature 64 Data Logger, were used at TR01, TR03, TR05, TR07, and TR09 during the 2016 monitoring project. These loggers were factory calibrated, encapsulated devices that cannot be re-calibrated.

To verify the accuracy of the factory calibration, SCCD performed a crushed-ice test before and after the sampling season. A seven-pound bag of crushed ice was emptied into a 2.5 gallon bucket. Distilled water was added to just below the top level of the ice and the mixture was stirred. The data loggers were submerged in the bath and placed in a refrigerator to minimize temperature gradients. If the ice bath was prepared properly and if the loggers maintained their accuracy, the loggers should read the temperature of the ice bath as 0°C ±0.232°C. The pre-season ice bath temperature on 4/5/2016 was reported to be between 0.01°C to 0.232°C, which was within the manufacturer's predicted range. The post-season ice bath temperature on 12/15/2016 also reported temperatures between 0.1°C to 0.232°C (Appendix Table B-3).

Onset suggests the loggers should maintain their accuracy unless they have been utilized outside their range of intended use (-20°C to 50°C). None of the data loggers were used outside of this range and returned the expected results in the crushed ice tests. All of the temperature loggers were considered to have maintained their accuracy and have provided valid water temperature data for the 2016 monitoring project.

5.5.3 Stage-Discharge Relationships

The relationship between stage height and discharge for a given location yields an equation that allows the calculation of discharge at various stage heights recorded on a staff gauge. A correlation coefficient (R^2 value) of at least 0.95 (95%) is desirable for proper calibration of the gauge. Stage-discharge relationships were established for all staff gauges installed by SCCD (Table 5-3). These relationships were developed by recording the stage height and measuring discharge using the mid-section method (WDEQ, 2015) on at least three occasions with varying flow conditions.

Staff gauges installed by SCCD were surveyed against established benchmarks upon installation and at the end of the season. The difference between the height of the gauge and the height of the benchmark were compared to verify gauge stability (Table 5-3).

Table 5-3. Summary of R^2 values for 2016 stage-discharge relationships

Site	Pre-Season Survey	Post-Season Survey	Pre/Post Survey Difference	Stage-Discharge Relationship R^2 Value
TR01	1.24	1.24	0.00	0.9775
PD01	6.09	6.08	0.01	0.9931
TR03	7.81	7.82	0.01	0.9988
GC01	1.96	1.98	0.02	0.9999
TR05	8.05	8.04	0.01	0.9992
TR07	1.53	1.53	0.00	0.9643
WC01	6.04	6.04	0.00	1.0000
FMC01	1.18	1.18	0.00	0.9926
TR08	4.84	4.84	0.00	0.9987
CC01	3.95	3.98	0.03	***0.9383***
LTR01	2.70	2.70	0.00	0.9995
SC01	3.40	3.42	0.02	0.9877
TR09	NA-USGS	NA-USGS	NA-USGS	NA-USGS

A gauge was not installed at TR09; flow information was obtained from USGS Station 06298000. None of the gauge surveys resulted in differences greater 0.05 between the pre-season and post-season surveys. Only CC01 had a coefficient value (0.9383) below the DQO of 0.95. Because the value approached the DQO and represented the best, and in some cases the only, flow information available, the value was used in the calculation of summary statistics and in the development of load estimates, where appropriate.

5.5.4 Blanks

Trip blanks were prepared to determine whether samples might be contaminated by the sample container, preservative, or during transport and storage conditions. One blank for every 10 samples for each parameter is required. Two *E. coli* and turbidity trip blanks were prepared for every sampling event. Prior to sampling, the contract laboratory filled sample containers with laboratory de-ionized water and the appropriate preservative. The trip blanks were maintained in the cooler with the collected samples and returned to the laboratory for analysis. No trip blanks used during the project contained detectable levels of *E. coli* or turbidity (Appendix Table B-4).

Field blanks were prepared to determine whether samples might be contaminated by conditions associated with sample collection procedures. One blank for every 10 samples for every parameter is required. *E. coli* and turbidity field blanks were prepared at two separate sites during every sampling event. At the designated sites, sample bottles were labeled, rinsed (if turbidity), and filled with de-ionized water provided by the contract laboratory. The bottles were then placed in the cooler and delivered to the contract laboratory with the other samples. No field blanks prepared during the project contained detectable levels of *E. coli*; one sample had a turbidity value of 0.6

NTU (Appendix Table B-4). Because the value approached the detection limit and the other blank sample for the day was below the detection limit, all bacteria and turbidity results were accepted.

5.5.5 *Sample Holding Times*

All laboratory data sheets were reviewed to ensure all samples were analyzed before their holding times had expired. This review found that all *E. coli* samples were analyzed within their required 8-hour holding time and all turbidity samples were analyzed within the required 48 hour holding time. All water quality field samples were analyzed on-site immediately following sample collection. Benthic macroinvertebrate samples were preserved on-site upon sample collection; there is no holding time for benthic macroinvertebrate samples.

5.5.6 *Duplicates*

The project SAP specified that duplicate chemical, physical, biological, and habitat samples be obtained for at least 10% of all field samples. Duplicate water quality samples were obtained by collecting consecutive water quality samples from a representative stream riffle. Duplicate macroinvertebrate samples were collected by two field samplers, each equipped with a surber net, collecting samples simultaneously and adjacent to one another. Intra-crew habitat duplicates were conducted simultaneously by each observer performing independent assessments without communication, at the same site and same time. All DQOs for duplicates were met (Table 5-4).

Table 5-4. Summary of 2016 Tongue River watershed monitoring duplicates

Parameter	No. of samples	No. of Duplicates	% Duplicated	DQO (%)
Water Quality Samples in 2016 (13 sites X 10 samples)	130	20	15.4	10
Macroinvertebrate Samples in 2016	5	1	20.0	10
Habitat Assessments in 2016	5	1	20.0	10

5.5.7 *Precision*

Precision was defined as the degree of agreement of a measured value as the result of repeated application under the same condition. The Relative Percent Difference (RPD) statistic was used, because the determination of precision is affected by changes in relative concentration for certain chemical parameters. Precision was determined for water quality samples by conducting duplicate samples at 10 percent of the sample sites. RPD is calculated by the formula: $RPD = [(A-B) / (A+B)] X 200$ where A is the value for duplicate 1 and B is the value for duplicate 2. With few exceptions, all parameters met the DQO's for precision (Table 5-5).

Table 5-5. Precision of 2016 Tongue River Watershed water quality monitoring data

Date	Duplicate Sample ID	Site Duplicated	TEMP RPD (%)	pH RPD (%)	COND RPD (%)	DO mg/L RPD (%)	DO % RPD (%)	TURB RPD (%)	E. coli RPD (%)
SCCD DQO Relative Percent Difference:			**10**	**5**	**10**	**20**	**20**	**20**	**50**
WDEQ DQO Relative Percent Difference or Other:			**10**	**±0.3SU**	**10**	**10**	**10**	**20**	**50 if >100 NA if <100**
5/18/16	Dup1	TR01	1.5	1.5	2.3	ND	ND	***79.0***	36.2
	Dup2	TR09	1.1	0.0	9.5	ND	ND	***20.7***	***66.7 <100***
5/31/16	Dup1	PD01	0.8	0.1	1.8	0.2	0.2	7.7	15.6
	Dup2	SC01	0.0	0.2	0.0	0.3	0.2	4.2	***77.5***
6/13/16	Dup 1	TR03	0.6	0.1	8.9	0.2	0.1	9.8	48.0
	Dup2	LTR01	0.6	0.0	1.3	0.8	0.7	3.8	21.6
6/27/16	Dup 1	GC01	0.5	0.2	0.2	1.0	0.7	14.0	42.1
	Dup 2	CC01	0.5	0.2	0.4	0.5	0.3	***32.0***	11.5
7/13/16	Dup 1	TR05	0.5	0.1	0.8	1.1	1.1	7.7	0.0
	Dup 2	TR08	0.0	0.1	1.4	0.6	0.6	8.0	9.0
7/28/16	Dup 1	TR07	0.0	0.2	0.5	2.6	1.9	2.7	***59.3***
	Dup 2	FMC01	0.0	0.3	1.7	***14.6***	***17.4***	***111.6***	7.5
8/10/16	Dup 1	WC01	0.5	0.2	0.2	0.4	0.1	0.0	18.3
	Dup 2	TR09	0.5	0.6	1.3	2.7	2.0	0.0	35.9
8/22/16	Dup 1	TR01	0.5	0.0	0.1	0.7	0.4	0.8	25.7
	Dup 2	SC01	1.9	0.1	2.1	1.3	0.9	3.4	10.7
9/7/16	Dup 1	PD01	0.6	0.1	0.3	0.3	0.2	4.3	17.1
	Dup 2	LTR01	0.7	0.1	1.2	0.6	0.5	9.5	7.3
9/20/16	Dup 1	TR03	0.6	0.5	0.8	1.0	1.0	8.0	***66.7<100***
	Dup 2	CC01	0.7	0.1	0.0	0.8	0.7	8.6	11.1
AVERAGE RPD FOR ALL SAMPLES			*0.61*	*0.25*	*1.73*	*1.64*	*1.61*	*16.79*	*29.04*

All temperature, pH, and conductivity samples met the appropriate DQO for precision. In addition to meeting the DQO of 5% RPD, all pH samples were within ±0.3 SU as required by WDEQ. One dissolved oxygen measurement (mg/L and percent saturation) exceeded the WDEQ precision DQO of 10% on 7/28/16. These samples were within the SCCD DQO of 20% and the other duplicate sample for the day was within 10%. All reported dissolved oxygen measurements, based on RPD, were accepted. However, all dissolved oxygen measurements from 5/18/16, including duplicates, were discarded because of meter malfunction.

Four turbidity samples exceeded the DQO of 20%. Because turbidity values can be relatively low, small variations can result in high RPDs. Samples from 7/28/16 and 6/27/16 were accepted because values were confirmed by the contract laboratory and RPDs from other duplicates collected on the same day were within the DQO of 20%. Both duplicates collected on 5/18/16 exceeded 20%; however, the RPD for one of the duplicates was only slightly over 20% and was calculated on very small values (3.2 and 2.6). All turbidity sample results were accepted based on RPD.

Four *E. coli* samples exceeded the SCCD precision DQO of 50%. Two of the samples, occurring on 5/18/16 at TR09 and 9/20/16 at TR03, were calculated on reported values that were less than 100. According to WDEQ requirements, the DQO of 50% would not apply to these samples. The RPDs for the sample from TR07 on 7/28/16, which was 59.3, was calculated on one sample that was less than 100 (76 col/100 mL) and one that was above 100 (140 col/100 mL). The duplicate sample for the sample collected at SC01 on 5/31/16 was reported as >2419.6 col/100 mL, which was converted to 2420 for calculation of the RPD statistic. This was a conservative estimate and may be closer to the sample site value, which was reported as 5480 col/100 mL. In addition, the RPDs for the other duplicate samples collected on the same sample day were within the DQOs. All of the data for bacteria samples, based on RPD, were accepted.

Duplicate macroinvertebrate samples and habitat assessments were collected at greater than 10% of the macroinvertebrate and habitat assessment sites. The RPD for total macroinvertebrate abundance was 8 percent, which was within the DQO of 50 percent (Table 5.6). The RPD for total macroinvertebrate taxa was 28 percent, which exceeded the DQO of 15 percent. The higher RPD for total taxa was due primarily to the presence of 8 taxa present in the duplicate 2 sample that were not present in the duplicate 1 sample. Each of the 8 taxa present in the duplicate 2 sample was represented by a single organism (Appendix Table E-2). Although a single organism was present for each of the 8 taxa, the abundance was reported as 2 organisms in Appendix Table E- 2 after adjustment by the correction factor of 1.429. The difference in total taxa between duplicate samples based upon the presence of several taxa each represented by a single organism should be considered an anomaly especially considering the RPD for total macroinvertebrate abundance was only 8 percent. The macroinvertebrate data was determined to be valid and of known quality based upon those considerations. The RPD for the duplicate habitat assessment was 6 percent (Appendix Table D-5), which was within the established DQO of 15 percent.

Table 5-6. Precision of 2016 Tongue River benthic macroinvertebrate and habitat data

Parameter	TR01 Duplicate 1	TR01 Duplicate 2	(% - RPD)	DQO (%)
Total Abundance	997	924	8	50
Total Taxa	31	41	28	15
Intra-Crew Habitat Assessment Score	152	162	6	15

5.5.8 *Accuracy*

Accuracy is the degree of agreement of a measured value with the true or actual value. Accuracy for water quality parameters measured in the field was assured by calibration of equipment to known standards. Conductivity, dissolved oxygen, and pH meters were calibrated on the morning of every sampling event. A "crushed ice test" was used to verify the accuracy of the continuous temperature data loggers. There are no current laboratory methods to determine the accuracy of biological samples; therefore, the accuracy of *E. coli* samples could not be determined. Accuracy for macroinvertebrate sampling and habitat assessment could not be determined since the true or actual value for macroinvertebrate populations or habitat parameters was unknown. Precision served as the primary QA check for *E. coli* bacteria, benthic macroinvertebrates, and habitat assessments.

5.5.9 *Completeness*

Completeness refers to the percentage of measurements determined to be valid and acceptable compared to the number of samples scheduled for collection. This DQO is achieved by avoiding loss of samples due to accidents, inadequate preservation, holding time exceedances, and proper access to sample sites for collection of samples as scheduled. DQOs for most parameters were met with the exception of dissolved oxygen measurements (Table 5.7). The dissolved oxygen meter malfunctioned on one sample day, which resulted in all of the measurements for that day being discarded. One set of *E. Coli* and turbidity samples on Five Mile Creek were discarded because of non-representative sample conditions.

Table 5-7. Completeness of 2016 Tongue River monitoring data

Parameter	# Samples Planned	# Samples Collected	% 2016 Completeness*	DQO (%)
Water Temperature	130	130	100.0	95
pH	130	130	100.0	95
Conductivity	130	130	100.0	95
Dissolved Oxygen	130	117	90.0	95
Discharge	130	130	100.0	95
Turbidity	130	129	99.2	95
E. coli	130	129	99.2	95
Total Abundance of Marcroinvertebrates	5	5	100	95
Total Taxa	5	5	100	95
Intra-Crew Habitat Assessments	5	5	100	10

*Bold values are below the DQO's percentage.

5.6 Data Validation

Data generated by the contract laboratories was subject to the internal contract laboratory QA/QC process before it was released. Data are assumed to be valid because the laboratory adhered to its internal QA/QC plan. Field data generated by SCCD were considered valid and usable only after defined QA/QC procedures and processes were applied, evaluated, and determined acceptable. Questionable data were rechecked by the contract laboratory and either confirmed or corrected. Data determined to be invalid were rejected and not used in preparation of this report.

Low flow values and lab results reported below the detection limit were to be reported as ½ the detection limit for the purpose of summary statistics, as specified in the SAP for this project (Gilbert, 1987 and SCCD, 2016). With the exception of field and trip blanks, there were no samples reported below the detection limit in 2016. Blank data were not used in the calculation of summary statistics, so no reporting adjustments were necessary.

One *E. coli* sample from SC01 on 5/31/16 was reported as >2419.6; SCCD used 2420 for calculation of relative percent difference for precision.

5.7 Documentation and Records

All water quality field data were recorded on data sheets prepared for the appropriate waterbody and monitoring station. After each sampling day, water quality field data sheets are scanned and filed electronically on SCCD's computer; hard copies were duplicated and maintained in a binder. Macroinvertebrate and habitat assessment data were recorded onto data sheets that were in a similar format to those used by WDEQ in the past. WDEQ now uses a more comprehensive protocol for macroinvertebrate and habitat assessments, but SCCD decided to continue with their existing data sheets for consistency and simplicity. Equipment checklists, COC forms, and calibration and maintenance logs were documented on the appropriate forms and are maintained on file and/or electronically in the SCCD office. Photographs and photograph descriptions were organized by station, maintained in digital format in the SCCD office (Appendix F).

Water quality and supporting QA/QC data were received electronically from the contract laboratory. Printed hard copies are maintained on file in the SCCD office. Macroinvertebrate sample results were received from the contract laboratory electronically and printed. All electronic data are maintained in a database on the SCCD server in Sheridan, Wyoming.

5.8 DATABASE CONSTRUCTION AND DATA REDUCTION

The project database consists of a series of electronic computer files. Each project database file was constructed with reportable data (accepted after QA/QC checks) by entering into Microsoft Excel® spreadsheets. Electronic files for water quality, discharge, continuous water temperature, macroinvertebrate, and habitat data were constructed. All computer data entries were checked for possible mistakes made during data entry. If a mistake was suspected, the original field or laboratory data sheet was re-examined and the data entry corrected. SCCD also maintains an ACCESS® Database for all reportable water quality data collected by SCCD; validated data are copied into the ACCESS Database only after approval of the monitoring report by WDEQ.

After data validation and database construction, data were statistically summarized for the following calculations (Appendix C):

- Number of samples;
- Maximum;
- Minimum;
- Median;
- Mean;
- Geometric mean; and
- Coefficient of variation.

These statistics and analyses provided insight for temporal and spatial water quality changes within the watershed. Microsoft Excel® was used to generate the statistical tables, geometric means, and graphics for this report. Geometric means were calculated for all water quality parameters for three reporting periods of 60 days each, including May 18-July 13, June 13-August 10, and July 28-September 20. Summary statistics did not include discarded data or instances where the staff gauge was submerged.

5.9 DATA RECONCILIATION

Data collected by SCCD were evaluated before being accepted and entered into the project database. Obvious outliers were flagged after consideration of "expected" values based upon evaluation of historical and current data. Field data sheets were re-checked and if no calibration or field note anomalies or excursions were identified, the data were accepted as presented. Otherwise, data were rejected and not included in the project database.

5.10 Data Reporting

Data collected by SCCD for this project are presented in tabular, narrative, and graphical formats throughout this report. This report will be submitted to WDEQ and other interested parties as necessary. Copies of this report will be available through the SCCD office. Compact disks containing the Microsoft Excel®, Microsoft Word®, Adobe Reader X®, and Arc Map 10® files used to construct this document will also be available.

In addition to this report, the SCCD will submit a separate data package to WDEQ. The complete data package will include copies of all field and laboratory data sheets, field and equipment calibration logs, survey notes, and QA/QC documentation. Other information may be submitted as requested by WDEQ.

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CHAPTER 6 WATER QUALITY STANDARDS AND DISCUSSION OF RESULTS

6.1 WATER QUALITY STANDARDS

Wyoming's surface waters are protected through application of numeric and narrative (descriptive) water quality standards. The applicable water quality standards and other recommendations were used in interpretation of results and included in this report (Table 6-1).

Table 6-1. Standards applicable for 2016 Tongue River watershed monitoring (WDEQ, 2013)

NUMERIC STANDARDS		
Parameter	**Reference**	**Standard / Description**
Dissolved Oxygen	Chapter 1 Sections 21 & 30 Appendix D	For Class 1, 2AB, 2B, and 2C waters 1 day minima Early life stages: 5.0 mg/L intergravel concentration 8.0 mg/L water column Other life stages: 4.0 mg/L
E. coli	Chapter 1 Section 27	Geometric mean of a consecutive 60 day period shall not exceed 126 organisms per 100 ml for primary contact recreation waters/seasons (May 1-Sept 30) and shall not exceed 630 organisms per 100 ml for secondary contact recreation waters/seasons.
pH	Chapter 1 Sections 21 & 26 Appendix B	6.5-9.0 standard units
Temperature	Chapter 1 Section 25	Discharge shall not increase temperature by more than 2 degrees F; maximum allowable temperature is 68 degrees F/20 degrees C (cold water fisheries) except on Class 2D, 3 and 4 waters.
Turbidity	Chapter 1 Section 23	For cold water fisheries and drinking water supplies, discharge shall not create increase of 10 NTU's.
NARRATIVE STANDARDS		
Settleable Solids	Section 15	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or plant and wildlife.
Floating and Suspended Solids	Section 16	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or plant and wildlife.
Taste, Odor, Color	Section 17	Substances shall not be present in quantities that would produce taste, odor, or color in: fish flesh, skin, clothing, vessels, structures, or public water supplies.
Macroinvertebrates	Chapter 1 Section 32 Hargett (2011)	Score for Full, Indeterminate, or Partial/Non Support *Sedimentary Mountains Bioregion: >52.3, 34.8-52.3; <34.8;* *High Valleys Bioregion: >48.8, 32.5-48.8, <32.5;* *Northeast Plains Bioregion: >58.4, 38.9-58.4, <38.9*
ADDITIONAL PARAMETERS AND RECOMMENDED STANDARDS		
Habitat	King (1993); Stribling et al. (2000)	Habitat condition no less than 50 percent of reference; total habitat score >100 to qualify as reference
Conductivity	King (1990)	Concentrations greater than 6900 µmhos/cm may affect aquatic organisms in ponds in NE Wyoming.

6.2 Field Water Chemistry and Physical Parameters

Water quality data were collected from May 18 through September 20, 2016 at 13 stations (Appendix Tables C-3 through C-15). Summary statistics were calculated for all instantaneous monitoring parameters on accepted data (Appendix Table C-16). Geometric means for three 60-day periods were calculated for bacteria samples; arithmetic means for all other parameters were established for the same 60-day periods as well as for the season.

In addition, USGS collected water quality data from four stations from 2013-2016:

- Station 06306300 Tongue River at State Line Near Decker, MT;
- Station 06306250 Prairie Dog Creek, Near Acme, WY;
- Station 06306020 Tongue River Below Youngs Creek Near Acme, WY; and
- Station No. 06299980, Tongue River near Monarch, WY.

For the most part, measurements were collected monthly from USGS Station 06299980 (Tongue River at Monarch), USGS 06306020 (Tongue River Below Youngs Creek) and USGS Station 06306250 (Prairie Dog Creek) and anywhere from zero to two times per month from USGS station 06306300 (Tongue River Near State Line). Among other things, the USGS collected temperature, pH, dissolved oxygen, specific conductivity, nutrients, and metals throughout the period. For these stations, only data similar in scope to the parameters collected by SCCD during 2016 are discussed.

6.2.1 Instantaneous Water Temperature

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at 12 of the 13 sites on at least one occasion (Table 6-2). The uppermost station (TR09) had a maximum instantaneous temperature of 18.6°C. Instantaneous temperature measurements do not necessarily represent daily minimum, maximum, or average water temperatures.

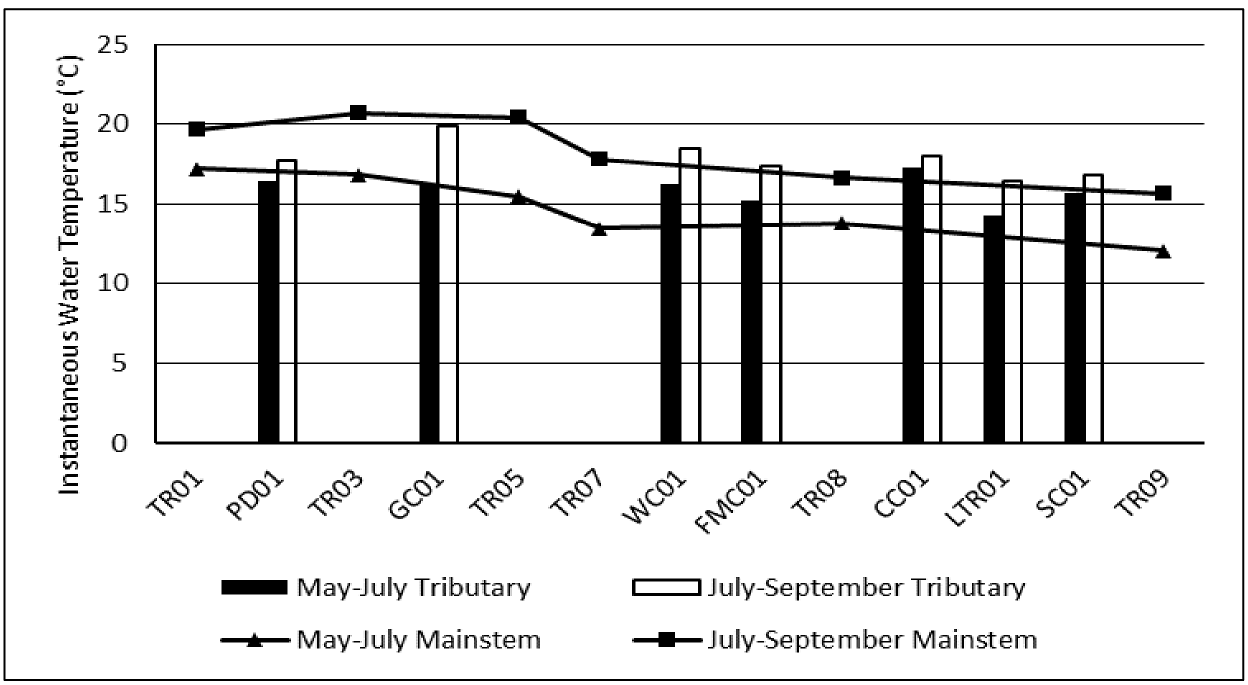
All stations reported the highest instantaneous temperature on July 28, 2016. The maximum instantaneous temperature for the season was recorded at TR05 (24.6°C). Average instantaneous temperature was higher in June-August period than in the May-July and July-September periods at all stations; however, there was very little difference in the June-August and July-September periods at station TR05 near Acme (20.5°C and 20.4°C, respectively).

Table 6-2. Instantaneous temperature measurements exceeding 20°C in 2016

Site	Temperature (°C)				
	6/27/2016	7/13/2016	7/28/2016	8/10/2016	8/22/2016
Tongue River (TR01)	21.6	20.4	23.6	22.2	
Prairie Dog Creek (PD01)			21.1	20.0	
Tongue River (TR03)	21.3	21.0	24.1	23.9	20.3
Goose Creek (GC01)	21.6	21.1	23.3	22.1	
Tongue River (TR05)			24.6	22.9	20.7
Tongue River (TR07)			22.5		
Wolf Creek (WC01)	21.4		23.5		
Five Mile Creek (FMC01)			21.2		
Tongue River (TR08)			20.5		
Columbus Creek (CC01)	20.9	20.4	22.7		
Little Tongue River (LTR01)			20.5		
Smith Creek (SC01)			21.1		

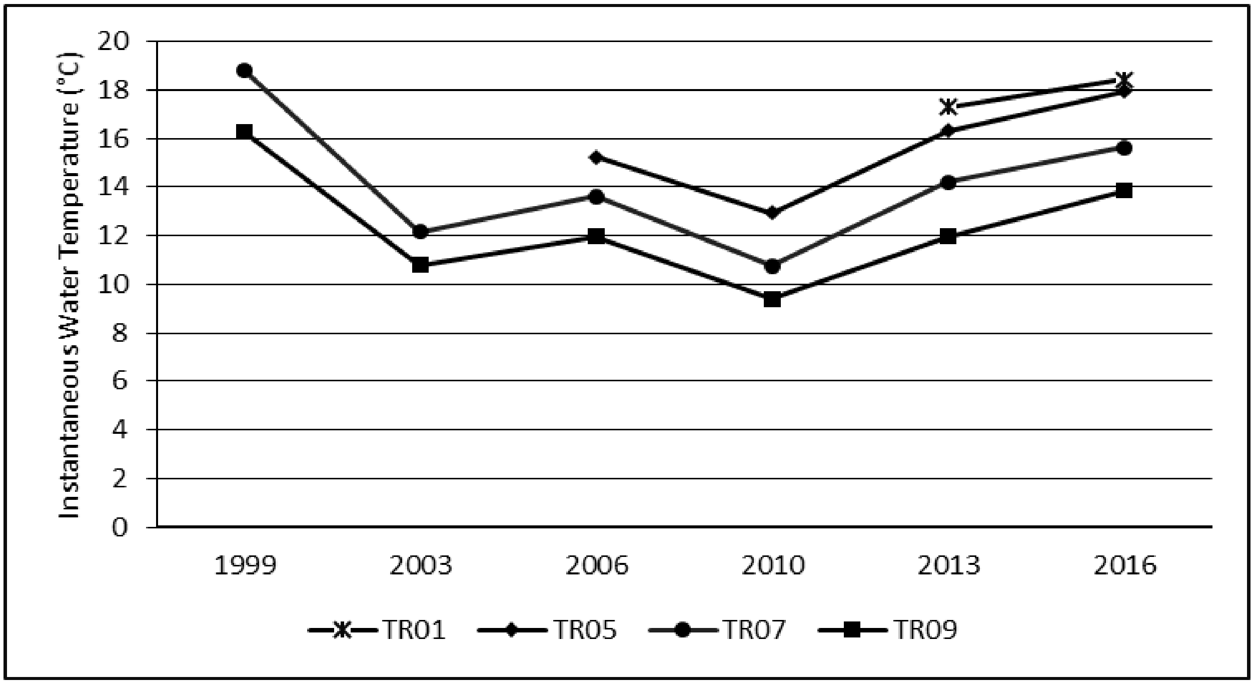
For Tongue River sites, average instantaneous water temperatures generally increased from upstream to downstream (Figure 6-1) and were higher at sites located downstream of the Interstate-90 crossing near Acme.

Figure 6-1. Average instantaneous water temperature in the Tongue River watershed by site and sample period in 2016



Changes in seasonal average instantaneous water temperatures were relatively consistent among sites (Figure 6-2). Seasonal average temperatures have increased since 2010. This could be attributed to higher than normal air temperatures, lower streamflows, or fewer samples being collected earlier in the season. Direct comparisons among years are difficult because of variations in water quantity and temperatures.

Figure 6-2. Seasonal average instantaneous water temperature at select Tongue River stations from 1999-2016



All USGS Stations reported instantaneous water temperatures that exceeded 20°C during certain periods (Appendix Tables C-17 through C-20). USGS 06306300 (Tongue River Near State Line) had the highest number of measurements over 20°C, including measurements in August 2014, July 2015, and June and July in 2016. The highest instantaneous measurement of 25.7 °C was observed at USGS Station 06299980 (Tongue River at Monarch) in July 2016.

6.2.2 Continuous Water Temperature

Continuous temperature data loggers were deployed at five Tongue River stations. Two loggers were found out of water at some point during the season and only have partial datasets. The data from the time the logger was discovered on the bank or out of water back to the previous sample date, when the logger was known to be in the water, was considered suspect and discarded. Data at TR05 is unavailable from 7/13 to 7/28; data at TR09 is unavailable from 7/28-8/10. All but one station reported temperatures that exceeded the temperature standard of 20° C. The uppermost station in Tongue River Canyon (TR09) was the only station that did not have any measurements above 20°C.

Temperatures at the three stations below the Town of Ranchester (TR01, TR03, and TR05) stayed above the standard for extended periods from late June through the middle of August. During the same period, temperatures at TR07 had daily maximum temperatures that exceeded 20°C, but daily minimums were below the standard. Maximum temperatures for each station occurred in late July or early August (Table 6-3). The loggers at TR05 and TR09 did not have full datasets; reported maximum temperatures may not represent the actual maximum daily temperature for those sites.

Table 6-3. Maximum daily water temperatures recorded by continuous data loggers in 2016

Site	Maximum Temperature (°C)		Maximum Temperature on Select Dates			
	Date	Temp	7/21	7/27	7/30	8/2
TR01	7/21	31.268	31.268	30.154	30.054	30.356
TR03	7/27	30.862	30.255	30.862	29.953	30.457
TR05*	7/30	30.054	ND*	ND*	30.054	29.953
TR07	8/2	25.513	24.158	24.448	25.319	25.513
TR09*	7/27	18.996	11.041	18.996	ND*	ND*

*Loggers at these stations were washed onto the bank for certain periods, which resulted in incomplete datasets.

Yearly comparisons for 2003, 2006, 2010 and 2016 at TR07 showed that daily average temperatures for 2016 were similar to 2003 and 2006 (Appendix Figure C-6). Daily average temperatures were generally lower in 2010 than in the other years from May-July.

6.2.3 pH

Ranging from 7.88 SU (FMC01) to 8.70 SU (TR01), all pH values were within the Wyoming water quality standard of 6.5-9.0 SU. There was little variability among samples in 2016; only three samples were below 8.00 SU (Appendix Tables C-3 through C-15). In addition, average pH values have remained relatively consistent since 1999 (Table 6-4).

USGS stations reported similar pH values, which ranged from 7.5 to 8.9 from October 2013 through October 2016 (Appendix Tables C-17 through C-20). Measurements were collected monthly from USGS Station 06299980 (Tongue River at Monarch), USGS 06306020 (Tongue River Below Youngs Creek) and USGS Station 06306250 (Prairie Dog Creek) and anywhere from zero to two times per month from USGS station 06306300 (Tongue River Near State Line).

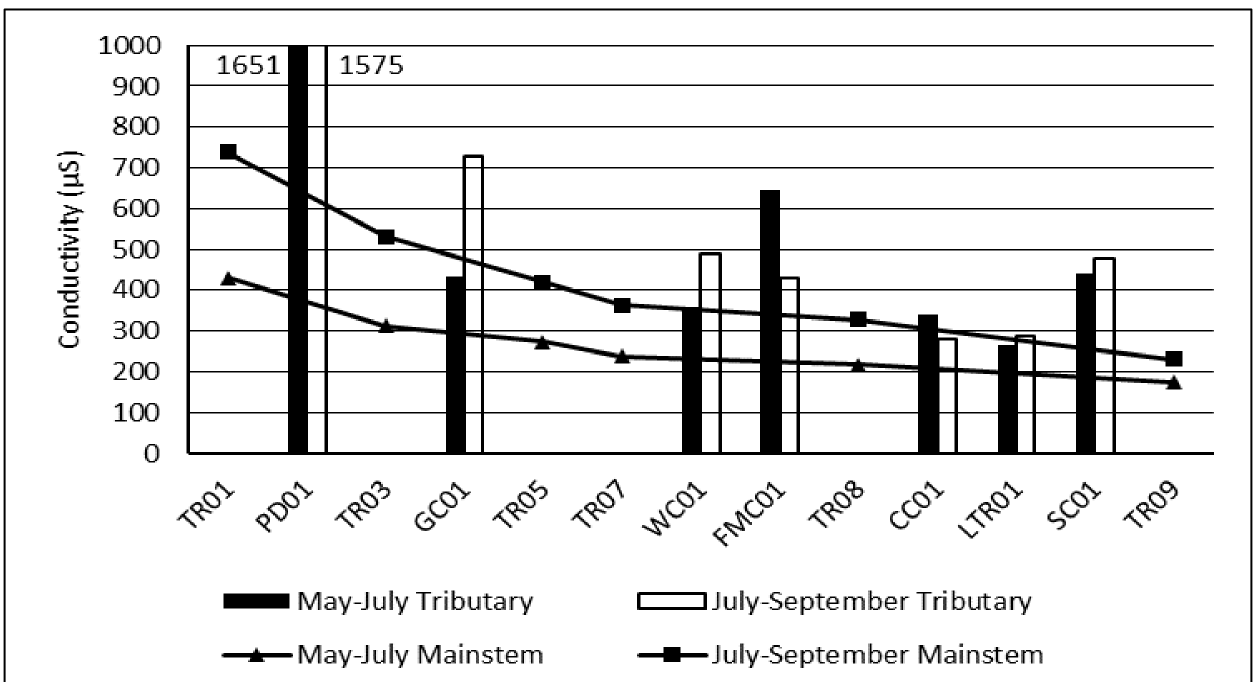
Table 6-4. Average seasonal pH within the Tongue River watershed from 1999-2016

Site	1999	2003	2006	2010	2013	2016
TR01					8.35	8.34
PD01					8.14	8.33
TR03					8.36	8.43
GC01					8.31	8.36
TR05			8.13	8.17	8.38	8.43
TR07	8.31	8.09	8.06	8.26	8.33	8.34
WC01	8.09	8.08	8.05	8.17	8.24	8.33
FMC01	8.08	7.95	7.98	8.19	8.15	8.13
TR08	8.23	8.14	8.04	8.38	8.44	8.47
CC01	7.97	8.06	8.09	8.24	8.32	8.20
LTR01	8.28	8.16	8.15	8.35	8.41	8.48
SC01	8.18	8.27	8.29	8.32	8.52	8.44
TR09	8.36	8.30	8.27	8.60	8.58	8.49

6.2.4 CONDUCTIVITY

The average conductivity increased from upstream to downstream on Tongue River stations in 2016 (Figure 6-3) and was higher in July-September than in May-July. Tributary stations were typically higher than the adjacent mainstem stations. Prairie Dog Creek (PD01) had the highest conductivity with a May-July average of 1651 µS and a July-September average of 1575 µS.

Figure 6-3. Average conductivity in the Tongue River watershed by site and sample period in 2016



Prairie Dog Creek and Five Mile Creek were the only stations with conductivity values over 1000 µS, with maximum values of 2800 µS and 1221 µS, respectively. All 2016 conductivity measurements from Prairie Dog Creek were above 1000 µS; values ranged from 1046 µS to 2800 µS.

With some exceptions, conductivity values were relatively consistent among years at most stations. For mainstem sites, yearly variability was greater in the downstream sites. Variability at all stations appeared to be higher in the early monitoring periods than in the later periods (Table 6-5).

Table 6-5. Average conductivity on the Tongue River Watershed from 1999-2016

Site	May					August					
	2003	2006	2010	2013	2016	1999	2003	2006	2010	2013	2016
TR01				595	431					831	739
PD01				1646	1651					2265	1575
TR03				369	313					577	532
GC01				436	432					718	729
TR05		224	349	314	273			548	426	505	420
TR07	275	206	336	287	239	327	372	433	375	407	364
WC01	354	268	383	373	358	490	616	661	573	628	491
FMC01	926	663	793	1080	647	679	584	440	415	442	429
TR08	270	191	302	263	218	285	341	384	325	374	328
CC01	1030	586	655	561	338	299	312	312	331	321	281
LTR01	420	442	476	664	263	454	330	407	426	412	289
SC01	900	548	620	565	441	495	619	567	621	506	479
TR09	193	157	202	192	174	219	224	237	252	245	230

Conductivity values reported by USGS from 2013-2016 ranged from 199 to 902 µS at mainstem stations; both the highest and lowest were observed at USGS 06299980, Tongue River at Monarch. USGS Station 06306250 (Prairie Dog Creek) reported the highest conductivity values, which ranged from 710 to 2020 µS; all but three of the values were above 1000 µS. USGS also reported Dissolved Solids, which followed a similar pattern. The highest values were reported from USGS Station 06306250 (Prairie Dog Creek) and ranged from 468-1500 mg/L. Values for the other USGS Stations ranged from 117-604 mg/L.

There is no standard for conductivity in the state of Wyoming; however, because conductivity is highly dependent on the amount of dissolved solids (such as salts), high values could become a concern for agricultural operations related to crop/hayland production. Quality standards are established for Wyoming groundwater such that concentrations of total dissolved solids (TDS) for domestic, agricultural, or livestock use shall not exceed 500 mg/L, 2000 mg/L, or 5000 mg/L, respectively (WDEQ, 2005). While conductivity is not directly proportional to the TDS concentration, conductivity can be used to estimate the relative concentration of TDS.

6.2.5 *Dissolved Oxygen*

All sites met the minimum instantaneous DO concentration standard of 4.0 mg/L for other life stages and the 5.0 mg/L for early life stages (Table 6-6). Because of meter issues on the first sample day, only nine measurements were collected per site. Four tributary stations and four mainstem stations had at least one sample below the 8.0 mg/L water column concentration recommended to achieve the 5.0 mg/L inter-gravel concentration for early life stages.

Table 6-6. Dissolved oxygen ranges and number of samples below 8.0 mg/L in 2016

Mainstem Sites			Tributary Sites		
Site	**# of samples below 8.0 mg/L**	**Range (mg/L)**	**Site**	**# of samples below 8.0 mg/L**	**Range (mg/L)**
TR01	4	6.35-10.10	PD1	2	6.83-9.80
TR03	1	7.32-9.31	GC1	1	6.10-12.10
TR05	1	7.03-10.19	WC1	0	8.30-12.08
TR07	1	7.10-10.91	FMC1	3	5.70-9.52
TR08	0	9.46-11.78	CC1	2	7.52-9.55
TR09	0	9.16-11.20	LTR1	0	8.50-10.84
			SC1	0	8.12-10.42

The uppermost mainstem stations (TR08 and TR09) and the uppermost tributaries (Little Tongue River and Smith Creek) did not have any values below 8.0 mg/L. Dissolved Oxygen on mainstem sites ranged from a minimum of 6.35 at TR01 to a maximum of 11.78 at TR08; on tributary sites, values ranged from 5.70 (FMC01) to 12.10 (GC01). The lowest dissolved oxygen measurement was on Five Mile Creek (5.70 mg/L), which had three measurements below 8.0 mg/L. The lowermost sample site, TR01, had the highest number of values below 8.0 mg/L with four values between 6.35 and 7.91 mg/L.

Dissolved Oxygen concentrations at USGS stations were above 5.0 mg/L from 2013-2016 (Appendix Tables C-17 through C-20), with the lowest value of 6.8 mg/L reported at two stations: USGS 06306300 (Tongue River at State Line) in July 2015 and USGS Station 06306020 (Tongue River Below Youngs Creek). In most cases, Dissolved Oxygen concentrations were above the 8.0 mg/L recommended water column concentration. The USGS station on Prairie Dog Creek (06306250), USGS 06306300 (Tongue River at State Line), and USGS Station 06306020 (Tongue River Below Youngs Creek) each had two occasions where dissolved oxygen concentrations were below 8.0 mg/L. All dissolved oxygen concentrations were above 8.0 mg/L at USGS Station 06299980 (Tongue River at Monarch).

Early and late season averages were above 4.0 mg/L and 5.0 mg/L at all sites during all sampling years (Table 6-7). Overall, there were more dissolved oxygen average values below 8.0 mg/L in the late season than in the early season, which had no averages below 8.0 mg/L. In 2013, five sites had late season averages below 8.0 mg/L.

Table 6-7. Average yearly comparisons of dissolved oxygen (mg/L) from 1999-2016

Site	May					August					
	2003	2006	2010	2013	2016	1999	2003	2006	2010	2013	2016
TR01				8.48	8.79					6.99	7.78
PD01				9.24	9.40					7.98	8.58
TR03				8.53	9.03					7.23	8.49
GC01				9.43	9.65					8.13	9.53
TR05		10.30	10.35	9.56	9.74			8.73	7.60	8.40	9.11
TR07	11.10	10.92	11.29	10.54	10.50	9.97	8.63	9.59	9.02	9.03	9.28
WC01	10.22	10.23	10.65	9.46	10.66	9.30	6.14	8.20	7.96	7.34	10.29
FMC01	9.18	10.64	10.01	9.70	8.90	9.88	7.46	8.49	8.06	6.98	8.02
TR08	11.61	11.02	11.76	11.00	10.26	9.53	9.07	9.71	9.42	9.10	10.33
CC01	9.62	10.12	9.94	8.98	8.52	8.67	7.77	9.35	8.27	7.84	8.44
LTR01	11.38	10.42	11.46	9.80	9.67	9.88	9.11	9.68	9.38	8.52	9.24
SC01	10.54	10.11	11.15	9.87	9.09	9.23	8.57	10.03	9.20	10.39	9.06
TR09	11.88	11.18	11.95	10.86	10.03	9.64	9.07	9.97	9.22	8.45	9.52

6.3 DISCHARGE

SCCD installed and used calibrated staff gauges to estimate discharge during water sampling events (Appendix Tables C3-C15). SCCD used a USGS gauge and "real-time" flow information at TR09 (Station 06298000 Tongue River Near Dayton). USGS Station PD01 (Station 06306250 Prairie Dog Creek, Near Acme, WY) was discontinued in July 2016 and a staff gauge was needed.

On mainstem sites, the highest flows occurred on 6/13/2016 for the lowermost sites (TR01 and TR03) followed by 5/31/16 (Table 6-8). For all other mainstem sites, these were reversed; the highest flows occurred on 5/13/16 followed by 6/13/16. A similar pattern was observed for the lowest flows. The lowest flows were on 7/28/16 followed by 8/10/16 for the two lower stations. With the exception of TR09, the remaining mainstem sites had the lowest flow on 8/10/16 followed by 7/28/16. The lowest flow observed at TR09 occurred on 8/22/16.

Discharge at tributary stations was much more variable. For the most part, the highest flows occurred in the early season and the lower flows occurred later in the summer/fall. However, the highest or 2nd highest flows were observed during the late season on Prairie Dog Creek (9/20) and Columbus Creek (8/22 and 8/10). On one occasion, the lowest flow was observed in the early season; the lowest observed flow on Five Mile Creek occurred on 5/18.

Table 6-8. Highest and lowest instantaneous discharge measurements in 2016

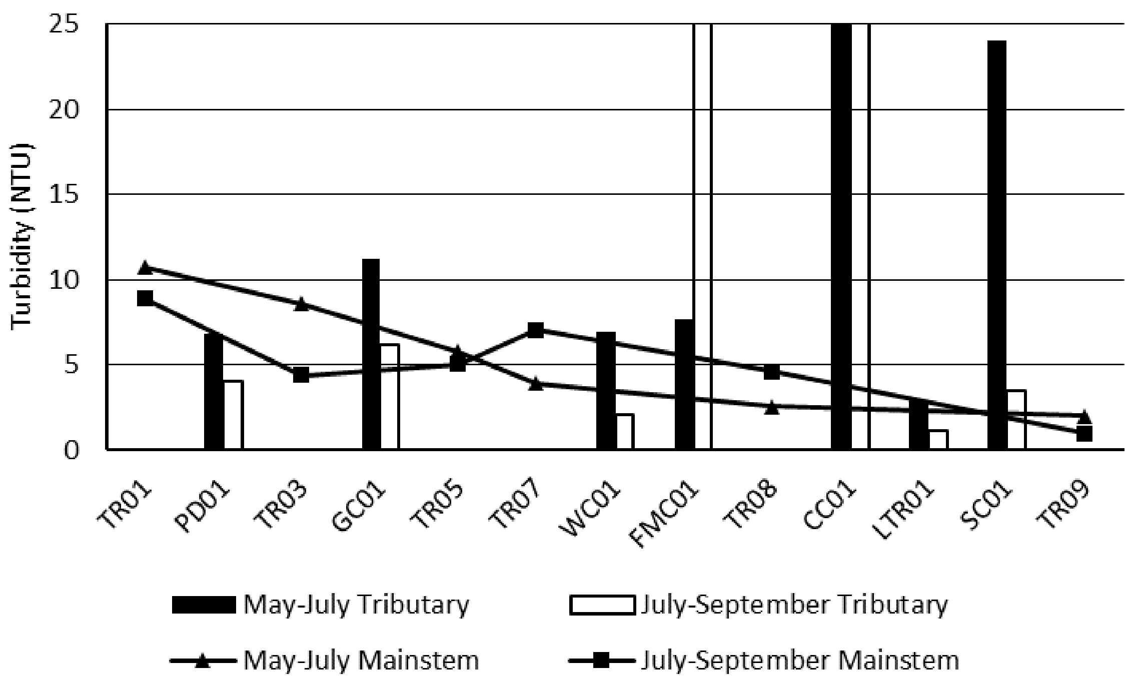
Site	Highest Discharge		2nd Highest Discharge		Lowest Discharge		2nd Lowest Discharge	
	Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
MAINSTEM SITES								
TR01	6/13	1192.10	5/31	917.39	7/28	30.43	8/10	80.67
TR03	6/13	549.76	5/31	508.88	7/28	36.01	8/10	59.43
TR05	5/31	423.61	6/13	332.35	8/10	30.56	7/28	44.08
TR07	5/31	208.66	6/13	182.95	8/10	23.95	7/28	41.68
TR08	5/31	271.21	6/13	242.87	8/10	29.27	7/28	39.52
TR09	5/31	383.00	6/13	373.00	8/22	55.00	8/10	57.00
TRIBUTARY SITES								
PD1	5/18	48.83	9/20	24.18	7/13	1.4	7/28	2.16
GC1	6/13	694.43	5/31	343.83	7/28	17.02	8/10	21.85
WC01	5/31	58.70	6/13	35.18	8/10	0.5	7/28	0.64
FMC01	6/27	4.32	6/13	3.02	5/18	1.02	8/10 & 9/20	2.37
CC01	8/22	13.53	5/31 & 8/10	7.16	7/13	0.42	7/28	1.77
LTR01	5/18	19.92	5/31	19.47	8/22	1.23	8/10	1.32
SC01	6/27	11.38	5/31	10.14	9/20	1.27	8/10	3.26

High flow values in 2016 correspond to high instantaneous discharge measurements reported by the USGS at mainstem sites on in May and June 2016; the highest instantaneous discharge measured at USGS stations on the Tongue River occurred on 5/26 followed by 6/22 and 6/24 (Appendix Tables C-17 through C20). Low discharge measurements on mainstem stations were reported by USGS on 7/27 and 8/25 at Stations 06306300 (Tongue River at State Line) and 06299980 (Tongue River at Monarch). USGS Station 06306020 (Tongue River Below Youngs Creek) did not report any discharge measurements after 6/24/16. USGS Station 06306250 on Prairie Dog Creek reported an instantaneous discharge of 116 cfs on 4/27/16, which was followed by 24 cfs on 5/26/17 and 11 cfs on 6/24/16. The gauge was discontinued after 6/24/216. USGS mean daily flows within the watershed for 2016 were typically below the normal mean daily flow, with a few exceptions (Appendix Figures C-7 through C-11).

6.4 TURBIDITY

Average early season and late season turbidity generally increased from upstream to downstream (Figure 6-4). Samples collected in the early season had higher average turbidity than samples collected later in the season at all stations except TR07 and TR08. Tributary sites were typically higher than adjacent mainstem stations in the early season. Five Mile Creek was the only tributary with higher average turbidity in the late season than in the early season.

Figure 6-4. Average turbidity in the Tongue River watershed by site and sample period in 2016



Average turbidity was typically lower in 2016 than in previous years in both the early season and late season samples (Table 6-9). In the early season, only Smith Creek had higher turbidity in 2016 than in 2013 and 2006 and Columbus Creek had higher turbidity in 2016 than in 2006.

Table 6-9. Yearly comparisons of Average Turbidity (NTU) from 1999-2016

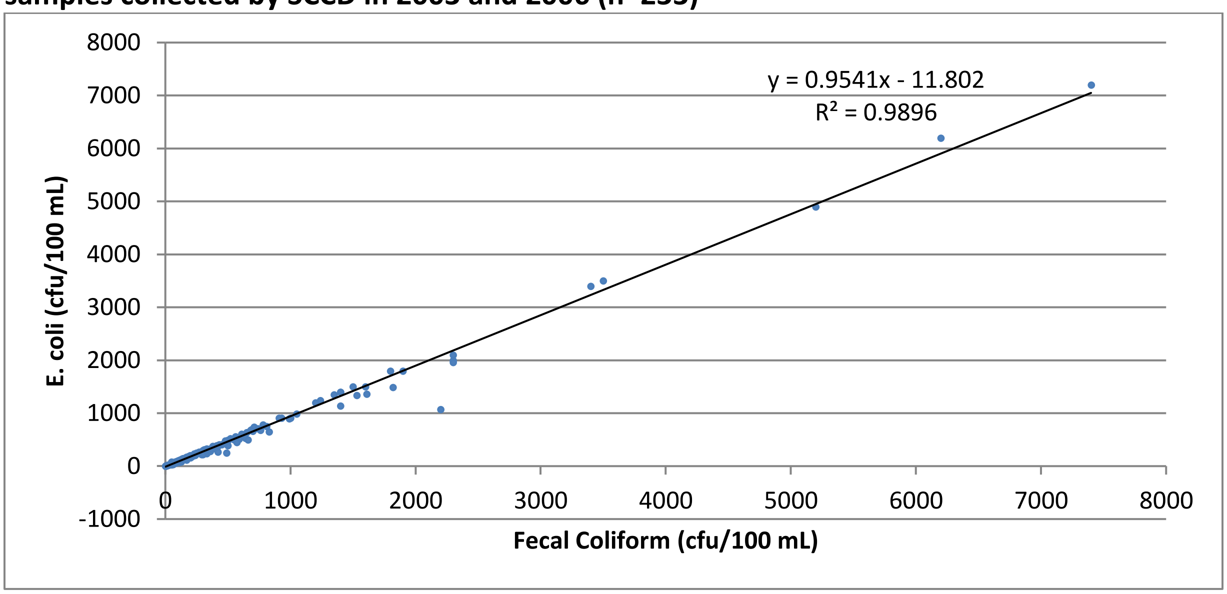
	May-July 2016					July-September 2016					
Site	2003	2006	2010	2013	2016	1999	2003	2006	2010	2013	2016
PD1				50.32	10.74					14.48	8.90
TR01				33.82	6.82					6.40	4.02
TR03				41.24	8.60					5.10	4.40
GC1				26.72	11.22					6.02	6.16
TR05		49.63	128.92	42.22	5.82			10.56	11.04	8.94	5.06
TR07	29.60	18.30	43.08	16.78	3.94	3.73	4.00	4.76	4.16	7.06	7.06
WC01	37.40	37.13	25.72	18.26	6.98	5.80	5.60	2.76	4.98	3.28	2.12
FMC01	684.80	31.23	96.62	152.88	7.66	43.48	36.00	24.80	15.74	19.02	40.50
TR08	15.20	10.85	31.48	11.30	2.58	3.50	3.80	2.76	2.52	4.74	4.64
CC01	79.00	24.58	182.02	76.22	34.52	64.50	57.40	18.64	23.50	18.52	33.24
LTR01	29.20	4.50	57.84	6.16	2.92	0.60	1.20	0.72	0.74	1.04	1.18
SC01	66.60	9.28	56.36	16.12	24.00	24.28	10.20	1.52	3.24	2.00	3.46
TR09	5.00	9.68	6.48	6.18	2.04	1.27	1.40	0.63	1.34	0.76	1.00

For late season samples, average turbidity on Five Mile Creek was higher in 2016 than all other sampling years except 1999. Turbidity on Columbus Creek was higher in 2016 than all years except 1999 and 2003. Turbidity in 2016 was only slightly higher than previous sampling years on Goose Creek and Smith Creek.

6.5 Bacteria

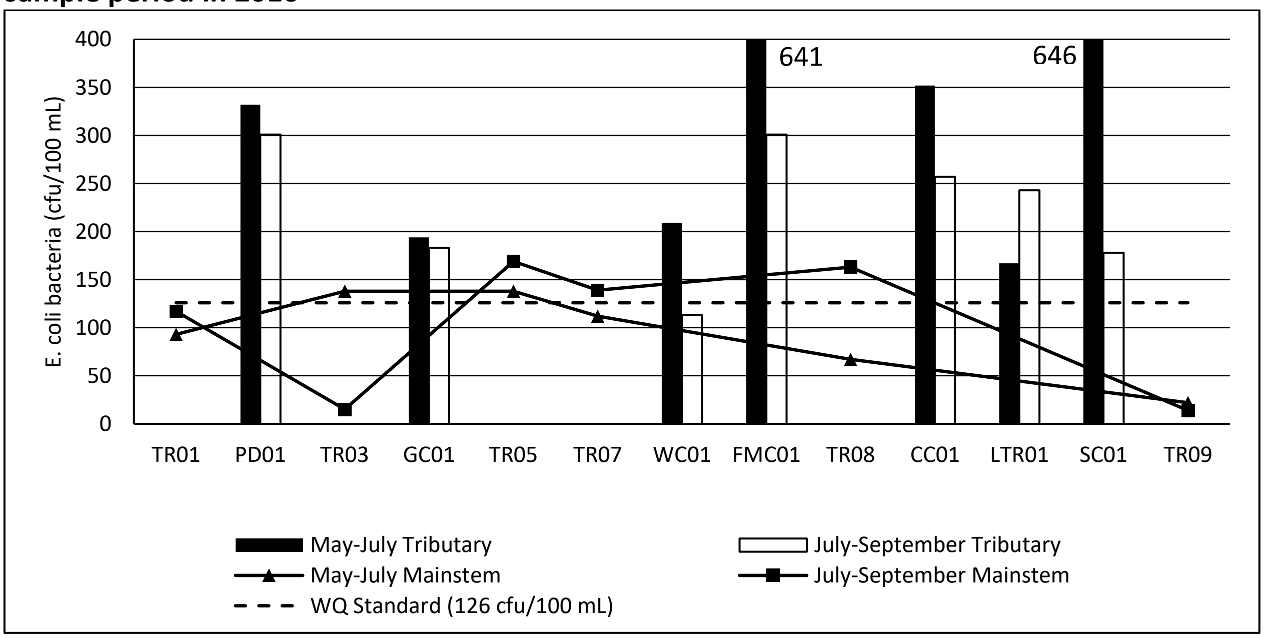
In 1996-1999, 2003, and 2006 fecal coliform bacteria were the indicator for pathogen impairments under Wyoming Water Quality Standards. During a 2007 revision, *E. coli* became the indicator. In anticipation of this change, SCCD collected both *E. coli* and fecal coliform in 2003 and 2006 so *E. coli* samples could be compared to fecal coliform data from previous years. While there is no standard conversion from fecal coliform to *E. coli*, it is possible to find a relatively consistent relationship within an individual watershed (Rasmussen, 2003). Within the Tongue River watershed, the R^2 value of this comparison was 0.99, which SCCD determined was sufficient for looking at long-term trends (Figure 6-5). Using the results of the comparison, SCCD converted fecal coliform values from 1999 to *E. coli* so comparisons among years could be made. Fecal coliform data collected from 1996-1998 were not converted, because samples were collected monthly and no geometric means were calculated. These converted data were not used in any listing determination or other regulatory action. Only one site (WCL) that did not exceed the fecal coliform bacteria standard in 1999 did exceed the *E. coli* standard when *E. coli* concentrations were calculated.

Figure 6-5. Tongue River watershed fecal coliform and *E. coli* bacteria comparison from samples collected by SCCD in 2003 and 2006 (n=233)



Ten *E. coli* bacteria samples were obtained from each of the 13 monitoring stations within two 60-day periods in May-July and July-September (Appendix Tables C-3 through C-15). Bacteria geometric mean concentrations in the early season were higher than in the late season on all tributaries except Little Tongue River (Figure 6-6). In contract, mainstem sites had higher bacteria concentrations in the late season with two exceptions; bacteria concentrations in the early season were higher at TR03 and TR09. Early season geometric means were within Wyoming Water Quality Standards at all mainstem sites except TR05 and TR03, both of which were 138 cfu/100 mL. While some mainstem sites did not meet Wyoming Water Quality standards during the late season, the highest bacteria concentration observed on mainstem site was 169 cfu/100 mL or 25% above the standard. Bacteria concentrations at tributary stations appeared to contribute to bacteria increases on the Tongue River at adjacent downstream stations in the upper portion of the watershed during the early season. With one exception, bacteria concentrations exceeded Wyoming Water Quality standards at all tributary stations in both the early season and the late season; late season bacteria concentrations on Wolf Creek were below 126 cfu/100 mL.

Figure 6-6. *E. coli* Bacteria geometric means in the Tongue River watershed by site and sample period in 2016



Comparisons among years could be made from 2003-2016 at the stations within and above the Town of Ranchester, which were within the original assessment boundary. The original assessment included sites TR07, TR08, and TR09 on the Tongue River. Tributary stations included Wolf Creek, Five Mile Creek, Columbus Creek, Little Tongue River, and Smith Creek. Comparisons between 2013 and 2016 could be made at all stations sampled in 2016.

Table 6-10. Bacteria geometric means and percent change among years at comparable stations in the Tongue River watershed

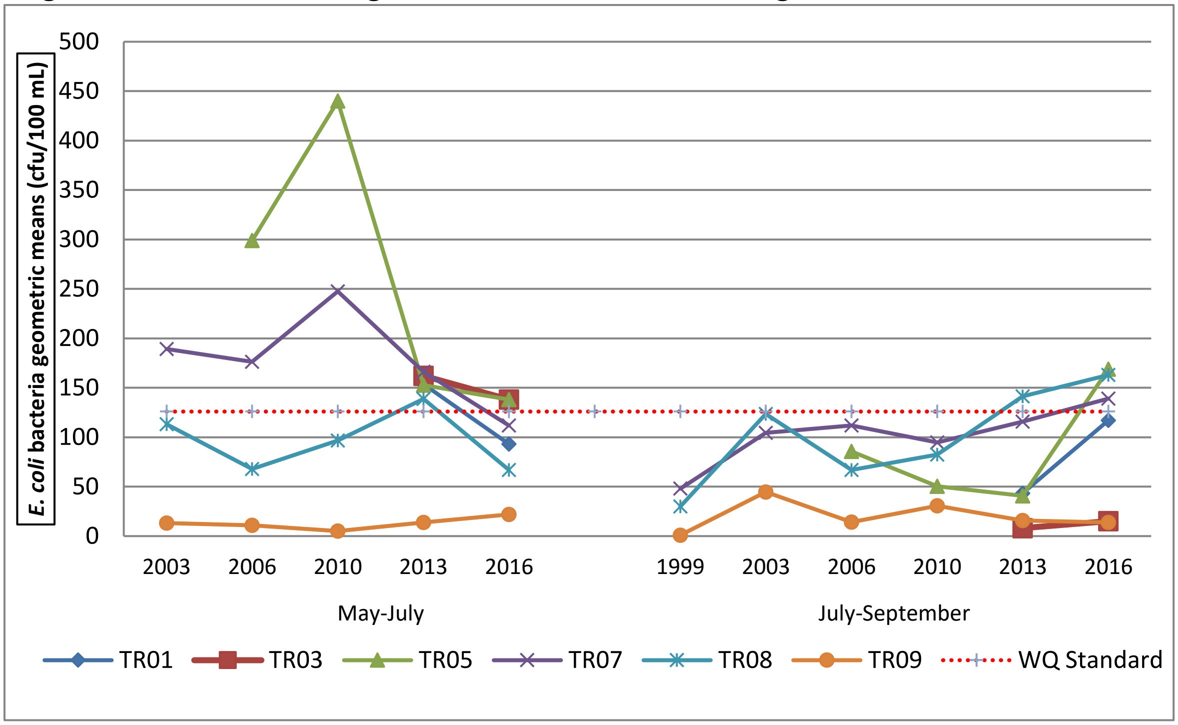
	Site	May-July *E. Coli* geometric means (cfu/100 mL)						2016 percent above/below WQ Standard	Percent Change	
		1999*	2003	2006	2010	2013	2016		2003-2016	2013-2016
Mainstem Stations	TR01					154	93	-35%		-40%
	TR03					162	138	9%		-15%
	TR05			299	440	153	138	9%		-10%
	TR07		189	176	248	166	112	-13%	-41%	-33%
	TR08		113	68	97	139	67	-88%	-41%	-52%
	TR09		13	11	5	14	22	-473%	67%	57%
Tributary Stations	Prairie Dog Creek (PD01)					144	332	62%		131%
	Goose Creek (GC01)					260	194	35%		-26%
	Wolf Creek (WC01)		339	145	427	197	209	40%	-38%	6%
	Fivemile Creek (FMC01)		2713	640	861	2399	641	80%	-76%	-73%
	Columbus Creek (CC01)		89	176	572	659	352	64%	295%	-47%
	Little Tongue River (LTR01)		74	72	136	126	167	25%	127%	33%
	Smith Creek (SC01)		768	163	516	319	646	80%	-16%	103%

Site		July-September *E. coli* geometric means (cfu/100mL)						2016 % above/below WQ Standard	Percent Change	
		1999*	2003	2006	2010	2013	2016		2003-2016	2013-2016
Mainstem Stations	TR01					43	117	-8%		170%
	TR03					8	15	-740%		85%
	TR05			86	50	41	169	25%		315%
	TR07	48	104	112	95	116	139	9%	33%	20%
	TR08	74	124	67	82	141	163	23%	32%	15%
	TR09	1	45	14	31	16	14	-800%	-69%	-11%
Tributary Stations	Prairie Dog Creek (PD01)					136	301	58%		121%
	Goose Creek (GC01)					92	183	31%		99%
	Wolf Creek (WC01)	128	253	145	257	143	113	-12%	-55%	-21%
	Fivemile Creek (FMC01)	519	689	250	378	463	301	58%	-56%	-35%
	Columbus Creek (CC01)	373	377	128	291	214	257	51%	-32%	20%
	Little Tongue River (LTR01)	261	1191	308	273	283	243	48%	-80%	-14%
	Smith Creek (SC01)	495	598	298	1337	209	178	29%	-70%	-15%

*1999 E. coli values were calculated using the conversion from Fecal Coliform concentrations

With one exception, early season bacteria concentrations decreased from 2003-2016 and from 2013-2016 at all mainstem sites. Bacteria concentrations at TR09 increased since 2003; however, concentrations in 2016 were still well below Wyoming Water Quality Standards at 22 cfu/100 mL (Table 6-10 and Figure 6-7). Bacteria concentrations later in the season increased at all mainstem stations except TR09.

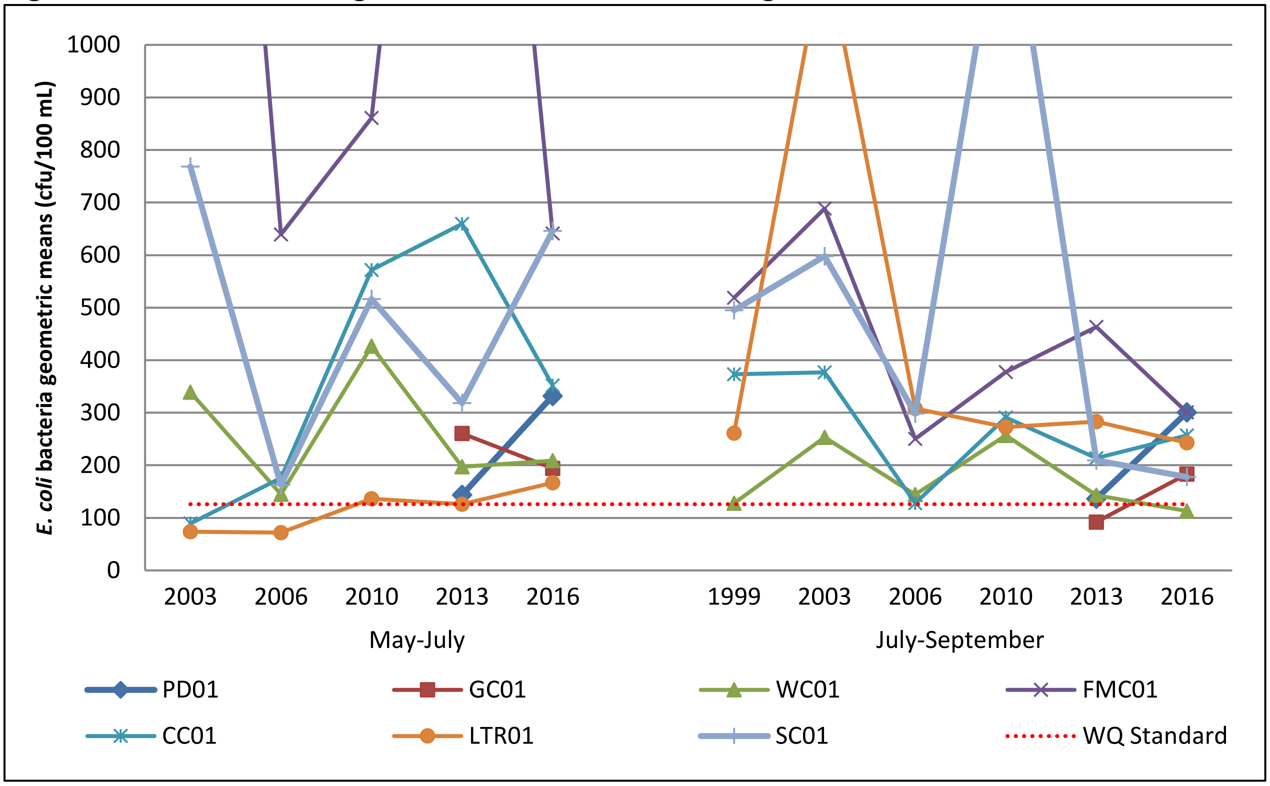
Figure 6-7. *E. coli* bacteria geometric mean trends on Tongue River stations from 1999-2016



*August 1999 *E. coli* values were based on the conversion from fecal coliform to *E. coli* calculation

Three tributary stations, Goose Creek, Columbus Creek, and Five Mile Creek had decreases in early season bacteria concentrations (Table 6-10 and Figure 6-8) from 2013-2016. The decrease on Five Mile Creek represented a change from 2399 cfu/100 mL in 2013 to 641 cfu/100 mL in 2016. All tributary stations showed decreases in late season bacteria concentrations from 2003-2016. However, increases were observed from 2013-2016 at Prairie Dog Creek, Goose Creek and Columbus Creek. All tributary stations continued to exceed Wyoming Water Quality standards in the early season and in the late season except for late season bacteria concentrations on Wolf Creek, which were 113 cfu/100 mL.

Figure 6-8. *E. coli* bacteria geometric mean trends on Tongue River tributaries from 1999-2016



*August 1999 *E. coli* values were based on the conversion from fecal coliform to *E. coli* calculation

6.6 Meteorological Data and Supporting Information

Mean daily air temperatures were above normal for most of May through July 2016 and below normal for most of September and October 2013 (Appendix Figure C-12). National Weather Service data at the Sheridan County Airport show normal mean daily air temperatures from May through October average 59.4°F while 2016 temperatures averaged 62.1°F. Monthly averages for air temperature were 0.42°F – 7.3°F higher in 2016 than normal (Table 6-11).

Cumulative precipitation through October 2016 was 13.95 inches, which was 1.61 inches higher than normal precipitation (Appendix Figure C-13). The higher than normal cumulative precipitation was largely due to higher than normal precipitation in January-April. Monthly precipitation for September 2016 was 0.07 inches higher than normal (Table 6-11).

Table 6-11. Air Temperature and Precipitation data collected by the National Weather Service from the Sheridan County Airport in 2016

	Average Daily Air Temperature (°F)		Precipitation (inches)			
	2016	Normal	2016	Normal	2016 Cumulative	Normal Cumulative
January-April					6.4	3.83
May	53.45	52.74	0.03	0.08	6.87	4.97
June	69.17	61.87	0.01	0.07	7.68	7.31
July	73.10	70.20	0.01	0.04	7.97	8.82
August	69.13	68.71	0.05	0.02	8.93	9.72
September	59.57	57.46	0.12	0.05	10.79	10.78
October	47.90	45.13	0.05	0.04	13.95	12.34

6.7 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates reside on and in the bottom substrate of streams and provide a valuable tool for the assessment of water quality in the Tongue River watershed. They are small but visible to the naked eye and large enough to be retained in a U.S. Standard Number 30 sieve.

Water chemistry sampling provides information for the quality of water at the time of sample collection. In contrast, macroinvertebrates serve as continuous monitors of stream water quality since they live in the water during the majority of their life cycle and are exposed to often variable concentrations of pollutants over extended periods of time. This is an important concept because water quality sampling may miss important changes in water quality due to normal seasonal and spatial variability, changes in land use, water management, or accidental pollutant spills. An optimal water quality monitoring program involves both water chemistry sampling and biological monitoring (Rosenberg and Resh 1993).

Wyoming Water Quality Standards for chemical and physical water quality parameters (WDEQ, 2013) were established to protect aquatic life and human health. Instead of using sampling results from individual chemical and physical water quality parameters, evaluation of benthic macroinvertebrate populations may serve as a direct measure for the attainment of the Aquatic Life beneficial use in addition to validating the effectiveness of individual numeric water quality chemical and physical standards. Benthic macroinvertebrates also serve to integrate water quality and habitat quality interaction, and evaluate potential synergistic effects from multiple chemical and physical water pollutants not measured during routine water quality monitoring. Wyoming has developed biological criteria for streams statewide, but they have not been adopted as numeric, enforceable standards (Stribling et al., 2000; Jessup and Stribling, 2002; Hargett and ZumBerge, 2006; Hargett, 2011). As such, they may be used as narrative standards to determine beneficial use for aquatic life and the protection and propagation of fish and wildlife. The Biological Criteria in Section 32 of the Wyoming Water Quality Standards provide a narrative standard for protection of indigenous or intentionally introduced aquatic communities (i.e. brown, brook, and rainbow trout species). In addition, Section 4 in the Wyoming Water Quality Standards relates the presence of food sources (e.g. benthic macroinvertebrates) for game and non-game fish as a criterion for Surface Water Classes and (beneficial) uses (WDEQ, 2013).

6.7.1 Previous Benthic Macroinvertebrate Sampling

The historic benthic macroinvertebrate data for forty (N = 40) samples collected in the Tongue River watershed from 1993 through 1999 were presented and discussed in the *Tongue River Watershed Assessment 1996-1999: Final Report* (SCCD, 2000). SCCD collected nine (N = 9) benthic macroinvertebrate samples from eight stations in 2003. The data from the 2003 sampling were presented and discussed in SCCD (2004). In 2006, a total of three benthic macroinvertebrate samples were collected by SCCD from two mainstem Tongue River monitoring stations (stations TRL (renamed TR07 in 2013) and TR1 (renamed TR05 in 2013)). These data were presented and discussed in the *2006 Tongue River Monitoring Project report* (SCCD, 2007). No benthic macroinvertebrate samples were collected in the Tongue River watershed by SCCD from 2007 through 2009. SCCD then collected a total of eleven (N = 11) benthic macroinvertebrate samples in 2010 from ten stations. Six of the samples were collected from Tongue River mainstem stations and five of the samples were collected from tributaries to the Tongue River. These data were presented and discussed in the *2010 Tongue River Watershed Interim Monitoring Project report* (SCCD, 2012).

A total of six (N = 6) benthic macroinvertebrate samples were collected by SCCD in 2013 from five stations. Two of the monitoring stations were new and included TR03 near the Decker Highway bridge crossing, and TR01 near the Wyoming/Montana state line. WDEQ previously collected a total of two (N = 2) benthic macroinvertebrate samples at station TR03 in 1998 and 2004 (see Appendix Tables C-7 through C-8 *in* SCCD, 2015). In addition, WDEQ collected a total of four (N = 4) samples from a location just downstream from SCCD station TR01 during 1998, 2003 and 2004 (see Appendix Tables C-9 through C-12 *in* SCCD, 2015).

Field benthic macroinvertebrate sample collection methods and laboratory analytical methods employed by both SCCD and WDEQ have been the same since sampling began by WDEQ in 1993 and SCCD in 1996 (i.e. 8 random composite Surber samples with 500-micron net, 500-600 organisms identified in the laboratory, and similar Standard Taxonomic Effort). This resulted in comparable benthic macroinvertebrate data sets generated by SCCD and WDEQ, and allowed all data to be used in the evaluation of biological condition for water bodies sampled within the project area.

6.7.2 *BENTHIC MACROINVERTEBRATE SAMPLING IN 2016*

A total of six (N = 6) benthic macroinvertebrate samples were collected by SCCD in 2016 from five stations (Appendix D). All samples were collected from Tongue River mainstem stations TR09, TR07, TR05, TR03 and TR01. Tongue River stations TR03 and TR01 were newer SCCD benthic macroinvertebrate monitoring sites established in 2013. No samples were collected from tributaries to the Tongue River. Included in the total number of samples was a duplicate benthic macroinvertebrate sample collected from station TR09. The duplicate sample was used only for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results. The duplicate sample was not used for the determination of biological condition.

A series of metrics were calculated for each sample. A metric is a characteristic of the macroinvertebrate community that changes in a predictable way to increased human influence. (Table 6-12). The change in certain macroinvertebrate metrics at a sample station over time, or between sample stations, can indicate change in water quality at or among stations. The metrics for macroinvertebrate samples collected in 2016 and for previous macroinvertebrate samples are presented in Appendix Tables D-7 through D-12.

Table 6-12. Definition of select macroinvertebrate metrics and expected response to perturbation including water quality and habitat change (from King, 1993 and Barbour et al., 1999)

Metric	Definition	Expected Response
Total Number Taxa	Measures the overall variety of the macroinvertebrate assemblage	Decrease
Total Number EPT Taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies, and Trichoptera (caddisflies)	Decrease
Total Number Ephemeroptera Taxa	Total Number of mayfly taxa	Decrease
% Ephemeroptera	Percent of mayfly nymphs	Decrease
Total Number Plecoptera Taxa	Total Number of stonefly taxa	Decrease
% Plecoptera	Percent of stonefly nymphs	Decrease
Total Number Insect Taxa	Total Number taxa in the Class Insecta	Decrease
Total Number Non - Insect Taxa	Total Number taxa <u>not</u> in the Class Insecta	Increase
% Non - Insects	Percent of Non - Insects	Increase
% Chironomidae	Percent of midge larvae	Increase
% Oligochaeta	Percent of worms	Increase
% 5 Dominant	Total Percent of the 5 most dominant taxa	Increase
% 10 Dominant	Total Percent of the 10 most dominant taxa	Increase
Number Predator Taxa	Number of taxa that feed upon other organisms or themselves in some instances	Variable, but appears to decrease in most regions of Wyoming
Total Number Scraper Taxa	Total Number of taxa that scrape periphyton for food	Decrease
% Scrapers	Percent organisms that scrape periphyton for food	Decrease
% Collector - Filterers	Percent organisms that filter Fine Particulate Organic Material from either the water column or sediment	Increase in most Wyoming ecoregions
% Collector - Gatherers	Percent organisms that either collect or gather food particles	Increase
Modified HBI	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution.	Increase
BCI CTQa	Tolerance classification based on nonpoint source impact of sedimentation and velocity alteration	Increase
Shannon H (Log base 2)	Incorporates both richness and evenness in a measure of general diversity and composition	Decrease
% Multivoltine	Percent of organisms having short (several per year) life cycle	Increase
% Univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years)	Decrease

6.7.3 Benthic Invertebrate Taxa

Taxa lists for Tongue River watershed benthic macroinvertebrate samples collected by SCCD in 2016 are presented in Appendix Tables D-1 through D-6. The list of benthic macroinvertebrate metrics for historic and current study samples collected at stations TR09, TR07, TR05, TR03 and TR01 from 1993 to 2016 is presented in Appendix Tables D-7 through D-12.

The benthic community at Tongue River TR09 station was generally dominated by cool water taxa indicative of good water quality and good habitat. A mixture of cool water and warm water taxa were present at stations TR07 and TR05. A shift to primarily warm water taxa dominated the benthic community at stations TR03 and TR01. Worms, leeches and other organisms indicating degraded water quality have comprised less than 1 percent of the macroinvertebrate community at TR09. A higher frequency of occurrence and number of worm and leech taxa were observed at downstream stations TR07, TR05, TR03 and TR01.

No threatened or endangered benthic macroinvertebrate taxa or fish species (incidentally captured during macroinvertebrate sampling) have been identified since sampling began in the Tongue River watershed in 1993. Two new taxa were identified during sampling in 2016. The genus *Musculium*, a clam in the family Pisidiidae, and the genus *Galba*, a snail in the genus Lymnaeidae have not been previously identified in the Tongue River watershed or north-central Wyoming waterbodies. Two specimens of *Musculium* were identified at station TR09 and numerous specimens of *Galba* were identified at station TR05. Smith (2001) reported that *Musculium* occurs throughout the United States. The occurrence of *Galba* was due to a change in nomenclature where the genus *Fossaria* was changed to the genus *Galba* (Johnson et al., 2013). *Fossaria* has been previously identified in samples from the Tongue River watershed.

The generally widespread occurrence of the freshwater shrimp genera *Gammarus* and *Hyalella*, and the freshwater shrimp species group *Hyalella azteca* (commonly used in laboratory toxicity tests) in the Tongue River watershed indicated that water in Tongue River and Tongue River tributaries contained no toxic substances in sufficient concentration to prevent the establishment and survival of these organisms.

The disappearance of stoneflies since the latter 1990's was noted at some mainstem Tongue River stations. Plecoptera (stoneflies) are considered one of the most pollution sensitive groups of aquatic organisms. At station TR07, from 3 to 5 Plecoptera taxa were collected each year from 1996 through 1999, but were absent from collections in 2003, 2004, 2006, and 2013. One immature stonefly in the family Perlidae was present in 2010 and one *Isoperla* was identified in the 2016 sample. No stoneflies have been collected at station TR05 since sampling began in 1995. The stonefly genus *Isoperla* was present at station TR03 in 1998, but has not been collected since then. At TR01, stonefly genera *Isoperla* and *Acroneuria* were present in 1998, but neither has been collected in samples since then. The general disappearance of stoneflies at Tongue River mainstem stations downstream of TR09 since the 1990's indicates that water quality and habitat change have negatively affected this pollution intolerant group of aquatic insects.

Whirling disease is caused by a destructive parasite that may decimate trout populations. Whirling disease has not been detected in the Tongue River watershed or nearby Little Goose Creek and Big Goose Creek watersheds. However, the disease has been detected at six locations in the adjacent Powder River watershed. *Tubifex tubifex* (a species of aquatic worm), is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout. No *T. tubifex* have been collected at Tongue River stations since monitoring began indicating a low probability for the occurrence of whirling disease. However, the presence of the genus *Tubifex* in a 2006 sample at TR07 and the presence of immature Tubificid worms in samples collected at TR01 suggest the future potential occurrence of *T. tubifex* at those locations.

Wyoming Game and Fish Department implemented an aquatic invasive species monitoring program throughout Wyoming including mandatory aquatic invasive species check stations. The program is designed to prevent the establishment of the zebra mussel (*Dreissena polymorpha)* and the quagga mussel (*Dreissena rostriformis bugensis)* in Wyoming waterbodies**.** The two clam species may produce serious negative impact to aquatic resources, ecological functions of waterbodies, drinking water intakes and water distribution systems. Although the mussels have been identified in Utah, Colorado, eastern South Dakota and eastern Nebraska, they are not present in Wyoming to date. No zebra or quagga mussels have been identified by SCCD sampling in the Tongue River watershed.

Other aquatic invasive species of significant concern currently in Wyoming include the New Zealand Mudsnail species (*Potamopyrgus antipodarum*) and the Asian Clam species (*Corbicula fluminea*). The New Zealand Mudsnail is present in Yellowstone National Park, the Snake River, Shoshone River and the Bighorn River. The distribution of the Asian Clam in Wyoming is restricted to a few locations in south-east Wyoming. Historic benthic macroinvertebrate sampling and current monitoring by SCCD have not identified the New Zealand Mudsnail or the Asian clam in the Tongue River watershed or adjacent Little Goose Creek and Big Goose Creek watersheds.

6.8 BIOLOGICAL CONDITION

The biological condition based on the benthic macroinvertebrate community was determined for each station sampled in 2016 and for those comparable stations sampled by WDEQ in 1998, 2003 and 2004. A total of forty-four (N = 44) biological condition calculations were completed and listed in Table 6-15.

Biological condition scores were derived using the Wyoming Stream Integrity Index (WSII) initially developed by Jessup and Stribling (2002), updated by Hargett and ZumBerge (2006) and Hargett (2011). The WSII is based on the analysis of benthic macroinvertebrate monitoring data collected by WDEQ from 1993 through 2009 from 1,488 reference and non-reference quality streams statewide. The WSII identified eleven bioregions for Wyoming. Each bioregion used different scoring criteria because the biological communities naturally differ between bioregions. Based on classifications provided by Hargett (2011), biological condition scoring criteria for three bioregions were used to evaluate biological condition (Table 6-13) as follows:

- Sedimentary Mountains bioregion for Tongue River location~~s~~ TR09;
- High Valleys bioregion for Tongue River location~~s~~ TR07 and TR05; and
- Northeastern Plains bioregion for Tongue River locations TR03 and TR01.

Table 6-13. Wyoming Stream Integrity Index (WSII) metrics and scoring criteria for benthic macroinvertebrate communities in the Sedimentary Mountains, High Valleys and Northeastern Plains bioregions (from Hargett, 2011)

Sedimentary Mountains Bioregion (TR09)		
Macroinvertebrate Metric	**Metric Scoring Formulae**	**5th or 95th %ile (as per formula)**
No. of EPT Taxa (less Arctopsychidae and Hydropsychidae)	100*X / 95th%ile	24
% Ephemeroptera (less Baetidae and *Tricorythodes*)	100*X / 95th%ile	43.7
% Collector-gatherer	100*(88.3-X) / (88.3-5th%ile)	14
% Scraper	100*X / 95th%ile	71.5
Number of Scraper Taxa	100*X / 95th%ile	8
HBI	100*X / 95th%ile	100
High Valleys Bioregion (TR07 and TR05)		
Macroinvertebrate Metric	**Metric Scoring Formulae**	**5th or 95th %ile (as per formula)**
% Chironomidae Taxa of Total Taxa	100*(33.3-X) / (33.3-5th%ile)	0
% Ephemeroptera Taxa of Total Taxa	100*X / 95th%ile	24
No. EPT Taxa	100*X / 95th%ile	23
% EPT (less Arctopsychidae and Hydropsychidae)	100*X / 95th%ile	81.3
% Scraper	100*X / 95th%ile	52
BCICTQa	100*(79.9-X) / (79.9-5th%ile)	54.2
Northeastern Plains Bioregion (TR03 and TR01)		
Macroinvertebrate Metric	**Metric Scoring Formulae**	**25th or 75th %ile (as per formula)**
Number of Ephemeroptera Taxa	100*X / 75th%ile	4
Number of Univoltine Taxa	100*X / 75th%ile	16
HBI	100*(6.8-X) / (6.8-25th%ile)	5.7

Metric values for the sample benthic macroinvertebrate community were compared to optimal benthic macroinvertebrate metric values (WSII) and expressed as a percent. The percentages were summed for each sample metric to provide a biological condition rating (Table6-14).

Table 6-14. Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII); (from Hargett, 2011) in the Sedimentary Mountains, High Valleys and Northeastern bioregions of Wyoming

Rating of Biological Condition (Aquatic Life Use Support)	Sedimentary Mountains bioregion	High Valleys bioregion	Northeastern Plains bioregion
Full Support	>52.25	>48.77	>58.42
Indeterminate Support	34.83-52.24	32.51 – 48.76	38.95-58.41
Partial/ (Non - Support)	0-34.82	0 – 32.50	0-38.94

The calculated biological condition rating was used to rate the biological community as Full-Support, Indeterminate, or Partial/Non-Support (Table 6-15). A biological condition rating of Full-support indicates full support for narrative aquatic life use. The Indeterminate biological classification is not an attainment category, but rather a designation requiring the use of ancillary information and/or additional data in a weight of evidence evaluation to determine a narrative assignment such as full support or partial/non-support (Hargett, 2011). The Partial/Non-support classification indicates the resident aquatic community is subjected to substantial anthropogenic stressors. Water quality and/or habitat improvements are required to restore the stream to full support for narrative aquatic life use.

TABLE 6-15. Biological condition score and rating for benthic macroinvertebrate samples collected from 1993 through 2016 from Tongue River stations based on the Wyoming Stream Integrity Index (WSII; from Hargett, 2011)

	Sedimentary Mountains Bioregion		High Valleys Bioregion		Northeastern Plains Bioregion	
Sampling Station and Year	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**
Tongue River - TR09 - Canyon (1993)[A]	70.3	Full	NA[B]	NA	NA[B]	NA
Tongue River - TR09 - Canyon (1994)[A]	58.5	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1995)[A]	52.0	Indeterminate	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1996)[A]	64.3	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1997)[A]	61.9	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1998)[A]	56.9	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1999)[A]	62.9	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (1999)[C]	63.1	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2000)[A]	55.2	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2001)[A]	66.5	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2002)[A]	72.5	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2003)	63.0	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2003)[A]	75.2	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2004)[A]	71.5	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2007)[A]	51.9	Indeterminate	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2009)[A]	59.4	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2010)	55.4	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2013)	71.6	Full	NA	NA	NA	NA
Tongue River - TR09 - Canyon (2016)	68.4	Full	NA	NA	NA	NA
Tongue River - TR07 - Co. Rd 67 (1996)	NA[B]	NA	46.6	Indeterminate	NA[B]	NA
Tongue River - TR07 - Co. Rd 67 (1997)	NA	NA	52.7	Full	NA	NA
Tongue River - TR07 - Co. Rd 67 (1998)	NA	NA	45.5	Indeterminate	NA	NA

[A] = Sample collected by WDEQ.
[B] = NA = WSII Score or Rating not applicable since sample was not collected in the bioregion.
[C] = Sample collected by USGS.

TABLE 6-15 (continued). Biological condition score and rating for benthic macroinvertebrate samples collected from 1993 through 2016 from Tongue River stations based on the Wyoming Stream Integrity Index (WSII; from Hargett, 2011)

	Sedimentary Mountains Bioregion		High Valleys Bioregion		Northeastern Plains Bioregion	
Sampling Station and Year	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**
Tongue River - TR07 - Co. Rd 67 (1999)	NA[B]	NA	48.2	Indeterminate	NA[B]	NA
Tongue River - TR07 - Co. Rd 67 (2003)	NA	NA	47.8	Indeterminate	NA	NA
Tongue River - TR07 - Co. Rd 67 (2004)[A]	NA	NA	41.7	Indeterminate	NA	NA
Tongue River - TR07 - Co. Rd 67 (2010)	NA	NA	29.8	Partial or Non	NA	NA
Tongue River - TR07 - Co. Rd 67 (2013)	NA	NA	30.4	Partial or Non	NA	NA
Tongue River - TR07 - Co. Rd 67 (2016)	NA	NA	47.9	Indeterminate	NA	NA
Tongue River - TR05 - Kleenburn (1995)[A]	NA	NA	63.6	Full	NA	NA
Tongue River - TR05 - Kleenburn (1998)[A]	NA	NA	56.0	Full	NA	NA
Tongue River - TR05 - Kleenburn (2004)[A]	NA	NA	58.0	Full	NA	NA
Tongue River - TR05 - Kleenburn (2006)	NA	NA	46.2	Indeterminate	NA	NA
Tongue River - TR05 - Kleenburn (2010)	NA	NA	48.5	Indeterminate	NA	NA
Tongue River - TR05 - Kleenburn (2013)	NA	NA	46.0	Indeterminate	NA	NA
Tongue River - TR05 - Kleenburn (2016)	NA	NA	34.0	Indeterminate	NA	NA
Tongue River - TR03 - Decker Hwy (1998)[A]	NA	NA	NA	NA	100.0	Full
Tongue River - TR03 - Decker Hwy (2004)[A]	NA	NA	NA	NA	66.7	Full
Tongue River - TR03 - Decker Hwy (2013)	NA	NA	NA	NA	73.2	Full
Tongue River - TR03 - Decker Hwy (2016)	NA	NA	NA	NA	62.7	Full
Tongue River - TR01 - State Line (1998)[A]	NA	NA	NA	NA	97.0	Full
Tongue River - TR01 - State Line (2003)[A]	NA	NA	NA	NA	75.9	Full
Tongue River - TR01 - State Line (2004)[A]	NA	NA	NA	NA	70.4	Full
Tongue River - TR01 - State Line (2013)	NA	NA	NA	NA	87.1	Full
Tongue River - TR01 - State Line (2016)	NA	NA	NA	NA	79.4	Full

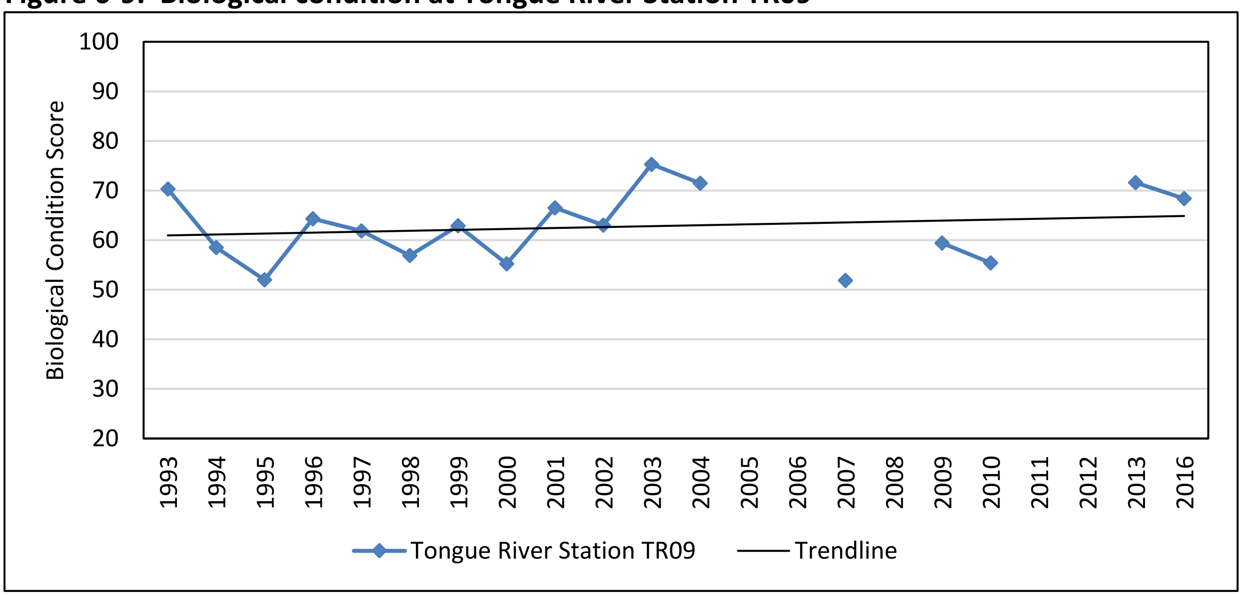
[A] = Sample collected by WDEQ.
[B] = NA = WSII Score or Rating not applicable since sample was not collected in the bioregion.
[C] = Sample collected by USGS.

6.8.1 *TONGUE RIVER TR09*

The Tongue River TR09 station represents the most upstream monitoring site on the mainstem Tongue River and is located in the Sedimentary Mountains bioregion. The station is identified as the reference, or control station, for macroinvertebrate monitoring on the mainstem Tongue River. The Tongue River TR09 station has been sampled annually for benthic macroinvertebrates from 1993 through 2004, and in 2007, 2009, 2010, 2013 and 2016 (Table 6-15). This station has been sampled by SCCD, WDEQ, USGS and EPA over the years and represents the most frequently sampled benthic macroinvertebrate station in north central Wyoming. It should be noted that data collected by EPA was not used to determine biological condition for this report since sampling and analysis methods were not directly comparable to those methods used by SCCD and WDEQ.

Biological condition scores have varied little over the years ranging from a score of 75.2 in 2003 to a score of 51.9 in 2007 (Table 6-15; Figure 6-9). With the exception of 1995 and 2007, the biological condition scores consistently indicated full support for aquatic life use. It should be noted that the biological condition scores in 1995 (52.0) and 2007 (51.9) were very close to achieving the full support score of 52.2. The slightly positive trendline shown in Figure 6-9 for biological condition indicates stability in the biological community and confirms that station TR09 is a representative reference station. The general stability in biological condition over the years indicated that despite variable stream flows and likely variable water temperature among years, water quality and habitat remained consistently good.

Figure 6-9. Biological condition at Tongue River Station TR09



The benthic community at Tongue River TR09 station was generally dominated by cool water taxa indicative of good water quality and good habitat. Worms, leeches and other organisms indicating degraded water quality comprised less than 1 percent of the macroinvertebrate community over the years. No *Tubifex tubifex* (a species of worm) have been collected at Tongue River TR09 since monitoring began in 1993 indicating a low probability for the occurrence of whirling disease.

The benthic macroinvertebrate data indicated that land use occurring upstream in the Bighorn National Forest (BNF) had no measurable effect on the Tongue River TR09 benthic macroinvertebrate community. Potential pollutants that may enter the Tongue River from BNF are apparently removed by natural stream processes resulting in good year-round water quality and healthy biological communities. The high biological condition scores confirmed the overall good water quality shown through water quality sampling, habitat assessment, and the resultant general full support for aquatic life use.

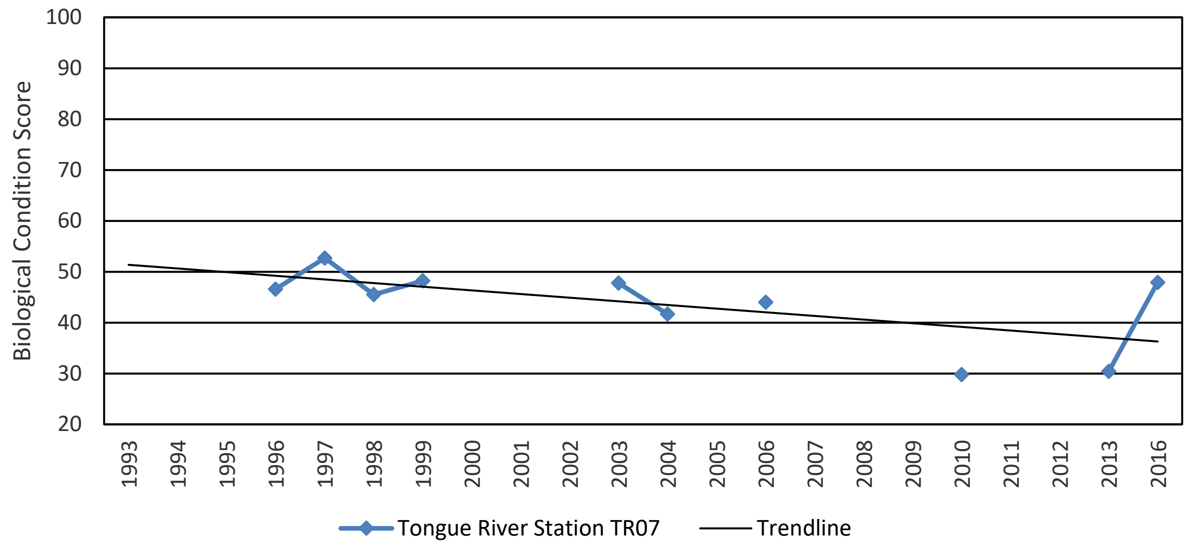
6.8.2 Tongue River TR07

The Tongue River TR07 station is located just upstream of the County Road 67 bridge near Ranchester, WY and is placed in the High Valleys bioregion near the lower boundary of the Sedimentary Mountains bioregion. The Tongue River TR07 station has been sampled annually for benthic macroinvertebrates from 1996 through 1999, and in 2003, 2004, 2006, 2010, 2013 and 2016 (Table 6-15). The sample collected by WDEQ in 2004 was comparable to samples collected by SCCD at TR07 since the WDEQ sampled in Conner Park about 250 yards downstream of SCCD location TR07.

The biological condition of the benthic macroinvertebrate community at Tongue River TR07 station varied little from the period of 1996 through 1999 (Table 6-15; Figure 6-10). Biological condition scores ranged from 46.6 in 1996 to 52.0 in 1997. The biological condition scores indicated indeterminate or full support for aquatic life use each year.

In 2003, the biological condition score dropped to 47.8 with further declines to 41.7 in 2004, 29.8 in 2010 and 30.4 in 2013 (Figure 6-10). The biological condition increased to 47.9 in 2016. Aquatic life use dropped from full support in 1997 to indeterminate or partial or non-support during subsequent years (Table 6-15). Although the improvement in biological condition from 2013 to 2016 was encouraging, the negative trendline shown in Figure 6-10 indicated a general decline in the biological condition since sampling began in 1996.

Figure 6-10. Biological condition at Tongue River Station TR07



The decline in biological condition was due to an increase in pollution tolerant organisms and a decrease in organisms sensitive to pollution. The total number of Non-Insect Taxa (generally more tolerant of pollution than Insect Taxa) and the HBI value (general community measure of pollution tolerant organisms) has been relatively high (Appendix Table C-9). Further, the number of Chironomidae taxa has generally increased since 1996. As previously noted was the near disappearance of Plecoptera (stoneflies) at Tongue River TR07 after 1999. Plecoptera are considered to be the most pollution sensitive group of aquatic organisms. From 3 to 5 Plecoptera taxa were collected each year from 1996 through 1999, but were absent from collections in 2003, 2004, and 2006 and 2013. One immature stonefly in the family Perlidae was present in 2010. Some Ephemeroptera (mayfly) taxa including the genera *Drunella* and *Ephemerella* (both indicative of good water quality and cooler water temperature) have nearly disappeared at Tongue River TR07 station since 1999.

The highest number of worm and leech taxa (N = 8 taxa) comprising 2.48% of the total benthic community occurred at Tongue River TR07 during 2006. In 2013 there were 5 worm and leech taxa comprising 4.19% of the total benthic community. Increase in the density of worms may be associated with organic pollution (Klemm, 1985), pollution from feedlots (Prophet and Edwards, 1973), and pollutants contained in urban storm water runoff (Lenat et al., 1979; Lenat and Eagleson, 1981). The number of worm taxa and percent contribution of worms in 2006 and 2013 did not indicate a severe pollution problem, but rather a moderate amount of pollution indicative of animal waste from agricultural, wildlife or urban sources.

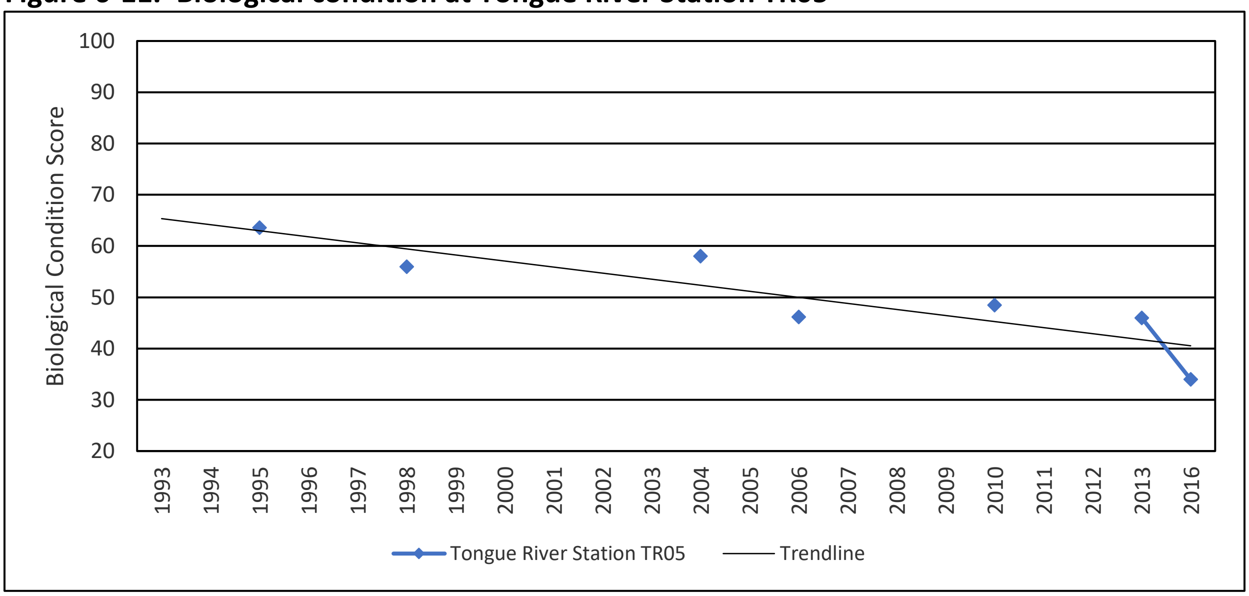
Tubifex tubifex (a species of worm) has not been collected at Tongue River TR07 station since monitoring began in 1996. However, the presence of the genus *Tubifex* in the 2006 sample

suggests the future potential occurrence of *T. tubifex* at Tongue River TR07.
The reasons for the general reduction in biological condition and the loss of cool water macroinvertebrate taxa at Tongue River TR07 since 1999 are unknown. An increase in the amount of sand in the stream substrate and relatively high embeddedness (amount of silt covering cobble and gravel) noted during 2006 in Section 7.6 in SCCD (2007) may produce adverse effects on the river benthic macroinvertebrate community and other aquatic organisms including fish. However, the combined amount of sand and silt at Tongue River TR07 station was low (1%) in 2010 suggesting that the lower biological condition rating in 2010 was not due to combined silt and sand or embeddedness. The combined amount of sand and silt in the substrate increased in 2013 (10%) (Appendix Table E2). The ongoing drought in northeast Wyoming from approximately 2000 to 2009 undoubtedly produced a negative effect on the aquatic communities in the Tongue River by reducing stream flow and likely increasing water temperature.

6.8.3 Tongue River TR05

The Tongue River TR05 station at the Kleenburn County Park was formerly known as Tongue River TR1 station. SCCD sampled TR05 for benthic macroinvertebrates in 2006, 2010, 2013 and 2016. WDEQ previously established a site identified as Tongue River at Kleenburn in 1995. WDEQ sampled this site in 1995, 1998 and 2004. The station is located in the High Valleys bioregion.

Figure 6-11. Biological condition at Tongue River Station TR05



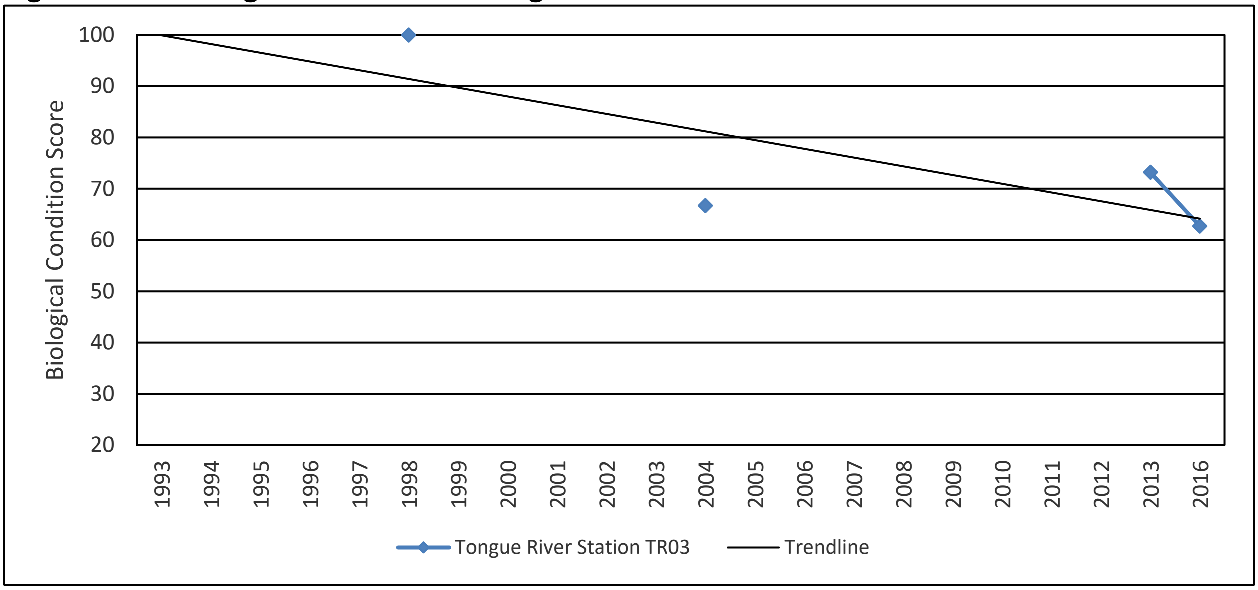
The biological condition scores at station TR05 ranged from a low of 34.0 in 2016 to a high of 63.6 in 1995 (Table 6-15). Sampling in 1995, 1998 and 2004 indicated full support for aquatic life use. Sampling in 2006, 2010, 2013 and 2016 indicated indeterminate support for aquatic life use. The trendline shown in Figure 6-11 indicates a gradual downward trend in biological condition since sampling in 1995. The downward trend in biological condition was primarily due to a reduction percentage of mayfly taxa to the total number of taxa in the benthic community, a reduction in the number of EPT taxa and a reduction in the percent of scrapers.

The benthic macroinvertebrate community was dominated by warm water taxa each year. The mayfly genus *Tricorythodes* dominated the community in 1998, 2006 and 2016, and was the second most dominant taxon in the community in 1995. The riffle beetle genus *Microcylloepus* co-dominated the community in 2006, and was the second most dominant taxon in the community in 2010. Trichoptera (caddisflies) were well represented in the benthic community each year. The genera *Helicopsyche, Hydropsyche* and *Cheumatopsyche* were the most common caddisfly taxa. *Helicopsyche* dominated the benthic community in 2004 and 2013. Several specimens in the stonefly genus *Isoperla* and one immature stonefly in the family Capniidae was present in 1998, but no stoneflies have been collected in samples since then. The disappearance of stoneflies since the latter 1990's was noted at other mainstem Tongue River stations.

6.8.4 Tongue River TR03

The Tongue River TR03 station located upstream of the Decker Highway bridge crossing was established and first sampled by SCCD in 2013. WDEQ previously established a site identified as Tongue River at Decker Highway in 1998. WDEQ sampled that site in 1998 and 2004. The station is located in the Northeastern Plains bioregion. The biological condition scores ranged from a low of 62.7 in 2016 to a high of 100.0 in 1998 (Table 6-15). Sampling in 1998, 2004, 2013 and 2016 indicated full support for aquatic life use. However, Figure 6-12 shows that there has been a downward trend in biological condition.

Figure 6-12. Biological condition at Tongue River Station TR03

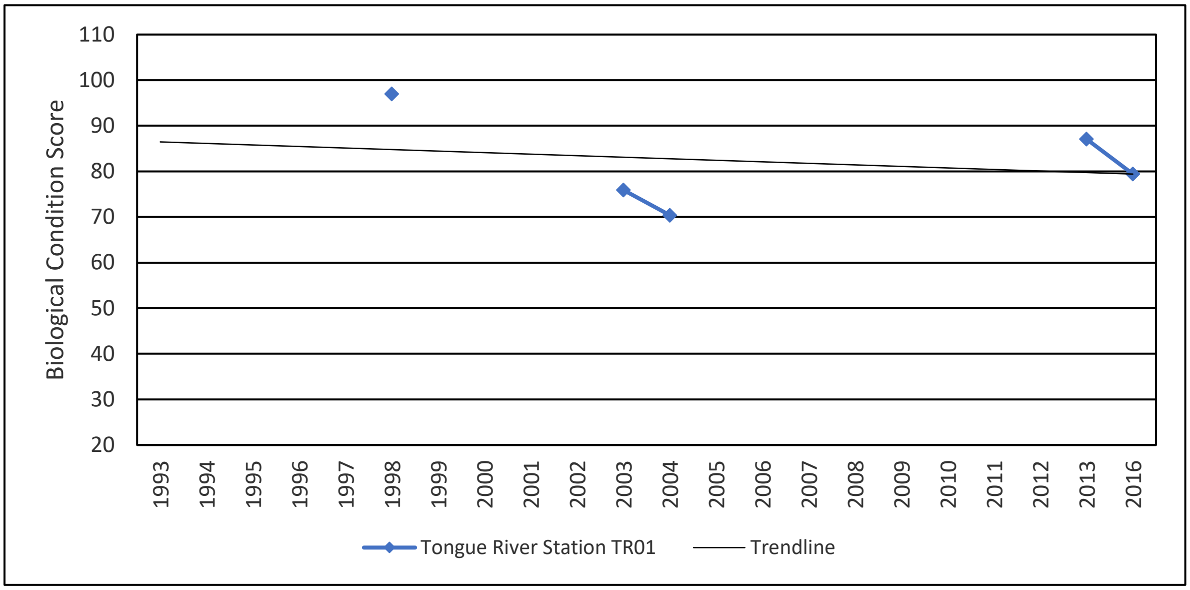


The benthic macroinvertebrate community was dominated by warm water taxa each year. The mayfly genus *Tricorythodes* dominated the community in 1998 and 2016, and was the second most dominant taxon in the community in 2004 and 2013. The riffle beetle genus *Microcylloepus* dominated the community in 2004 and 2013, and was the second most dominant taxon in the community in 1998 and 2016. Trichoptera (caddisflies) were well represented in the benthic community each year. The genera *Hydropsyche*, *Helicopsyche* and *Oecetis* were the most common caddisfly taxa in 1998, 2004, 2013 and 2014. The stonefly genus Isoperla was present in 1998, but has not been collected in samples since then. The disappearance of stoneflies since the latter 1990's was noted at other mainstem Tongue River stations.

6.8.5 Tongue River TR01

The Tongue River TR01 station near the Wyoming – Montana border in the Northeastern Plains bioregion is the lowermost sampling station on the mainstem Tongue River within the project area. SCCD established and first sampled this station in 2013. WDEQ previously established a site identified as Tongue River – State Line in 1998. WDEQ sampled that site in 1998, 2003 and 2004. The WDEQ station is located near U.S. Geological Survey Station 06306300 downstream of SCCD station TR01. Biological condition at Tongue River TR01 was relatively stable from 1998 to 2003, but declined from 2003 to 2014 and from 2014 to 2016 (Figure 6-13).

Figure 6-13. Biological condition at Tongue River Station TR01



The biological condition scores ranged from a low of 70.4 in 2004 to a high of 97.0 in 1998 (Table 6-15). Sampling during each year indicated full support for aquatic life use. WDEQ concurred with this finding, but added that effects due to stressors such as temperature, sulfates, nutrients, and sediment were present (WDEQ, 2002). These stressors appeared to affect the mainstem Tongue River system below the confluence with Goose Creek (between Tongue River stations TR05 and TR03). The biological condition trendline shown in Figure 6-13 indicated that biological condition has declined over time. Full support for aquatic life use may change should the decline in biological condition continue.

The benthic macroinvertebrate community was dominated by warm water taxa each year. No one taxon has dominated the benthic community over the years. The mayfly genera *Tricorythodes* and *Fallceon* were abundant at times along with the caddisfly genera *Hydroptila* and *Oecetis*, and the chironomid genus *Rheotanytarsus*. The riffle beetle genus *Microcylloepus* was the second most abundant taxon in 2016. Immature Tubificid worms were abundant in 1998. The stonefly genera *Isoperla* and *Acroneuria* were present in 1998, but have not been collected in samples since then. The disappearance of stoneflies since 1998 was noted at other mainstem Tongue River stations upstream of TR01.

Tubifex tubifex (a species of worm) has not been collected at Tongue River TR01 station since monitoring began in 1998. However, the presence of immature Tubificid worms in all samples collected over the years suggests the potential occurrence of *T. tubifex* at Tongue River TR01.

6.8.6 *Summary of Biological Condition*

The collection and analysis of stream benthic macroinvertebrate samples during 2016 revealed similar trends in biological condition observed during previous monitoring at Tongue River mainstem stations. No Tongue River tributary stations were sampled during this 2016 report period.

Biological condition scores at reference station TR09 varied little over the years. With the exception of 1995 and 2007, the biological condition scores consistently indicated full support for aquatic life use. It should be noted that the biological condition scores in 1995 (52.0) and 2007 (51.9) were very close to achieving the full support score of 52.2. The slightly positive trendline at station TR09 for biological condition indicated stability in the biological community and confirmed that station TR09 was a representative reference station.
The biological condition of the benthic macroinvertebrate community at Tongue River TR07 station varied little from the period of 1996 through 1999. Biological condition scores ranged from 46.6 in 1996 to 52.0 in 1997. The biological condition scores indicated indeterminate or full support for aquatic life use each year. There was an improvement in biological condition from 2013 to 2016; however, a negative trendline indicated a general decline in the biological condition since sampling began in 1996.

The biological condition scores at station TR05 in 1995, 1998 and 2004 indicated full support for aquatic life use. Sampling in 2006, 2010, 2013 and 2016 indicated indeterminate support for aquatic life use. The negative trendline graph for biological condition indicated a gradual downward trend in biological condition since sampling in 1995.

Biological condition scores at the most downstream station TR01 located near the Montana border indicated full support for aquatic life use during each year since 1998. However, a graph of biological condition scores indicated that biological condition has declined over time. Full support for aquatic life use may change should the decline in biological condition continue.

Those stations that have the partial or non-support classification for biological condition indicated the aquatic communities were stressed and water quality or habitat improvements were required to restore the stream to full support for the narrative WDEQ standard for aquatic life use. Planning and implementation of remedial measures must continue to restore full aquatic life use support in the streams in the Tongue River watershed. Continued benthic macroinvertebrate sampling should be conducted at stations in the watershed to track changes in biological condition.

No threatened or endangered benthic macroinvertebrate taxa or fish species have been identified since sampling began in the Tongue River watershed in 1993. The generally widespread occurrence of freshwater shrimp genera indicated that water in Tongue River contained no toxic substances in sufficient concentration to prevent the establishment and survival of these organisms.

The disappearance of stoneflies since the latter 1990's noted at some mainstem Tongue River stations continued. The general disappearance of stoneflies at Tongue River stations downstream of TR09 since the 1990's indicates that water quality and habitat change have negatively affected this pollution intolerant group of aquatic insects.

Historic and SCCD monitoring of aquatic benthic macroinvertebrate communities in the Tongue River watershed have not identified the presence of aquatic invasive species of concern to the WGFD. No zebra mussel (*Dreissena polymorpha)*, quagga mussel (*Dreissena rostriformis bugensis),* New Zealand Mudsnail (*Potamopyrgus antipodarum)* and the Asian Clam (*Corbicula fluminea*) have been identified in the Tongue River watershed or adjacent Little Goose Creek and Big Goose Creek watersheds. Recommended future benthic macroinvertebrate monitoring by SCCE will be attentive to the presence of aquatic invasive species.

Tubifex tubifex, a species of aquatic worm*,* involved in the whirling disease life cycle that may decimate trout populations, have not been collected at Tongue River stations since monitoring began in 1993 indicating a low probability for the occurrence of whirling disease. However, the presence of the genus *Tubifex* and immature Tubificid worms in samples collected in the Tongue River watershed suggest the future potential occurrence of *T. tubifex*. Whirling disease has not been detected in the Tongue River watershed or nearby Little Goose Creek and Big Goose Creek watersheds. However, the disease has been detected at six locations in the adjacent Powder River watershed to the east. *Tubifex tubifex* (a species of aquatic worm)*,* is significantly involved in the whirling disease life cycle caused by a parasite (*Myxobolus cerebralis*) that penetrates the head and spinal cartilage of fingerling trout. Whirling disease may eventually cause death in trout.

6.9 Habitat Assessments

Qualitative habitat assessments were conducted by SCCD during 2016 at mainstem Tongue River stations TR09, TR07, TR05, TR03 and TR01. WDEQ used the same habitat assessment method as that used by SCCD through 2004. WDEQ changed their habitat assessment methods after 2004, thus no habitat data is presented for WDEQ assessments after that time. Habitat assessment data, substrate data, and embeddedness (silt cover) data for Tongue River mainstem stations are presented in Appendix Tables E-1 through E-5. Because habitat assessments were subjective, SCCD used caution by providing a conservative interpretation of data.

The average habitat score at reference station Tongue River TR09 from 1993 through 2004, 2010, 2013 and 2016 was 170 (Appendix Table E-1). The range in annual habitat scores at Tongue River TR09 station was from 150 in 2010 and 2016 to 184 in 2003. Although assessments were generally conducted on sampling dates within $\pm$ two (2) weeks of one another each year, differences in annual discharge affected scoring for some habitat parameters because they were flow dependent. Scores for instream cover, velocity / depth, channel flow status and width depth ratio will normally score higher when discharge is increased, but will score lower when discharge is decreased.

The average habitat score at Tongue River TR07 station from 1996 through 1999, 2003, 2004, 2006, 2010, 2013 and 2016 was 139 (Appendix Table E-2). Scores at TR07 ranged from 108 in 2006 to 163 in 2016. Variation in habitat scores between years appeared to be primarily related to difference in annual stream discharge at the time that the habitat assessment was conducted.

The reduction in habitat score from the reference upstream station TR09 to the downstream Tongue River TR07 station was generally due to lower scores for embeddedness (silt cover on or surrounding cobble and gravel), channel flow status, channel shape, channelization, width depth ratio and bank stability. Reduced scores for some of these parameters were related not only to current land use practices, but to lingering effects from the period of extensive channelization that apparently occurred in the late 1950's to early 1960's. Effects of channelization from that period continue to affect the Tongue River stream channel to this day requiring patch work repair and bank stabilization projects. Despite the lower habitat score at Tongue River TR07 station, this station ranked high when compared to habitat scores at other Wyoming streams in the Sedimentary Mountains bioregion. This observation indicated that although Tongue River in-stream and riparian habitat have been altered due to channelization, habitat was still in better condition when compared to most Wyoming streams in the Sedimentary Mountains bioregion.

The semi-quantitative stream substrate particle size distribution varied little between the Tongue River TR09 and TR07 stations. Cobble dominated the stream substrate at each station. Average percent cobble was 66 percent at station TR09 and 55 percent at station TR07 (Appendix Tables E-1 through E-2). Average percent coarse gravel ranged from 17 percent at Tongue River TR09 to 27 percent at TR07. Silt deposition was minimal. The Tongue River TR09 station averaged less than 1 percent silt in the stream substrate and TR07 station averaged 1 percent. Sand comprised 6 percent of the average total substrate at both TR09 and TR07 stations. The amount of silt and sand in the stream substrate is important since silt and sand are detrimental to trout egg survival and maintenance of healthy benthic macroinvertebrate populations that provide food for trout (Chutter, 1969). The dominance of cobble and coarse gravel at each station allowed comparison of macroinvertebrate communities between stations because the variability caused by potential differences in the stream substrate was minimal.

Embeddedness (silt covering on or surrounding cobble and gravel) was low at the upstream reference Tongue River TR09 station. Average weighted embeddedness at TR09 from 1996 through 1999, 2003, 2004, 2006, 2010, 2013 and 2016 was 95.2. The higher the weighted embeddedness value, the lower the embeddedness or amount of silt deposited on cobble and gravel. The weighted embeddedness value of 95.2 indicated that about 95 percent of the surface of cobble and gravels were free of silt. The average weighted embeddedness at Tongue River TR07 station for the period of 1996 through 1999, 2003, 2004, 2006, 2010, 2013 and 2016 was 49.9 indicating that about 38 percent of the surface of cobble and gravels were free of silt.

The decrease in weighted embeddedness from Tongue River TR09 station to downstream TR07 station indicated increased deposition of silt on cobble and gravel stream substrate between stations. Deposition of silt is controlled by the amount of silt contained in the water column and by the current velocity. Silt deposition will normally increase as current velocity decreases. The average current velocity measured at Tongue River TR09 station was 2.02 feet per second (fps) and 2.16 fps at the TR07 station. Because average water current velocity was slightly higher at the Tongue River TR07 station when compared to the upstream TR09 station, the apparent increased silt deposition at TR07 station was not related to difference in current velocity, but was due to increased amount of silt contained in the water column.

The general decrease in substrate particle size from the Tongue River TR09 to the Tongue River TR07 station was normal because particle size generally decreases as stream size and stream order increase (Rosgen, 1996). The observed increase in embeddedness from the TR09 station to the TR07 station was likewise considered normal for the size and stream order of the Tongue River. Embeddedness at the TR07 station should be considered moderate when compared to weighted embeddedness values at other comparable streams in the High Valleys bioregion.

The habitat assessments conducted at Tongue River TR05 station at the Kleenburn Park indicated similar habitat characteristics to the upstream Tongue River TR07 station. The average habitat score at the Tongue River TR05 station for sampling years 1995, 1998, 2004, 2006, 2010, 2013 and 2016 was 139 (Appendix Table E-3). Total habitat assessment scores at Tongue River TR05 ranged from 147 in 1998 to 127 and 127 in 2004. Although the Tongue River TR05 station was several miles downstream of TR07, the habitat quality was similar at both stations.

The semi-quantitative stream substrate particle size distribution indicated that Tongue River TR05 was dominated by cobble (47percent of substrate) and coarse gravel (28 percent of substrate) (Appendix Table E-3). Silt deposition was minimal and comprised an average of 2 percent of the stream substrate. Sand accounted for about 6 percent of the substrate. The average embeddedness was 50.8 indicating that about 40 percent of the surface of cobble and gravels were free of silt. The average measured current velocity was 2.00 fps.

Tongue River TR03 located just upstream of the Decker Highway bridge crossing was a newer monitoring station established by SCCD in 2013. WDEQ conducted sampling at this station in 1998 and 2004.

The total habitat scores at Tongue River TR03 station in 1998, 2004, 2013 and 2016 were 114, 133, 131 and 134 respectively (Appendix Table E-4). The relatively low habitat assessment score was due to high embeddedness (the amount of silt covering cobble and gravel), low pool to riffle ratio, low width to depth ratio, high disruptive pressures and low riparian width.

The semi-quantitative stream substrate particle size distribution at Tongue River station TR03 showed a reduction in cobble to more coarse and fine gravel when compared to upstream stations TR09, TR07 and TR05. Cobble comprised an average of 31 percent, coarse gravel 32 percent and fine gravel 22 percent of substrate since 1998 (Appendix Table E-4). Silt deposition was minimal and comprised an average of 2 percent of the stream substrate. Sand accounted for about 6 percent of the substrate. The average embeddedness value was 49.6 indicating that about 37 percent of the surface of cobble and gravels were free of silt. The average measured current velocity was 1.29 fps.

The Tongue River TR01 station near the Wyoming – Montana border was established and sampled by SCCD in 2013. WDEQ previously sampled a site downstream of Tongue River TR01 in 1998. The WDEQ station was identified as Tongue River – State Line and was sampled in 1998, 2003 and 2004.

The average total habitat assessment score at TR01 was 134 with a range from 127 in 2013 to 137 in 2004 (Appendix Table E-5). The stream substrate was dominated by cobble (average 40 percent) followed by coarse gravel (average 33 percent), fine gravel (average 15 percent), sand (average 11 percent) and silt (average 1 percent). The average embeddedness score was 35.7 indicating that about 80 percent of the surface of cobble and gravels were covered or surrounded by silt. The average measured current velocity was 1.49 fps.

The riparian indicator parameters including bank vegetation, bank stability, disruptive pressures and riparian zone width scored relatively high indicating that the stream banks were stable, well vegetated, and utilization of bank vegetation was low.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

Water quality monitoring for 2016 was performed at 13 stations; six sites on the mainstem of the Tongue River, and seven sites on the major tributaries that flow into the Tongue River. These seven tributaries included Smith Creek, Little Tongue River, Columbus Creek, Five Mile Creek, Wolf Creek, Goose Creek, and Prairie Dog Creek. Stations were equipped with a SCCD calibrated staff gauge or located at USGS gauging stations.

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at 12 of the 13 sites on at least one occasion; the uppermost station (TR09) did not have any temperature measurements above 20°C. Continuous temperature loggers reported temperatures above 20°C at all but the uppermost station in Tongue River Canyon. Conductivity and pH were within the expected ranges during 2016. Turbidity values were considered normal for the watershed with occasional high values occurring during late-spring, early summer precipitation and run-off events. All sites met the minimum instantaneous dissolved oxygen concentration for early and other life stages. Four tributary stations and four mainstem stations had one or more samples that were below the 8.0 mg/L water column concentration recommended to achieve the inter-gravel concentrations for early life stages.

Bacteria geometric mean concentrations in the early season were typically higher than in the late season on tributary sites. In contrast, mainstem sites had higher bacteria concentrations in the late season except on TR03 and TR09. While some mainstem sites did not meet Wyoming Water Quality Standards, the highest bacteria concentration observed at a mainstem site was 169 cfu/100 mL or 25% above the standard. Bacteria concentrations at tributary stations appeared to contribute to bacteria increases on the Tongue River at adjacent downstream stations in the upper portion of the watershed during the early season. Except for Wolf Creek during the late season, bacteria concentrations at all tributary stations exceeded Wyoming Water Quality standards in both the early season and the late season.

For the most part, bacteria concentrations decreased from 2003-2016 and from 2013-2016 at all mainstem sites in the early season but increased in the late season. In contrast, bacteria concentrations at TR09 in the early season increased since 2003, but were still well below Wyoming Water Quality standards.

With the exception of upstream reference station TR09, biological condition has trended lower since the 1990’s at downstream stations TR07, TR05, TR03 and TR01. No threatened or endangered benthic macroinvertebrate taxa or fish species have been identified since sampling began in 1993. The general disappearance of stoneflies at Tongue River stations downstream of TR09 since the 1990’s indicates that water quality and habitat change have negatively affected this pollution intolerant group of aquatic insects.

Monitoring of aquatic benthic macroinvertebrate communities in the Tongue River watershed since 1993 have not identified the presence of aquatic invasive species of concern to the WGFD including zebra mussel, quagga mussel, New Zealand mudsnail and the Asian Clam. Recommended future benthic macroinvertebrate monitoring by SCCD will be attentive to the presence of aquatic invasive species.

Tubifex tubifex, a species of aquatic worm*,* involved in the whirling disease life cycle that may decimate trout populations, have not been collected at Tongue River stations since monitoring began indicating a low probability for the occurrence of whirling disease. However, the presence of the genus *Tubifex* and immature Tubificid worms at some stations suggest the future potential occurrence of *T. tubifex*. Whirling disease has not been detected in the Tongue River watershed or nearby Little Goose Creek and Big Goose Creek watersheds.

Continued benthic macroinvertebrate sampling should be conducted at stations in the Tongue River watershed to track the health of aquatic communities, changes in biological condition, potential occurrence of aquatic invasive species and presence of indicator species associated with whirling disease.

Attempts to determine if improvements in overall water quality have been achieved are often difficult, especially when comparing water quality data that has been collected during seasons with different hydrological and meteorological conditions. Although normal flow conditions cannot be anticipated nor expected during monitoring, these varying conditions do make water quality comparisons more difficult. Bacteria concentrations, in particular, are known to vary in response to a number of different water quality and water quantity factors, including changes in water temperature, water quantity, and suspended sediment loads. Higher *E. coli* bacteria concentrations in May could be associated to precipitation events in the spring, including run-off from snowmelt, that contribute surface contaminants and increases their concentrations. Bacteria deposits from livestock, humans, wildlife, and other sources can be transported from upland areas to streams through overland run-off. In addition, deeper, faster moving water within the stream channels can scour and suspend sediment that has been previously deposited on the channel bottom. These bed sediments have been found to contain elevated levels of bacteria. Rangeland studies in Idaho have shown that *E. coli* concentrations can be 2 to 760 times greater in bottom sediment than in the water column (Stephenson and Rychert, 1982). A similar study on the Goose Creek watershed showed up to 3-fold increases of fecal coliform bacteria when disturbing the bed sediment (SCCD, 2003). The approximate duration for which sediment dwelling bacteria populations can remain viable is unknown.

From 2000 through 2006, the local area was in a prolonged drought and below average stream discharge conditions were experienced. Years 2001 and 2002 lacked adequate peak flows during May and June which normally “flush” stream channel sediment accumulated during the previous year. During 2003 and 2010, the Tongue River experienced higher than normal peak flows, which may have had the ability to “flush” streambed sediment that had accumulated during the several previous drought years. Flows in 2013 and 2016 were generally below normal at most stations, especially during the early season.

The positive effects that improvement projects have on water quality may not be immediately determined due to factors such as the bacteria storage capacity of bed sediment, which is normally suspended during bankfull flows. This bacteria “storage” in bed sediments and their annual release during high flows may cause a delay in observing quantifiable changes in bacteria currently entering the system. The data provided by the 1996 – 1999 watershed assessment and subsequent interim monitoring indicate the need for additional improvement projects as well as additional future monitoring to create and measure positive water quality changes. The SCCD anticipates that voluntary, incentive based watershed planning and implementation will be successful; however, it may require several years to actually measure these achievements. Nonetheless, each improvement project that has been implemented or is currently being implemented on the watershed certainly induces positive water quality changes, whether they are immediately apparent or not.

SCCD will continue to monitor water quality in the Tongue River Watershed on a three-year rotation, pending available funding sources. Planning and implementation of remedial measures to restore full aquatic life use support in the streams in the Tongue River watershed should continue. Continued benthic macroinvertebrate sampling should be conducted at stations in the watershed to track potential changes in biological condition.

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APPENDICES

APPENDIX A

Tongue River 2016 Watershed Maps

APPENDIX B

2016 Tongue River Watershed Quality Assurance/Quality Control Documentation

APPENDIX C

2016 Tongue River Watershed
Water Quality Data

APPENDIX D

2016 Tongue River Watershed Macroinvertebrate Data

APPENDIX E

2016 Tongue River Watershed
Habitat Assessment Data

APPENDIX F

2016 Tongue River Watershed Photos