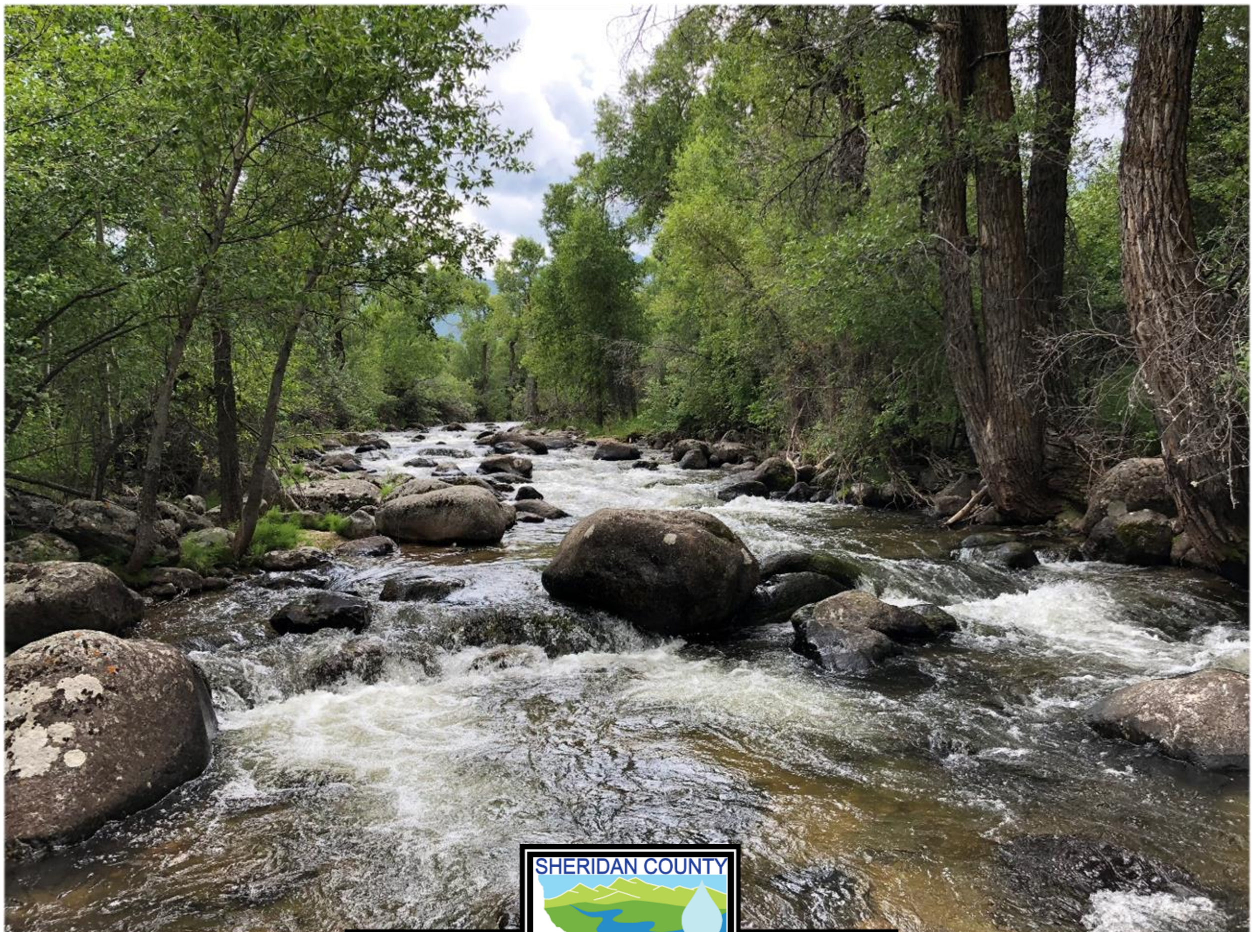

SHERIDAN COUNTY CONSERVATION DISTRICT

• ESTABLISHED 1972 •

2018 Goose Creek Watershed Interim Monitoring Project

Final Report

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EXECUTIVE SUMMARY

The Goose Creek Watershed encompasses 267,520 acres (418 square miles) in Sheridan County located in north-central Wyoming. Big Goose Creek and Little Goose Creek originate in the Big Horn Mountains in the Bighorn National Forest (BNF) west of Sheridan. The creeks pass through the unincorporated town of Big Horn, several ranches, and rural subdivisions before joining to form Goose Creek within the City of Sheridan. Goose Creek continues north to its confluence with the Tongue River near the old Acme town site. Soldier Creek is the only major tributary to Goose Creek below the confluence of Big and Little Goose Creeks. Major tributaries to Big Goose Creek include Rapid Creek, Park Creek, and Beaver Creek. Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek are the major tributaries to Little Goose Creek.

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 boundary. Below the BNF, the Goose Creek watershed is predominately rangeland, with irrigated crop and hay lands along the streams and tributaries. Ranching operations within the Goose Creek Watershed contain irrigated hay and crop lands, as well as pastureland for cattle grazing and corrals for feeding. In rural residential/small acreage areas, there may be more horses and domestic animals other than cattle. Subdivisions, converted from rural areas that are occasionally prime farmlands, are becoming more common along Big and Little Goose Creek. Big game, waterfowl, and other wildlife habitat can also be found on privately owned lands. The municipal water supply for the City of Sheridan and surrounding area is in the upper portion of the Goose Creek Watershed.

Accessible to over 30,000 Sheridan County residents, these streams and their tributaries are used extensively throughout the year. Local citizens of all ages commonly recreate on these streams, especially in Sheridan's city parks and along recreational pathways. Due to their extensive use, easy access, and direct contact with the public it is essential that these waterways are of the highest quality.

Streams in the Goose Creek Watershed are classified as 2AB. Class 2AB waters are perennial waterbodies expected to support drinking water supplies (when treated), fish, and aquatic life, recreation, wildlife, industry, and agricultural uses (WDEQ, 2018d). Some tributaries and other draws, which may be Class 3B surface waters, are not expected to support fish populations or drinking water supplies. Big Goose Creek, Little Goose Creek, Goose Creek and several of the associated tributaries have been identified as impaired for recreational use support because of high bacteria concentrations. All impaired segments (including tributaries) were addressed in the Goose Creek Watershed TMDL, which was completed in September 2010.

Past sampling efforts in the Goose Creek Watershed started several decades ago by the United States Geological Survey (USGS) and the WDEQ. Since then, the SCCD, in partnership with USDA Natural Resources Conservation Service (NRCS), Sheridan County, and the City of Sheridan, has done extensive work to try to understand and address water quality concerns in the Goose Creek Watershed. In 2001-2002, SCCD conducted the Goose Creek Watershed Assessment, in partnership with Sheridan County and the City of Sheridan. Interim monitoring was also

conducted in 2005, 2009, 2012, 2015 and in 2018 to evaluate changes in water quality over the long-term. During interim monitoring, samples were collected at fewer stations and for fewer parameters than the initial assessment.

Watershed planning was initiated during the fall of 2003 and concluded in December 2004 with the development of the Goose Creek Watershed Management Plan. The plan included goals and objectives such as the continuation of local improvement programs offered by the SCCD-NRCS to address bacteria and sediment contributions from livestock facilities, septic systems, unstable stream banks, and stormwater run-off. Despite efforts to increase awareness and installation of improvement projects, levels of bacteria within the Goose Creek Watershed continued to exceed water quality standards. In the summer of 2008, WDEQ decided to move forward with the development of a TMDL on the Goose Creek watershed, which was completed in September of 2010. The Goose Creek Watershed TMDL and associated implementation strategies include continued water quality monitoring to evaluate whether planning and improvement efforts are impacting water quality over the long-term.

The purpose of this project was to complete the 2018 interim monitoring milestone in the Goose Creek Watershed Improvement Effort Implementation Strategy, which was developed by the local steering committee to address recommendations in the Goose Creek Watershed TMDL. 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.

In 2018, SCCD monitored water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli* at 18 stations. Continuous water temperature data loggers were used to monitor temperature at 15 minute intervals at seven stations. Macroinvertebrate sampling and habitat assessments were also performed at eight stations. Of the 18 stations, there were two sites on Goose Creek, four on Big Goose Creek, four on Little Goose Creek, and one each on Soldier Creek, Beaver Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek.

Instantaneous water temperatures were recorded above the maximum 20°C instream standard at most of the lower and mid-watershed mainstem stations and on five tributaries during various dates from June-August. Continuous temperature loggers recorded temperatures that exceeded the standard at all stations except for the uppermost station in Little Goose Canyon. All pH values were within the standard of 6.5-9.0 SU. For the most part, conductivity was within the expected range at all stations, apart from two tributary stations. Two mainstem stations and five tributary stations did not meet the dissolved oxygen standard of 8.0 mg/L. High discharge in late May-early June corresponded to higher than normal precipitation for the period. Turbidity values were considered normal for the watershed with occasional high values occurring during late spring, early summer precipitation and run-off events.

Bacteria concentrations were typically lower in the early season than in the late season at Goose Creek and Big Goose Creek stations. Concentrations at Little Goose Creek stations were more variable between the early and late seasons. Mainstem sites typically had lower bacteria concentrations than adjacent tributary sites. Most stations had at least one 60-day average that exceeded standards in 2018, including eight mainstem stations and seven tributaries during the early season and eight mainstem stations and eight tributaries during the late season.

During the early season, bacteria concentrations increased at all but one mainstem station from 2015 to 2018. The opposite was true during the late season; concentrations decreased from 2015 to 2018 at all but two mainstem stations. Concentrations at tributaries increased from 2015 to 2018 at most stations during both the early and late season. An increase in bacteria concentrations was observed at every comparable site and sampling period from 2001 to 2018 except for at a few tributaries.

Benthic macroinvertebrate sampling was conducted at eight stations in October 2018. Biological condition was then determined based on the analysis of the benthic macroinvertebrate community.

Since 1998 biological condition at the lowermost Goose Creek station GC01, was indeterminate except for 2012 when it was partial/non-supporting. Biological condition has generally declined since 1998. However, biological condition at Goose Creek station GC01 was better than biological condition at the upper Goose Creek station GC02. This observation was in contrast to a general decline in biological condition from upstream to downstream stations noted at other Big Goose Creek and Little Goose Creek stations. Biological condition at station GC02 has exhibited an upward trend since 1998.

Biological condition was fully supporting at Big Goose Creek station BG02 during 2018. Biological condition varied at this station from full support in 1998 and 2018 to partial/non-supporting and indeterminate supporting from 2001 to 2015. Biological condition at Big Goose Creek station BG10 has been variable since sampling began in 2001. Biological condition was fully supporting in 2001 with a subsequent decline to Indeterminate support from 2002 to 2009. Biological condition increased in 2009, decreased to partial/non-supporting in 2012, and increased to Indeterminate support in 2015 and 2018. Benthic macroinvertebrate sampling at the uppermost control station BG18 since 1998 found biological condition was fully supporting. However, sampling in 2018 showed a reduction in biological condition from full support to indeterminate support. The reduction in biological condition did not appear to be related to a reduction in water quality, but to an increase in sand in the stream substrate starting in 2012.

The biological condition at Little Goose Creek station LG2A has been variable since sampling by WDEQ began in 1994. The trend in biological condition at station LG2 has improved since 1994 at station LG2. This is an important observation since other than Goose Creek station GC02, no other station sampled in 2018 in the Goose Creek watershed exhibited an improving trend in biological condition. Biological condition at station LG10 was Indeterminate from 1998 to 2002, then decreased to partial/non-supporting from 2005 to 2018.

Biological condition at the uppermost Little Goose Creek control station LG22 was fully supporting from 1996 to 2018. However, the trend in biological condition at station LG22 was similar to the trend in biological condition observed at Big Goose Creek control station BG18 in that both stations have exhibited a decline in biological condition since 1998.

Continued benthic macroinvertebrate sampling is recommended at current Goose Creek, Big Goose Creek, and Little Goose Creek stations, and at all original Goose Creek watershed stations as funding allows, to track changes in biological condition. Planning and implementation of remedial measures should continue to restore full aquatic life use support in streams in the Goose Creek watershed.

Attempts to determine if improvements in overall water quality have been achieved are often difficult, particularly 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 make water quality comparisons more difficult.

Like other watersheds in Sheridan County, the Goose Creek watershed serves as an important resource for agriculture, wildlife and scenic value. In addition, the Goose Creek Watershed provides the municipal water supply for the City of Sheridan and surrounding area. The watershed, as it exists today, has been defined by residential development, irrigation practices, and agricultural production. Best Management Practices addressing bacteria and sediment sources, irrigation water conservation and management, and riparian livestock management can be implemented to improve water quality and the overall health of the watershed.

The Goose Creek Watershed effort has increased local awareness about several important resource issues and has led to more public interest in the watershed. Continued monitoring can provide information on water quality changes over the long-term. SCCD will continue to monitor water quality in the Goose Creek Watershed on a three-year rotation, pending available funding sources. 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. Nonetheless, each improvement project implemented in the watershed certainly induces positive water quality changes, whether they are immediately evident or not.

CHAPTER 1 PROJECT AREA DESCRIPTION

1.1 WATERSHED DESCRIPTION

The Goose Creek Watershed encompasses 267,520 acres (418 square miles) in Sheridan County located in north-central Wyoming (Appendix A-1). The watershed is identified by hydrologic unit code (HUC) 1009010101. Big Goose Creek and Little Goose Creek originate in the Big Horn Mountains in the Bighorn National Forest (BNF) west of Sheridan. The creeks pass through the unincorporated Town of Big Horn, several ranches, and rural subdivisions before joining to form Goose Creek within the City of Sheridan. Goose Creek continues north to its confluence with the Tongue River near the old Acme town site.

Stream elevation is 4533 feet at the uppermost sample site on Little Goose Creek (LG22) and 4505 feet on Big Goose Creek (BG18), both of which are below the BNF. The elevation drops to 3660 feet at the lower most sample station on Goose Creek (GC01), above the confluence with the Tongue River. The lower portion of the watershed is in the 14-16” precipitation zones (Appendix A-2). Precipitation in the upper watershed, within the BNF, ranges from 20-36”. All sampling stations are in precipitation zones that are less 20”. About half of the watershed is in the 20+” Mountains Ecological Site group (Appendix A-3); however, most of the sample sites are in the 15-19” Northern Plains Ecological Site group. The 10-14” Northern Plains Ecological Site group encompasses the northern tip of the watershed and contains the lowermost sample site on Goose Creek (GC01). After leaving the Big Horn Mountains, the predominant geology along the Goose Creek, Big Goose Creek, and Little Goose Creek channels is alluvium and colluvium comprised of clay, silt, sand, and gravel (USGS, 1985). Soils are primarily of the general Haverdad-Zigweid-Nuncho group, which are very deep, loamy, and clayey soils typically found in floodplains, alluvial fans, and terraces (USDA, 1986).

Soldier Creek is the only major tributary to Goose Creek below the confluence of Big and Little Goose Creeks. Major tributaries to Big Goose Creek include Rapid Creek, Park Creek, and Beaver Creek. Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek are the major tributaries to Little Goose Creek.

1.2 LAND OWNERSHIP AND USES

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 boundary (Appendix A-4). Approximately 136,700 acres (50%) are privately owned lands that include small and large ranch operations and residential development. The BNF consists of approximately 115,000 acres (43%) that are managed for recreation, seasonal cattle grazing, logging, and wildlife. The remaining 15,820 acres (7%) includes other state, county or other federal lands.

Below the BNF, the Goose Creek watershed is predominately rangeland, with irrigated crop and hay lands along the streams and tributaries (Appendix A-5). Ranching operations within the Goose Creek Watershed contain irrigated hay and crop lands, as well as pastureland for cattle grazing and corrals for feeding. In rural residential/small acreage areas, there may be more horses and domestic animals other than cattle. Big game, waterfowl, and other wildlife habitat can also be found on privately owned lands. The density of rural housing generally increases from the mountain foothills downstream to Sheridan. North and downstream of Sheridan, agriculture again becomes the dominant land use. During recent years, this northern area of the watershed has also been used for the development of coal-bed methane production. Subdivisions, converted from rural areas that are occasionally prime farmlands, are becoming more common along Big and Little Goose Creek. The municipal water supply for the City of Sheridan and surrounding area is in the upper portion of the Goose Creek watershed.

Since the area was settled in the late 1800's, a significant amount of change has been imposed on the stream channel systems within the project area. Miles of irrigation ditches and trans-basin diversions have been created. Several reservoirs have been built on the BNF for domestic and irrigation uses. Throughout Sheridan, much of Goose Creek, Big Goose Creek, and Little Goose Creek have been placed into straightened channels, often made of concrete, for flood control. Goose Creek, near the Tongue River confluence, has been extensively channelized as part of coal mine reclamation.

Accessible to over 30,000 Sheridan County residents, these streams and their tributaries are used extensively throughout the year. Local citizens of all ages commonly recreate on these streams, especially in Sheridan's city parks and along recreational pathways. Sheridan was settled around these streams and today they remain highly accessible; Big Goose Creek flows through Kendrick Park, Little Goose Creek flows through South, Emerson, and Washington Parks, and Goose Creek passes through Thorne-Rider and North Parks. Since early 2000, an extensive cement bike path follows these waterways within the city limits. Due to their extensive use, easy access, and direct contact with the public it is essential that these waterways are of the highest quality.

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, 2018c). 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, 2018c)

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	When Present	When Present	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3 (A-D)	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4 (A-C)	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

[1] Class 1 waters are based on value determinations rather than use support and are protected for all uses in existence at the time or after designation.

[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 species considered "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within 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 organisms designated "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within 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.

[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, 2018c) describes the surface water classes and designated uses, as well as the water quality standards that must be achieved for a Wyoming waterbody to support its designated uses.

Streams in the Goose Creek Watershed are classified as 2AB. Class 2AB waters are perennial waterbodies expected to support drinking water supplies (when treated), fish, and aquatic life, recreation, wildlife, industry, and agricultural uses (WDEQ, 2018d). Some tributaries and other draws, which may be Class 3B surface waters, are not expected to support fish populations or drinking water supplies. On previous classification lists, Beaver Creek was identified as Class 3B; however, it was later classified as 2AB.

1.4 STREAM IMPAIRMENTS AND LISTINGS

States are required to summarize water quality conditions through section 305(b) of the Clean Water Act, commonly known as the 305(b) report. 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 TMDL established to support the designated uses. Wyoming's 305(b) report and 303(d) list are published every two years. If a waterbody exceeds narrative or numeric water quality standards, it is listed as impaired or not meeting its designated uses. Big and Little Goose Creek were first placed on the list of impaired waters in 1996 for various parameters, including pathogens (Little Goose) and silt. In 2000, Beaver Creek, Big Goose Creek, Goose Creek, Jackson Creek, Kruse Creek, Little Goose Creek, Park Creek, Rapid Creek, Sackett Creek, and Soldier Creek were added for fecal coliform bacteria (Table 1-2).

Currently, impaired waterbodies are first included on the Wyoming 303(d) list of Waters Requiring TMDLS under Category 5 (WDEQ, 2018d). Once a TMDL is completed, a waterbody is moved from Category 5 to Category 4, which includes the list of waterbodies with TMDLs. The Goose Creek Watershed TMDL was completed in 2010, thus all impaired segments within the watershed are listed as Category 4 waters in the 2016/2018 Integrated Report (WDEQ, 2018d).

Table 1-2. Impaired Stream Segments in the Goose Creek Watershed (WDEQ, 2018d)

Name	Class	Location	Miles	Causes
Goose Creek	2AB	From the confluence with Little Goose Creek downstream to the confluence with the Tongue River	12.7	Fecal Coliform
Goose Creek	2AB	From the confluence with Little Goose Creek downstream to the confluence with the Tongue River	12.7	Habitat Alterations, Sediment
Soldier Creek	2AB	From the confluence with Goose Creek to a point 3.1 miles upstream	3.1	Fecal Coliform
Soldier Creek*	2AB	From 3.1 miles upstream from the confluence with Goose Creek to a point 17.0 miles upstream	17.0	Flow Alterations
Big Goose Creek	2AB	From the confluence with Little Goose Creek upstream to the confluence with Rapid Creek	19.2	Fecal Coliform
Beaver Creek	2AB	From the confluence with Big Goose Creek upstream to the confluence with Apple Run	6.5	Fecal Coliform
Park Creek	2AB	From the confluence with Big Goose Creek to a point 2.8 miles upstream	2.8	Fecal Coliform
Rapid Creek	2AB	From the confluence with Big Goose Creek to a point 3.2 miles upstream	3.2	Fecal Coliform
Little Goose Creek	2AB	From the confluence with Big Goose Creek upstream to Brundage Lane in Sheridan	3.5	Fecal Coliform
Little Goose Creek	2AB	From the confluence with Big Goose Creek upstream to Brundage Lane in Sheridan	3.5	Habitat Alterations, Sediment
McCormick Creek	2AB	From the confluence with Little Goose Creek to a point 2.2 miles upstream	2.2	Fecal Coliform
Kruse Creek	2AB	From the confluence with Little Goose Creek upstream to the confluence with East Fork Kruse Creek	2.5	Fecal Coliform
Jackson Creek	2AB	From the confluence with Little Goose Creek to a point 6.4 miles upstream	6.4	Fecal Coliform
Sackett Creek	2AB	From the confluence with Little Goose Creek upstream to the confluence with East Fork Sackett Creek	3.1	Fecal Coliform

*The segment of Soldier Creek listed for Flow Alterations is listed as Category 4C, which indicates that "pollution, not a pollutant is the source of impairment (WDEQ, 2018)". All other listed segments in the Goose Creek watershed are identified as Category 4A, which indicates that "a TMDL has been completed and approved by USEPA (WDEQ, 2018d).

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Chapter 2 Project Background

2.1 Previous SCCD Monitoring Efforts

Past sampling efforts in the Goose Creek Watershed started several decades ago by the United States Geological Survey (USGS) and the WDEQ. Since 2000, the SCCD, in partnership with USDA Natural Resources Conservation Service (NRCS), Sheridan County, and the City of Sheridan, has done extensive work to try to understand and address water quality concerns in the Goose Creek Watershed.

The Goose Creek Watershed Assessment, which was initiated in April 2001, included collecting samples for pH, water temperature, specific conductivity, dissolved oxygen, total residual chlorine, fecal coliform, turbidity, alkalinity, biochemical oxygen demand, chloride, total hardness, sulfate, ammonia, nitrate nitrogen, total phosphorus, and total suspended solids samples. In total, 46 monitoring stations were sampled on Goose Creek, Big Goose Creek, Little Goose Creek, and the eight tributaries. Five stations were installed on Goose Creek, 15 on Big Goose Creek, and 18 on Little Goose Creek. In addition, each of the eight tributaries was monitored at a single, lower station located near its mouth. Fecal coliform and turbidity samples were collected five times during the months of April, May, August, and October to comply with WDEQ's fecal coliform monitoring protocol. Continuous temperature recorders were used to monitor water temperatures at 15-minute intervals at the lowermost Goose Creek station, three Big Goose Creek stations, and three Little Goose Creek stations. Benthic macroinvertebrate collection and habitat assessments were conducted at 19 sites on Goose Creek, Big Goose Creek, and Little Goose Creek during September. Monitoring in 2002 was like monitoring in 2001 with a few modifications. All tributaries, Goose Creek through the City of Sheridan, and the lower segments of Big Goose and Little Goose Creek exceeded state standards for bacteria. The lowermost station on Goose Creek (just before the confluence with Tongue River) and the upper reaches of Big and Little Goose Creek were within water quality standards for the most part. Evaluation of 2001, 2002, and historic macroinvertebrate data suggested that Goose Creek was not meeting its designated use for aquatic life from the Plachek Pit (located south of the confluence of Goose Creek and Tongue River) to the confluence of Big and Little Goose Creeks. Lower Big Goose Creek and lower Little Goose Creek also failed to meet their aquatic life designated uses.

Interim monitoring was not as comprehensive as the 2001-2002 assessment but focused on evaluating changes in bacteria and sediment, along with benthic macroinvertebrates and habitat assessments, at a limited number of stations. The first round of interim water quality monitoring included 18 of the original 46 sites and occurred from April through October of 2005. The parameters included: water temperature, pH, specific conductivity, dissolved oxygen, discharge, turbidity, fecal coliform, and *E. coli*. *E. coli* sampling was conducted (along with fecal coliform) in anticipation of a change in WDEQ water quality standards. Continuous water temperature data loggers were used to monitor temperature at seven stations on Goose Creek, Big Goose Creek, and Little Goose Creek. Macroinvertebrate sampling and habitat assessments were also performed at six stations. Results of the 2005 monitoring were generally like data collected during the 2001-2002 assessment (SCCD, 2006). The wet spring experienced on the watershed during 2005 produced higher bacteria concentrations, in general, than those observed during the 2001-2002 assessment.

Subsequently, interim monitoring on the Goose Creek occurred in 2009, 2012 and 2015 using many of the same monitoring sites, water quality parameters, and sampling periods, with some exceptions (SCCD, 2011 and SCCD, 2014). In 2009, fecal coliform was replaced with *E. coli* bacteria sampling due to a WDEQ change in water quality standards. In 2012, some additional sites were added, but were discontinued in 2015 due to limited staff and funding resources.

The general trend in bacteria concentrations on Goose Creek appeared to increase upward from 2001 to 2018. Drought conditions in 2001-2002 may have contributed to the lower concentrations in those years, although 2012 also experienced drought conditions throughout the sampling season. Wetter conditions in 2005 and 2009 may have contributed to increased bacteria concentrations through additional run-off and overland flow and resuspension of instream sediments. The 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.

Sampling for benthic macroinvertebrates and habitat by SCCD began in 2001. Biological condition determined by the sampling and analysis of the stream macroinvertebrate samples has varied among the Goose Creek, Big Goose Creek and Little Goose Creek sampling stations. The uppermost control stations on Big Goose Creek (BG18) and Little Goose Creek (LG22) have generally been fully supporting for the narrative WDEQ standard for aquatic life use. The intermediate and lower stations on Big Goose Creek and Little Goose Creek as well as the two monitoring stations on Goose Creek were generally partially/non supporting or indeterminately supporting aquatic life use. The partial/non-support or indeterminate support determination for aquatic life use indicated that the aquatic communities were stressed and water quality or habitat improvements are required to restore the stream to full support.

2.2 WATERSHED PLANNING AND IMPLEMENTATION

In 2003, SCCD received Clean Water Act (CWA) Section 319 funding to initiate watershed planning and improvement efforts on the Goose Creek watershed. This funding allowed SCCD to administer and guide a public Goose Creek watershed planning process, develop a watershed plan, implement remediation projects, develop a progress register, and conduct interim water quality monitoring. Watershed planning was initiated during the fall of 2003 and concluded in December 2004 with the development of the Goose Creek Watershed Management Plan (SCCD, 2004). The planning process included monthly planning meetings that averaged about 20 landowners, watershed residents, SCCD, Natural Resources Conservation Service (NRCS), WDEQ, Sheridan County officials, City of Sheridan officials, and members of the Sheridan County Planning Commission.

The Goose Creek Watershed Management Plan described goals and objectives to address watershed issues identified by meeting participants. The plan included the continuation of local improvement programs offered by the SCCD-NRCS to address bacteria and sediment contributions from livestock facilities, septic systems, unstable stream banks, and stormwater run-off. SCCD has assisted with approximately 65 projects within the watershed including livestock facility improvements, septic replacements, diversion replacements, and bank/channel stabilization through structural work or willow planting (Appendix A-6).

In 2003, SCCD assisted the Department of Health and WDEQ in posting signs along the creeks to warn residents of the potential for pathogens in highly used areas. The City of Sheridan, with assistance from SCCD, implemented a storm drain stenciling program to educate residents about dumping materials into City storm drains. Additional public information and education efforts for the Goose Creek watershed have included:

- Development of a watershed logo by a local student;
- Distribution of a booklet summarizing watershed issues to ~2300 residents;
- Distribution of annual watershed newsletters to ~9500 residents;
- Distribution of a Goose Creek Watershed Social Indicators Survey to ~1525 households;
- Creation of an informational stormwater display for use at public events;
- Workshops on pathogens, animal feeding operations, and septic systems; and
- Various news stories in the local paper, radio stations, and television broadcasts.

Despite efforts to increase awareness and installation of improvement projects, levels of bacteria within the Goose Creek Watershed continue to exceed water quality standards. In the summer of 2008, WDEQ decided to move forward with the development of a TMDL on the Goose Creek watershed, which was completed in September of 2010 (SWCA, 2010).

2.3 Project Purpose and Objectives

The purpose of this project was to complete the 2018 interim monitoring milestone in the Goose Creek Watershed Improvement Effort Implementation Strategy (SCCD, 2012), which was developed by the local steering committee to address recommendations in the Goose Creek Watershed TMDL (SWCA, 2010). The 2018 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 #5 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 to:

- Identify and prioritize areas affected by nonpoint source pollution and
- 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 2001-2002 Assessment. These historical data were previously summarized in the *Goose Creek Watershed Assessment 2001-2002 Final Report* (SCCD, 2003). The Final Report included a comprehensive compilation of known water quality data for the watershed and contained historical and current data through 2002. Data collected by SCCD, government agencies, and various other sources were provided in tabular form in the appendices of the 2001-2002 Final Report. These data are not repeated in this document.

USGS collected water quality and/or hydrologic information from two sites in the Goose Creek Watershed from 2015-2018 (Table 3-1). Much of the hydrologic and water quality data previously collected by USGS have been discontinued due to funding availability except for Station 06305700 (Goose Creek near Acme), and Station 06304500 (Little Goose Creek at Sheridan), which periodically collect field/lab water-quality samples and instantaneous discharge.

Table 3-1. Active USGS Stations in the Goose Creek Watershed in 2015-2018

Site ID	Drainage Area (miles^2)	"Real-time" Observations	Field Lab Water Quality Samples	Daily/Monthly/ Annual Statistics
06302000 Big Goose Near Sheridan	120	6/1963-9/2000	5/1987-2/1999	4/1930-9/2000
06304500 Little Goose Cr at Sheridan	159	NA	3/1979-6/2016	NA
06305700 Goose Creek near Acme, WY	413	Discharge 10/1/2015-Current	10/1983-8/2008 Field Discharge 5/2/1984-11/7/2018	Discharge 5/1984-11/2018

Station 06305700 (Goose Creek near Acme) has intermittently collected hydrologic information since 1983; "real-time" flow observations began again in February of 2018 and extended through the remainder of the sample season. SCCD instantaneous discharge measurements were compared to hydrographs developed for Station 06305700 and Station 06302000, which correspond to SCCD stations GC01 and BG18.

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CHAPTER 4 MONITORING DESIGN

4.1 KEY 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 Assistant provided sampling assistance and served as the Field Supervisor when needed. Other NRCS personnel provided assistance throughout the project. WDEQ provided assistance and oversight as well as administration of the funds provided through Section 319 of the Clean Water Act. Stakeholders and landowners provided site access for sampling and other information.

Table 4-1. Key Personnel and Organizations Involved

Personnel/Organization	Project Role
Carrie Rogaczewski, SCCD District Manager	Project management/oversight; field monitoring; QA/QC protocol and oversight; data validation; reporting
Jackie Carbert, SCCD Program Assistant	Assistance with field data collection, data management, QA/QC protocols, and reporting
Catherine Winnop, SCCD Summer Intern	Assistance with field data collection and data management
Oakley Ingersoll, NRCS Sheridan Field Office	Site set-up and survey assistance
Jesus Lopez, NRCS Summer Intern	Assistance with field data collection
SCCD Board of Supervisors	Project review; field monitoring assistance
Wyoming Department of Environmental Quality	Project review; QA/QC review; field audits; 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 2018 included water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli*. Water quality monitoring was performed at 18 stations (Appendix A-1). Continuous water temperature data loggers were used to monitor temperature at 15 minute intervals at seven stations. Macroinvertebrate sampling and habitat assessments were also performed at eight stations (Appendix A-1).

4.3 SAMPLING AND ANALYSIS METHODS

Water quality sample collection, discharge measurements, macroinvertebrate sampling, and habitat assessments were performed by the methods described in the *2018 Goose Creek Watershed Monitoring Project Sampling Analysis Plan* (SCCD, 2018a), the *SCCD Water Quality Monitoring Program Quality Assurance Project Plan*, *2018 Update* (SCCD, 2018b), Natural Resources Conservation Service *National Handbook of Water Quality Monitoring* (USDA-NRCS, 2003), and WDEQ sampling procedures (WDEQ, 2018a) according to accepted analytical methods (Table 4-2). Water quality and macroinvertebrate samples were obtained from representative sample riffles.

Table 4-2. Standard Field and Laboratory Methods Applicable to 2018 Monitoring

Parameter	Units	Method / Reference[1, 2,3]	Analyses Location	Preservative	Holding Time
Water Temperature	ºC	USEPA 170.1	On-site	n/a	n/a
pH	SU	USEPA 150.2	On-site	n/a	n/a
Specific Conductivity	µS/cm	USEPA 120.1	On-site	n/a	n/a
Dissolved Oxygen-Probe	mg/L	USEPA 360.1	On-site	n/a	n/a
E. coli	col/100 ml	SM9223B	IML[4]	Cool to 10ºC	8 hours
Turbidity	NTU	SM2130B	IML	Cool to 6ºC	48 hours
Stage Height	feet	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] Mid-section method reference from Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ, 2018a)
[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 estimation. During site reconnaissance, staff gauges were inspected, surveyed, and replaced if needed. Upon installation and inspection, gauges were surveyed and compared with a permanent benchmark. Staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter using the mid-section method (WDEQ, 2018a). The resulting stage-discharge relationships were used to estimate flow during sampling events.

Grab samples for *E. coli* and turbidity were collected during 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 securing the data loggers to the staff gauges and downloading the collected information.

Sample containers for bacteria and turbidity were provided by the contract laboratory and left unopened until sample collection. The bacteria containers were sealed, clear, cylindrical, IDEXX bottles that contained the sample preservative. The turbidity containers were 125 mL plastic, opaque bottles. Bacteria and turbidity containers had blank labels, which were completed in the field. Containers for macroinvertebrate samplers were 32 ounce, 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. Benthic macroinvertebrate samples were sorted by Aquatic Assessments, Inc. (AA) in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon.

4.4 Site Descriptions

Sites were selected based on a review of the historical data, historical SCCD sampling sites, availability, and access (Table 4-3). All sites chosen for this project were previously used in the 2001-2002 assessment and subsequent monitoring years. 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.

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 requires written permission to access property 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 4-3. 2018 Goose Creek Watershed Interim Monitoring Sample Site Descriptions

Site	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (feet)	Land Use(s)
Water Quality Sites						
GC01	On Goose Creek approximately 75 yards downstream of HWY 339 bridge crossing near USGS Station 06305700	0343021E, 4971863N	44° 52.974’ N 106° 59.262’W	100901010109 Goose Creek	3,660	Wildlife habitat, cattle grazing, and irrigated haylands. A few residences, small subdivisions and the City of Sheridan upstream. Railroad and HWY 338 run parallel to creek on east side.
GC02	On Goose Creek approximately 200 yards downstream of Sheridan WWTP	0344758E, 4965129N	44° 49.368’ N 106° 57.819’W	100901010109 Goose Creek	3,701	In a commercial/industrial area in the City of Sheridan. A concrete plant is located south of creek with settling ponds north of creek. Sheridan WWTP is upstream.
GC-SC01	On Soldier Creek approximately 10 yards downstream from Dana Avenue bridge.	0344842E, 4964802N	44° 49.186’ N 106° 57.749’W	100901010109 Goose Creek	3,705	In the Downer Addition in the City of Sheridan. Rural properties upstream.
BG01	On Big Goose Creek off the bike path near Senior Center that is across from the YMCA upstream of the confluence	0344886E, 4962931N	44° 48.176’ N 106° 57.681’W	100901010108 Lwr Big Goose	3,735	Urban/residential. Adjacent to hill side below Sheridan Junior High School.
BG-BC01	Beaver Creek above the confluence with Big Goose Creek near County Road 87 (Beaver Creek Road)	0335841E, 4958351N	44°45.583’N 107°04.451’W	100901010108 Lwr Big Goose	3,955	Rural residential, wildlife habitat, horse and cattle grazing, and irrigated haylands.
BG10	On Big Goose Creek approximately 40 yards upstream from the County Road 87 bridge crossing	0335790E, 4958405N	44° 45.611’ N 107° 04.490’W	100901010108 Lwr Big Goose	3,955	Rural residential, wildlife habitat, horse and cattle grazing, and irrigated haylands.
BG-PC01	On Park Creek approximately 15 meters downstream of the culvert crossing under Big Goose Road near Beckton	0331392E, 4957019N	44° 44.802’ N 107° 07.795’W	100901010104 Up Big Goose	4,060	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands. An animal feeding operation is upstream.
BG14	On Big Goose Creek approximately 100 yards upstream of the Big Goose Road bridge crossing	0331315E, 4956620N	44° 44.585’ N 107° 07.845’W	100901010104 Up Big Goose	4,060	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands. An animal feeding operation is to the northwest.

Table 4-3. 2018 Goose Creek Watershed Interim Monitoring Sample Site Descriptions (cont.)

Site	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (feet)	Land Use(s)
Water Quality Sites						
BG-RC01	On Rapid Creek approximately 25 yards downstream of the County Road crossing	0330489E, 4954616N	44° 43.492' N 107° 08.431'W	100901010104 Up Big Goose	4,160	Horse and cattle grazing, irrigated haylands, and wildlife habitat.
BG18	On Big Goose Creek near the mouth of Big Goose Canyon at USGS Station No. 06302000	0327127E, 4952184N	44° 42.131' N 107° 10.927'W	100901010104 Up Big Goose	4,505	Primarily wildlife habitat. Cattle and horse grazing. The BNF boundary is about 1 mile upstream.
LG02	On Little Goose Creek approximately 30 yards upstream from the concrete flood channel in downtown Sheridan	0345586E, 4962760N	44° 48.093' N 106° 57.147'W	100901010107 Lwr Little Goose	3,725	Urban – mostly business with some light industrial and residential areas. Railroad tracks are adjacent to the east bank.
LG08	On Little Goose Creek approximately ¼ mile downstream from McCormick Creek	0345473E, 4953671N	44° 43.181' N 106° 57.062'W	100901010107 Lwr Little Goose	3,895	Small acreage properties with livestock grazing, wildlife habitat, and irrigated haylands.
LG-MCC01	On McCormick Creek approximately 20 yards upstream from the confluence	0345218E, 4953494N	44° 43.086' N 106° 57.258'W	100901010107 Lwr Little Goose	3,905	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG-KC01	On Kruse Creek approximately 100 yards upstream from the confluence	0344955E, 4952623N	44° 42.613' N 106° 57.441'W	100901010107 Lwr Little Goose	3,915	Small acreage properties with cattle grazing and irrigated haylands.
LG13	On Little Goose Creek approximately 10 yards upstream from the bridge crossing at Knode Ranch subdivision	0344059E, 4951792N	44° 42.152' N 106° 58.104'W	100901010106 Mid Little Goose	3,940	Large subdivisions with small acreage lots, wildlife habitat, and haylands.
LG-JC01	On Jackson Creek approximately 20 yards upstream from the confluence	0342645E, 4950336N	44° 41.348' N 106° 59.147'W	100901010106 Mid Little Goose	4,020	Small acreage properties with cattle grazing and irrigated haylands.
LG-SC01	On Sackett Creek approximately 10 yards upstream from the confluence	0342526E, 4949684N	44° 40.994' N 106° 59.225'W	100901010106 Mid Little Goose	4,040	Small acreage properties with cattle grazing and irrigated haylands upstream and residences within Big Horn.
LG22	On Little Goose Creek downstream of County Road 77 bridge crossing at USGS Station No. 06303700.	0338336E, 4942856N	44° 37.253' N 107° 02.267'W	100901010106 Mid Little Goose	4,533	Ranch buildings, cattle grazing, and wildlife habitat. BNF boundary is approximately 3 miles upstream.

Table 4-3. 2018 Goose Creek Watershed Interim Monitoring Sample Site Descriptions (cont.)

Site	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (feet)	Land Use(s)
Benthic Macroinvertebrate and Habitat Assessment Sites						
GC01	Base of riffle located approximately 300 yards upstream from the HWY 339 bridge	0343037E, 4971851N	44° 52.974' N 106° 59.262'W	100901010109 Goose Creek	3,660	Wildlife habitat and cattle and horse grazing and irrigated haylands. A few residences.
GC02	Riffle is located about 200 yards downstream of Sheridan WWTP discharge	0344758E, 4965129N	44° 49.368' N 106° 57.819'W	100901010109 Goose Creek	3,701	A concrete plant is located south of creek with settling ponds north of creek. Sheridan WWTP is upstream.
BG02	Located at first riffle upstream from the footbridge at Works and Elk Street	0344138E, 4962221N	44° 47.783' N 106° 58.235'W	100901010108 Lwr Big Goose	3,745	Predominantly urban / residential.
BG10	Located at riffle near first bend upstream from County Road 87 bridge crossing	0335790E, 4958405N	44° 45.611' N 107° 04.490'W	100901010108 Lwr Big Goose	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
BG18	Located at riffle upstream of old USGS gauge station	0327127E, 4952184N	44° 42.131' N 107° 10.927'W	100901010104 Up Big Goose	4,505	Primarily wildlife habitat. Cattle and horse grazing.
LG2A	Riffle is located near first bend downstream (100-150 yards) from Coffeen Avenue bridge crossing	0346413E, 4961063N	44° 47.188' N 106° 56.490'W	100901010107 Lwr Little Goose	3,750	Predominantly urban/residential.
LG10	Located at first riffle below the Kruse Creek confluence	0344898E, 4952854N	44° 42.737' N 106° 57.488'W	100901010107 Lwr Little Goose	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.
LG22	Riffle is located just upstream of County Road 77 bridge crossing	0338336E, 4942856N	44° 37.253' N 107° 02.267'W	100901010106 Mid Little Goose	4,533	Ranch buildings, cattle grazing, and wildlife habitat.

4.5 MONITORING SCHEDULE

The 2018 monitoring schedule included sampling to determine the geometric means of *E. coli*, based on five samples collected within a 60-day period in May-June and five samples collected within a 60-day period in August-September (Table 4-4). A total of ten water quality samples were collected at all but one site; Park Creek was dry on September 25, resulting in only nine samples being collected from that site.

Sample dates were randomly selected from Monday-Thursday due to lab availability and sampling holding times. Continuous temperature data loggers were deployed to measure instream temperatures mid-May through early October. Macroinvertebrate collections and habitat assessments were also completed in early October.

Table 4-4. Sample Schedule for 2018 Goose Creek Watershed Monitoring

Date(s)	Sites	Parameters
May 22-Early October	GC01, BG01, BG10, BG18, LG02, LG08, LG22	Continuous Temperature
May 22	GC01, GC02, GC-SC01, BG01, BG-BC01, BG10, BG-PC01, BG14, BG-RC01, BG18, LG02, LG08, LG-McC01, LG-KC01, LG13, LG- JC01, LG-SC01, LG22	Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/ Discharge, Turbidity, and *E. coli*
June 6		
June 20		
July 2		
July 18		
July 30	GC01, GC02, GC-SC01, BG01, BG-BC01, BG10, BG-PC01, BG14, BG-RC01, BG18, LG02, LG08, LG-McC01, LG-KC01, LG13, LG- JC01, LG-SC01, LG22	Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/ Discharge, Turbidity, and *E. coli*
August 14		
August 30		
September 12		
September 25		
End of September or Early October	GC01, GC02, BG02, BG10, BG18, LG2A, LG10, LG22	Macroinvertebrates, Habitat, Photo

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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, and 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; USEPA, 1990). 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. The QA/QC procedures for the SCCD Watershed Program are described in the project SAP (SCCD, 2018a) and the SCCD QAPP (SCCD, 2018b).

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). NRCS Sheridan field office staff assisted with site set-up, surveys, discharge measurements, water quality monitoring, and macroinvertebrate collection when needed. During monitoring activities, SCCD personnel collected the samples and 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; 20+ years of experience with the SCCD; WACD Water Quality Training
Jackie Carbert Program Assistant	B.S. University of Wyoming in Geography and Environment and Natural Resources with a Journalism Minor; Natural Resource Management and GIS Concentrations; 1+ year of experience with SCCD

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 logbook 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, placed on ice, and hand delivered to the contract 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 COC procedures were implemented.

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 picked up by the contract laboratory for sorting. COC forms were signed by SCCD and the contract laboratory personnel 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. 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 specific conductivity meter was calibrated using a 1413 µmhos/cm calibration standard. All calibration solutions were discarded after each use. The YSI Pro20 dissolved oxygen meter membrane cap was replaced the night before each sampling event. The meter was calibrated by inserting the probe into the moist calibration chamber. The barometric pressure on the DO meter was cross referenced to the barometric pressure at the Sheridan County airport to check calibration accuracy before leaving the office. Calibration of each meter was documented on the corresponding instruments calibration logbook.

Equipment maintenance, including battery replacement, was performed according to the SAP and manufacturer's instructions. All maintenance activities were documented in the calibration logs.

The Marsh-McBirney flow meter was factory calibrated and did not require field calibration; however, SCCD conducted a zero check at the beginning and end of the field season using a five-gallon bucket of water. Factory calibration of Onset HOBO data loggers, used for continuous temperature monitoring, was checked by performing a crushed-ice test at the start 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. Surber sampler nets and other equipment were checked for damage prior to entering the field.

5.5 SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL

Data Quality Objectives (DQOs) are qualitative and quantitative specifications used by water quality monitoring programs to limit data uncertainty to an acceptable level. DQOs 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 Project SAP (SCCD, 2018a) and WDEQ protocols (WDEQ, 2018a).

Table 5-2. Data Quality Objectives

Parameter	Precision (%)[1]	Accuracy (%)[2]	Completeness (%)	Reporting Limit
Temperature	10	10	95	0.2°C
pH	0.3 SU	5	95	0.01 SU
Conductivity	10	10	95	1 µmhos/cm
Dissolved Oxygen	10	20	95	0.1 mg/L
Turbidity	20	20	95	0.1 NTU
E. coli	50[3]		95	1 MPN/mL
Macroinvertebrates	Total Abundance= ±50% Total Number of Taxa= ±15%		95	
Total Taxa	15		95	
Habitat Assessment			95	
Intra-Crew	15		10	
Discharge			95	
Stage-Discharge Relationships			95	$r^2 \geq 0.95$

Precision DQOs from WDEQ Quality Assurance Protection Plan. Reporting limits from WDEQ Manual of Standard Operating Procedures (WDEQ, 2018a), apart from current laboratory analyzed parameters (turbidity and *E. coli*).

[1] For parameters with reporting limits, see WDEQ Quality Assurance Protection Plan (WDEQ, 2018b) for values below 10 times the reporting limit.

[2] Accuracy values shown are acceptable departures from 100 percent accuracy.

[3] The Relative Percent Difference (RPD) between Most Probable Number (MPN) duplicate samples should be <50% for MPNs >100. Due to the increased variability for MPNs <100, no RPD limit is required for duplicate pairs in which at least one of the MPNs is below 100.

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 current project data must be comparable to past and future data in order to confidently detect changes in water quality. 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. 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 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 or more samples collected within a 60-day period (WDEQ, 2017). As a result, SCCD incorporated 60-day geometric means into future schedules. 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. Arithmetic means are used for all other non-bacteria parameters.

5.5.2 Continuous Temperature Data Loggers

Onset's HOBO Pendent Temperature 64 Data Loggers were deployed at GC01, BG01, BG10, BG18, LG02, LG08, and LG22 to record water temperature during the 2018 monitoring project. These loggers are factory calibrated, encapsulated devices that cannot be re-calibrated.

To verify the accuracy of the factory calibration, before the sampling season, SCCD performed a crushed ice test. To perform the test, a seven pound bag of crushed ice was emptied into a 2.5 gallon bucket. Distilled water was added to just below the level of the ice and the mixture was stirred. The data loggers were submerged in the ice bath and the bucket was 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. All but three loggers reported temperatures between 0.01-0.232°C during the initial pre-season ice bath (Appendix Table B-6). Two of the three loggers reported temperatures within the appropriate range during subsequent ice baths; the other would not read any data and was discarded and replaced. A crushed ice test was also completed at the end of the season with the same loggers and all results were within 0°C ±0.232°C.

Onset suggests the loggers should maintain their accuracy unless they have been used outside the range of intended use (-20°C to 50°C). None of the loggers were used outside of this range. All temperature loggers used for the 2018 monitoring project were considered to have maintained their accuracy and to have provided valid water temperature data.

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. Stage-discharge relationships were established for all staff gauges installed by SCCD. These relationships were developed by recording the stage height and measuring discharge using the mid-section method (WDEQ, 2018a) on at least three occasions with varying flow conditions. A correlation coefficient (R^2 value) of at least 0.95 (95%) is desirable for proper calibration of the gauge (Table 5-3).

Staff gauges installed by SCCD were surveyed against established benchmarks upon installation and at the end of the season. The difference between pre- and post-season survey results were compared to verify gauge stability (Table 5-3). A difference equal to or less than 0.05 is preferred between the pre- and post-season surveys. When the difference is greater, the survey should be repeated, and the stability of the benchmark and gauge should be checked.

Table 5-3. Summary of 2018 Gauge Surveys and R^2 Values for Stage-Discharge Relationships

Site	Pre-Season Survey	Post-Season Survey	Pre/Post Survey Difference	Stage-Discharge Relationship R^2 Value
GC01	1.83	1.83	0.00	0.9999
GC02	3.71	3.69	0.02	0.6753
GC-SC01	8.02	7.97	0.05	0.9474
BG01	8.88	8.83	0.05	0.9995
BG-BC01	9.00	9.02	0.02	0.9649
BG10	7.56	7.58	0.02	0.9861
BG-PC01	0.58	0.62	0.04	0.8249
BG14	5.67	5.68	0.01	0.9970
BG-RC01	4.50	4.55	0.05	0.9984
BG18	2.47	2.43	0.04	0.9319
LG02	1.74	1.72	0.02	0.9808
LG08	0.00	0.00	0.00	0.9969
LG-McC01	0.76	0.73	0.03	0.9996
LG-KC01	1.45	1.44	0.01	1.0000
LG13	1.96	1.95	0.01	0.9152
LG-JC01	0.50	0.47	0.03	1.0000
LG-SC01	5.94	5.99	0.05	0.9397
LG22	2.64	2.63	0.01	0.9763

The R^2 values for Soldier Creek (GC-SC01), BG18, and Sackett Creek (LG-SC01) were slightly below the DQO value of 0.95. Because these values approached the DQO and presented the only flow information available for each site, discharge measurements were used in the calculation of summary statistics and in the development of load estimates, where appropriate. Due to streambank and channel alterations at LG13, the staff gauge was repositioned several times during the first part of the season. As a result, flow data taken prior to July 18th was discarded, and the R^2 value was only calculated on discharge taken after the final gauge was installed. All discharge information for GC02 and BG-PC01 was discarded. Erratic flows at GC02 resulted in a low R^2 value (0.6753) and inaccurate gauge calibration. Low flows at BG-PC01 made it difficult to obtain accurate flow readings.

Each site reported gauge survey differences equal to or less than 0.05 between pre- and post-season surveys; therefore, all gauges were considered stable.

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. Two *E. coli* and two 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*. Both trip blanks reported turbidity levels of 0.2 on June 6 and of 0.1 on September 25 (Appendix Table B-5). One trip blank reported a turbidity level of 0.6 on July 2. The turbidity data were considered acceptable because they were at or near the minimum detection limit value of 0.1 NTU.

Field blanks were prepared to determine whether samples might be contaminated by conditions associated with sample collection procedures. *E. coli* and turbidity field blanks were prepared at two separate sites during all sampling events. 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. One field blank prepared during the project reported an *E. coli* level of 1.0 cfu/100 mL on July 2; however, because the level was low, this data was retained (Appendix Table B-4). 17 out of 20 field blanks reported turbidity values above the detection limit, ranging from 0.1 to 1 NTUs. Since there have been no changes in the sample collection procedures or personnel, the higher than usual occurrence of turbidity detections in 2018 field blanks may be attributed to the high purity water, or deionized water, used for field blanks. Because of this, and the low levels detected, the data were considered acceptable.

5.5.5 Sample Holding Times

Laboratory data sheets prepared by IML were reviewed to ensure all samples were analyzed before their holding times had expired. This review found that all turbidity samples were analyzed within the required 48-hour holding time; however, 13 *E. coli* samples were not analyzed within their required 8-hour holding time. The data from these samples was retained because the samples had been kept on ice and the exceedances did not surpass 60 minutes. 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. Duplicate habitat assessments were performed by two field samplers performing independent assessments, without communication, at the same site and same time. All DQOs for duplicates were met (Table 5-4).

Table 5-4. 2018 Goose Creek Watershed Monitoring Summary of Duplicates Collected

Parameter	No. of samples	No. of Duplicates	% Duplicated	DQO (%)
Water Quality Samples in 2018 (18 sites X 10 samples)	179*	20	11.17%	10%
Macroinvertebrate Samples in 2018	8	1	12.5%	10%
Habitat Assessments in 2018	8	1	12.5%	10%

*Park Creek was dry during final sample day; therefore, only 179 out of 180 samples were collected

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. With few exceptions, all samples met the DQOs for precision (Table 5-5).

All temperature, pH, and dissolved oxygen duplicate samples met the appropriate DQO for precision. One conductivity measurement exceeded 10% RPD at 14.0, which was only slightly above the DQO. Two turbidity samples exceeded the 20% RPD with values of 23.3 and 146.7. Because turbidity values can be relatively low, small variations can result in high RPDs. Three *E. coli* samples exceeded the precision DQO of 50%. The RPD calculated at LG22 on May 22 included *E. coli* values that were less than 100, therefore the DQO of 50% does not apply (WDEQ, 2017). The RPD for the other samples, which were collected from LG08 on July 2 and from LG-JC01 on September 12, were 70.0 and 61.5. The RPD for the other conductivity, turbidity, and *E. coli* duplicate samples collected the same sample day were within the DQOs. As a result, data for those samples were retained.

Table 5-5. Precision of 2018 Water Quality Monitoring Data in the Goose Creek Watershed

Date	Duplicate Sample ID	Site Duplicated	TEMP RPD (%)	pH RPD	COND RPD (%)	DO mg/L RPD (%)	DO % RPD (%)	TURB RPD (%)	*E. coli* RPD (%)
WDEQ DQO Relative Percent Difference or Other:			10	0.3 SU	10	10	10	20	50 if >100 NA if <100
5/22/18	Dup1	GC01	2.6	0.05	6.6	0.9	0.3	13.6	16.5
	Dup2	LG22	4.2	0.15	**14.0**	3.95	3.7	11.1	**143 < 100**
6/6/18	Dup1	BG-BC01	0.0	0.02	1.4	1.22	0.5	4.4	16.1
	Dup2	BG14	0.0	0.23	9.0	3.1	2.8	**23.3**	16.7
6/20/18	Dup 1	BG-PC01	0.0	0.01	8.5	2.55	2.5	15.4	0.0
	Dup2	BG18	0.8	0.28	4.5	1.0	1.0	**146.7**	20.0
7/2/18	Dup 1	BG01	1.2	0.06	3.2	8.16	7.9	4.3	9.9
	Dup 2	LG08	1.0	0.01	1.3	0.87	0.6	5.4	**70.0**
7/18/18	Dup 1	BG-RC01	0.0	0.01	1.0	2.2	2.1	5.6	11.0
	Dup 2	LG-KC01	0.5	0.00	0.5	1.3	1.2	4.8	34.1
7/30/18	Dup 1	GC02	0.0	0.00	0.5	0.0	0.1	3.5	25.1
	Dup 2	BG10	0.6	0.02	0.0	0.4	0.4	2.1	0.0
8/14/18	Dup 1	GC-SC01	1.6	0.08	0.8	0.9	0.9	3.3	38.2
	Dup 2	LG-SC01	0.5	0.01	0.9	1.1	0.5	12.5	19.0
8/30/18	Dup 1	LG13	0.0	0.01	1.6	0.2	0.3	10.0	11.4
	Dup 2	LG-McC01	0.7	0.01	0.0	1.8	1.4	7.3	24.6
9/12/18	Dup 1	LG-JC01	0.7	0.00	0.1	0.3	0.2	12.9	**61.5**
	Dup 2	BG-BC01	0.8	0.01	0.1	0.4	0.2	16.2	26.6
9/25/18	Dup 1	LG02	0.0	0.01	0.3	0.8	0.7	19.5	22.8
	Dup 2	LG13	0.8	0.01	0.2	0.3	0.5	0.0	2.7
AVERAGE RPD FOR ALL SAMPLES			***0.8***	***0.0***	***2.7***	***1.6***	***1.4***	***16.1***	***28.5***

Duplicate samples were collected at 11% of the macroinvertebrate and habitat assessment sites. Intra-crew habitat duplicates were conducted simultaneously by each observer conducting the assessment without communication. The RPD for total macroinvertebrate abundance was 7.0% and the RPD for total taxa was 2.9% (Table 5.7). Precision for each parameter was within the established DQO. The RPD for the duplicate intra-crew habitat assessment at station BG02 was 4.6%, which was within the established DQO of 15%.

Table 5-6. Precision of 2018 Macroinvertebrate and Habitat Assessment Data

Parameter	Dup 1 (#)	Dup 2 (#)	Precision (%-RPD)	DQO (%)
Total Abundance	11,258	10,492	7.0	50
Total Taxa	34	35	2.9	15
Intra-Crew Habitat Assessments	133	127	4.6	15

5.5.8 ACCURACY

Accuracy is the degree of agreement of a measured value with the true or actual value. For water quality parameters measured in the field, accuracy 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. Proficiency tests are run twice annually by IML for *E. coli* and turbidity. Accuracy cannot be determined for macroinvertebrate samples or habitat assessments because the true or actual values are unknown, therefore precision served as the primary QA check for these parameters.

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, failure to meet holding times, and proper access to sample sites for collection of samples as scheduled. DQOs for most parameters were met except for discharge measurements (Table 5-7).

On June 6, dissolved oxygen data was discarded for three sites due to erratic readings (GC02, GC-SC01 and BG01). Completeness values for all parameters were affected by dry conditions that prevented sample collection at Park Creek on September 25. Discharge data was discarded for all sampling days at GC02 and Park Creek as erratic and/or low flows caused gauge calibration issues at both sites. All discharge data from May 22-July 18 at LG13 was discarded due to bank and channel alterations. Values at Beaver Creek were outside of the calibrated range on May 22 and July 6. Gauges that were submerged, broken, or otherwise unusable because of high or low flows also affected completeness values for discharge.

All scheduled benthic macroinvertebrate samples and habitat assessments were conducted as planned during 2018 resulting in 100% completeness.

Table 5-7. Completeness of 2018 Monitoring Data

Parameter	% 2018 Completeness	DQO (%)
Water Temperature	99	95
pH	99	95
Conductivity	99	95
Dissolved Oxygen	98	95
Discharge	81	90
Turbidity	99	95
E. coli	99	95
Macroinvertebrates	100	95
Habitat Assessments	100	95

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. Data determined to be invalid were rejected and not used in preparation of this report.

The project SAP specifies that low flow values and lab results reported below the detection limit be reported as ½ the detection limit for the purpose of summary statistics (Gilbert, 1987 and SCCD, 2018). Except for blanks and some *E. coli* samples, there were no samples reported below the detection limit in 2018. When *E. coli* samples are reported as less than 1 colony/100 mL or greater than 2419 colonies/100 mL, the SAP requires that 1 colony/100 mL or 2420 colonies/100 mL be used for summary statistics, respectively. Three *E. coli* values were reported as >2419.6 col/100mL from LG02 and McCormick Creek on June 20, and Kruse Creek on August 15. One *E. coli* value was reported as <1 col/100 mL from Duplicate 02 at LG22 on May 22.

High flows caused gauges at BG18 and LG08 to become broken or unusable. After replacement of these gauges, the surveys of the new gauges were compared to those of the old gauges. Gauge heights from the beginning of the season were adjusted accordingly and used for discharge calculations and summary statistics.

Two discharge measurements, on May 22 and June 6 at Beaver Creek, were unreasonably high for the site conditions and were determined to be outside of the calibrated range of the staff gauge. These measurements were discarded and not used in the calculation of summary statistics.

The gauge at LG13, which had been mounted on a bridge support, was out of water in early July. A new gauge was installed upstream of the bridge; however, following re-installation a series of streambank and channel alterations took place, leaving the gauge in the middle of the channel. With a multitude of changing factors occurring throughout the first half of July, it is difficult to justify the accuracy of the discharge measurements or adjustments. Therefore, all discharge data at LG13 through July 18th were discarded. Only data obtained after the final gauge installation on July 25th was used.

5.7 Documentation and Records

All water quality field data were recorded on data sheets prepared for the appropriate waterbody and monitoring station. 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 has continued with their existing protocol/data sheets for consistency and to allow valid comparability of data collected between historic and current assessments. Equipment checklists, COC forms, and calibration logs were documented on the appropriate forms and are maintained on file in the SCCD office. Photographs and photograph descriptions were organized by date taken and site ID and are maintained on file in the SCCD office.

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

5.8 DATABASE CONSTRUCTION AND DATA REDUCTION

The project database consists of a series of Excel© spreadsheets and computer files. Each project database was constructed with reportable data (accepted after QA/QC checks) by inputting 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 Table C-21):

- 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. Arithmetic means were calculated for all water quality parameters except for *E. coli* using the ten sampling dates and then separately for the five samples collected in May-July and in July-September. Geometric means were calculated for *E. coli* for the same time periods. Summary statistics did not include discarded data or instances where the staff gauge was submerged or unreadable.

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 were identified, the data were accepted as presented. Otherwise, data were rejected and not included in the 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 can be produced upon request.

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.

CHAPTER 6 DISCUSSION OF RESULTS

6.1 WATER QUALITY STANDARDS

Wyoming's surface waters are protected through application of numeric and narrative (descriptive) water quality standards. These water quality standards and other recommendations were used in interpretation of results for the 2018 monitoring (Table 6-1).

Table 6-1. Numeric and Narrative Water Quality Standards Applicable for 2018 Monitoring (WDEQ, 2018c)

NUMERIC STANDARDS		
Parameter	**Reference**	**Standard / Description**
Dissolved Oxygen	Sections 24 and 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	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	Sections 26; Appendix B	6.5-9.0 standard units
Temperature	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	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 degrade aesthetics, aquatic life habitat, public water supplies, agricultural or industrial use, or plants and wildlife.
Floating and Suspended Solids	Section 16	Shall not be present in quantities that degrade aesthetics, aquatic life habitat, public water supplies, agricultural or industrial use, or plants 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	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
Specific 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 22 to September 25 at 18 stations (Appendix Tables C-3 through C-20). Summary statistics were calculated for all instantaneous monitoring parameters on accepted data (Appendix Table C-21). Geometric means for three 60-day periods were calculated for bacteria samples; arithmetic means were calculated for all other parameters for the same 60-day periods as well as for the season.

In addition, USGS collected the following data from two stations from 2015-2018:

- Water quality data once per month in November 2015, February 2016 and June 2016 from *Station 06304500 Little Goose Creek at Sheridan, WY* (Appendix Table C-22)
- Daily discharge data from February 2018-January 2019 from *Station 06305700 Goose Creek Near Acme, WY* (Appendix Figure C-9)

Among other things, the USGS collected temperature, pH, dissolved oxygen, conductivity, discharge, and bacteria for *Station 06304500*. Only data similar in scope to the parameters collected by the SCCD are presented. Historical discharge data was used for discharge comparisons on site BG18 from *Station 06302000 Big Goose Creek Near Sheridan, WY* (Appendix Figure C-10).

6.2.1 Instantaneous Water Temperature

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at 10 stations on July 18 (Table 6-2). Temperatures above 20°C were also observed at four stations on June 6, three stations on July 2 and six stations on August 14. The maximum instantaneous temperature was observed at LG02 (24.8°C) on July 18. Instantaneous water temperature measurements collected during 2018 did not necessarily represent daily minimum, maximum, or average water temperature.

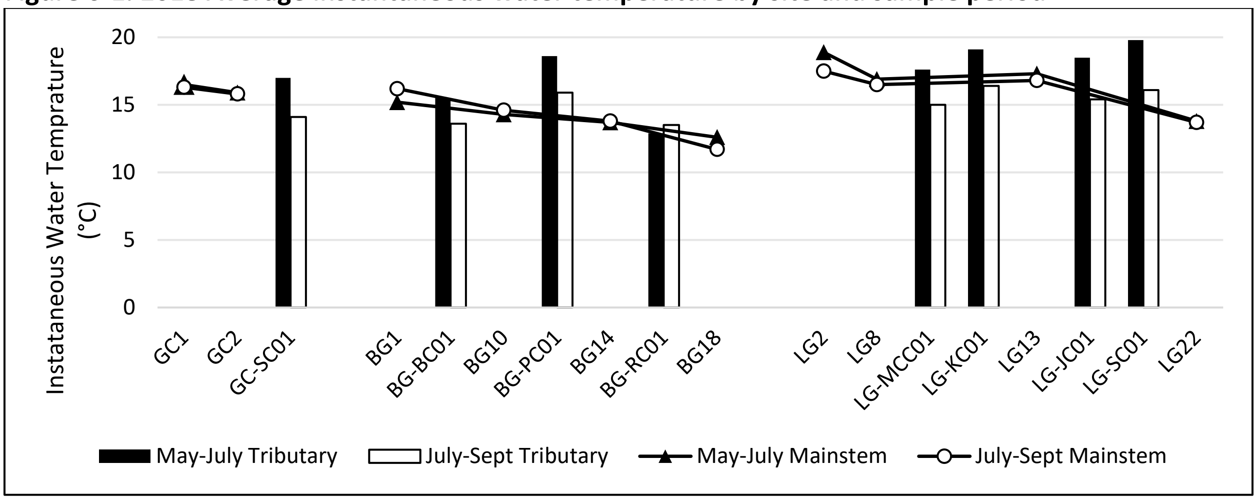
Table 6-2. 2018 Instantaneous water temperature measurements exceeding 20°C

Site*	Temperature (°C)			
	6/6/2019	7/2/2018	7/18/2018	8/14/2018
(Goose Creek) GC01			21.6	20.5
(Goose Creek) GC02			21.0	
(Big Goose) BG01			21.1	20.2
(Park Creek) BG-PC01	20.6			
(Little Goose) LG02		21.2	24.8	21.0
(Little Goose) LG08			22.7	20.6
(McCormick Creek) LG-MCC01			20.1	
(Kruse Creek) LG-KC01	21.5		21.5	20.6
(Little Goose) LG13		21.2	23.5	20.2
(Jackson Creek) LG-JC01	20.5		21.9	
(Sackett Creek) LG-SC01	22.4	21.1	21.7	

*Sites that did not exceed the standard include Soldier Creek (GC-SC01), Beaver Creek (BG-BC01), Big Goose Creek (BG10), Big Goose Creek (BG14), Rapid Creek (BG-RC01), Big Goose Creek (BG18), and Little Goose Creek (LG22).

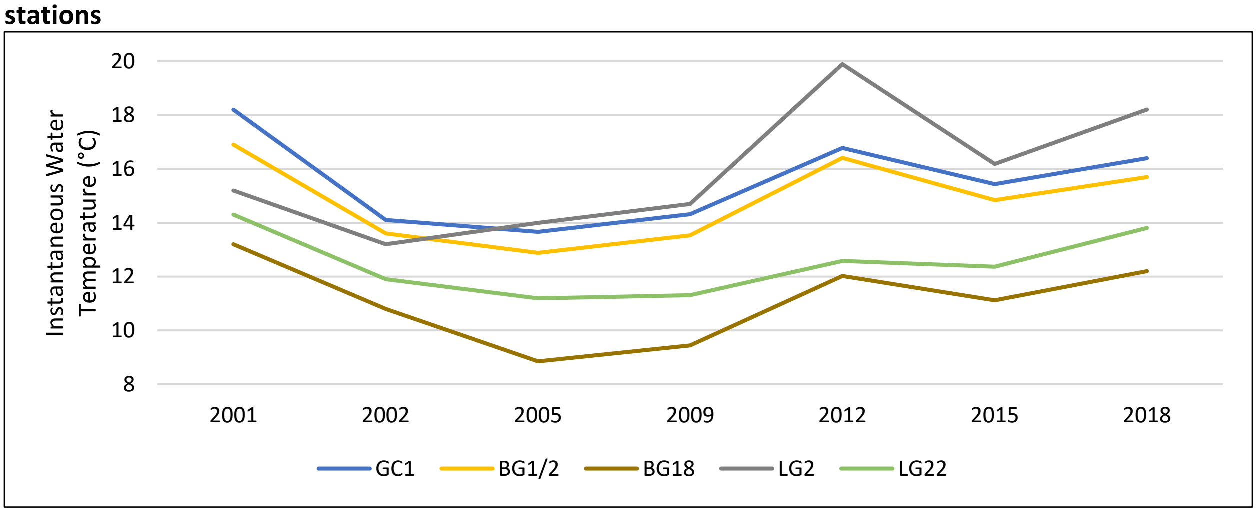
Average instantaneous temperatures were higher in the early season (May-July) at all but one tributary site, Rapid Creek (Figure 6-1). Most of the Goose Creek and Big Goose sites reported higher or similar average temperatures in the late season (July-September) than in the early season, whereas most Little Goose sites reported higher temperatures in the early season than in the late season. For mainstem sites on Big Goose Creek and Little Goose Creek, instantaneous temperatures generally decrease from downstream to upstream. The tributary stations in the Little Goose Creek subwatershed generally had higher temperatures than the tributaries in the Goose Creek and Big Goose Creek subwatersheds.

Figure 6-1. 2018 Average instantaneous water temperature by site and sample period



Changes in annual average instantaneous water temperatures were relatively consistent among mainstem stations (Figure 6-2). Average annual temperatures were slightly higher in 2018 than in 2015. Annual averages of comparable periods were highest in 2001 and 2012 than in other sampling years. Direct comparisons among years are difficult because of variations in water quantity and air temperatures.

Figure 6-2. 2001-2018 Seasonal average instantaneous temperatures at select mainstem stations



6.2.2 *Continuous Water Temperature*

One continuous temperature data logger was deployed on Goose Creek, three loggers on Big Goose Creek, and three on Little Goose Creek. The logger at BG18 could not be found on June 6 and was presumed lost in high flows; a replacement logger was deployed on July 11. The initial logger was later found in good condition and submerged underwater. Data downloaded from the initial logger appeared appropriate for conditions and was merged with the data from the replacement logger for a full dataset. All loggers reported temperatures over 20°C except for the uppermost station in Little Goose Canyon (Appendix Figures C-1 through C-7).

Five stations (GC01, BG10, LG02, LG08 and LG22) reported maximum temperatures on July 10 (Table 6-3), ranging from 18-29°C. Most minimum temperatures were reported on September 28, ranging from 5-8°C. The lower and mid-watershed stations experienced the highest number of days where maximum temperatures exceeded 20°C; 34-41% of total days sampled resulted in a maximum temperature exceeding 20°C at all sites apart from BG18 and LG22. BG18 reported one daily maximum temperature exceeding 20°C; LG22 did not report any maximum, minimum or average temperatures in exceedance of the standard.

Table 6-3. 2018 Daily Maximum, Minimum and Average Continuous Temperatures

Site	Max Temperature (°C)		Min Temperature(°C)		Seasonal Average Temp (°C)	# of Days Maximum Temp >20°C	# of Days Minimum Temp >20°C	# of Days Average Temp >20°C
	Temp (°C)	Date	Temp (°C)	Date				
GC01	27.37	7/10	8.18	9/29	18.06	56	30	44
BG01	26.39	8/12	7.48	9/29	17.27	51	20	42
BG10	29.65	7/10	6.37	9/28	16.12	55	0	32
BG18	20.23	7/13	5.14	9/28	12.45	1	0	0
LG02	27.66	7/10	7.48	9/28	17.47	55	13	39
LG08	25.9	7/10	7.68	9/28	16.27	46	3	23
LG22	18.62	7/10	5.04	9/28	12.53	0	0	0

Yearly comparisons from GC01 showed that mean daily water temperatures for 2018 were similar to previous years with some exceptions (Appendix Figure C-8). Mean daily temperatures in 2018 were typically higher than in 2005-2009, but lower than 2012. Temperatures in July 2018 were generally higher than in July 2015; temperatures in late August-September 2018 were generally lower than in 2015. Mid to late-September temperatures in 2018 were lower than all other years.

6.2.3 *pH*

Ranging from 7.81 (Park Creek) to 8.82 SU (LG02), all pH values were within the Wyoming water quality standard of 6.5-9.0 SU. When averaged for the sampling season, pH was within standards for all stations; the same is true for all sampling years (Table 6-4). Average pH values have remained relatively consistent since 2001.

Table 6-4. 2001-2018 Average Seasonal pH for Goose Creek Watershed Stations

Site/Year	2001	2002	2005	2009	2012	2015	2018
GC01	8.14	8.27	8.15	8.33	8.22	8.53	8.19
GC02	8.20	8.20	8.08	8.54	8.42	8.41	8.28
Soldier Creek	7.99	8.10	8.14	8.38	8.22	8.18	8.30
BG01/02[A]	8.20	8.30	8.09	8.63	8.51	8.44	8.27
Beaver Creek	8.31	8.40	8.22	8.44	8.44	NS	8.38
BG10	8.10	8.30	8.04	8.59	8.65	8.44	8.26
Park Creek [C]	7.84	7.99	NS	NS	8.07	7.98	7.88
BG14	8.20	8.40	NS	NS	8.47	8.43	8.25
Rapid Creek	8.25	8.34	8.10	8.41	8.52	8.30	8.17
BG18	7.80	8.00	7.88	8.69	8.80	8.62	7.99
LG02	8.10	8.20	8.20	8.48	8.41	8.21	8.50
LG08	8.00	8.10	8.28	8.53	8.42	8.31	8.41
McCormick Creek	8.06	8.21	8.11	8.33	8.41	8.15	8.28
Kruse Creek	8.21	8.30	8.14	8.43	8.39	8.36	8.26
LG13	8.10	8.20	8.34	8.82	8.54	8.58	8.48
Jackson Creek	7.85	8.13	8.36	8.56	8.55	8.44	8.53
Sackett Creek	8.03	8.22	8.07	8.34	8.52	8.28	8.24
LG22	7.70	8.00	7.85	8.83	8.86	8.86	8.13

[NS] Site not sampled during year
[A] Includes values from BG01 in 2001, 2002, 2012, 2015, and 2018 and values from BG02 in 2005 and 2009
[D] Park Creek was dry in August 2001 and 2002; thus 2001 and 2002 averages are for May only. Park Creek was dry in late September 2018; therefore 2018 average is from 9 out of 10 samples

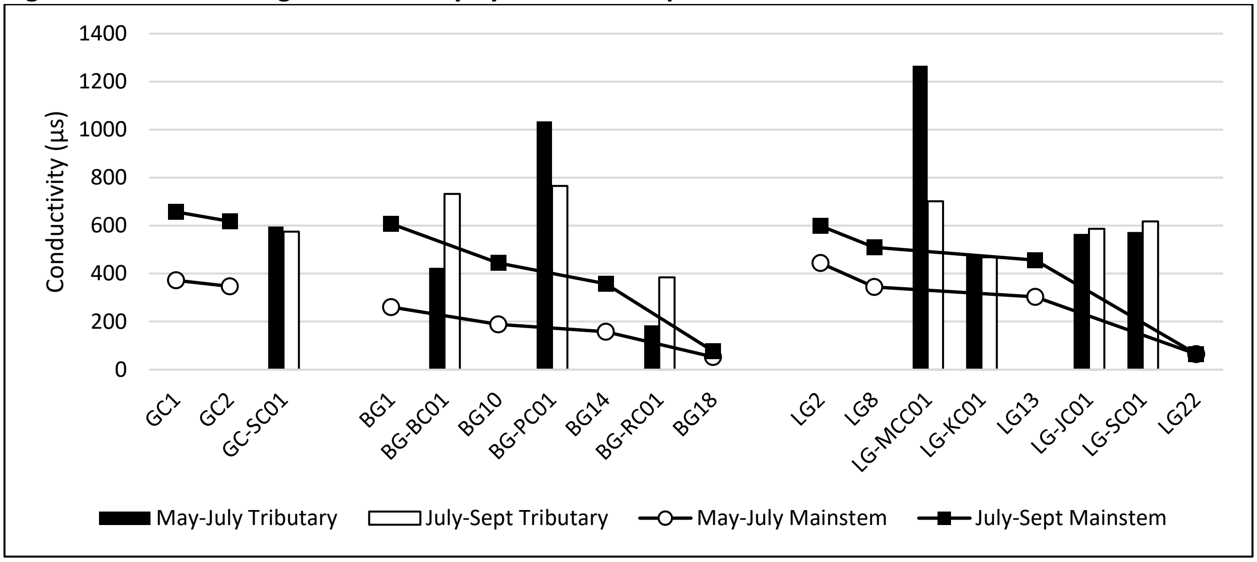
Similar pH values were measured at USGS Station 06304500 (Little Goose Creek at Sheridan). Measurements were taken once per month in November 2015, February 2016 and June 2016, and ranged from 7.8 to 8.3 SU, all remaining within the Wyoming water quality standards.

6.2.4 Conductivity

Conductivity averages increased from upstream to downstream at all mainstem stations in 2018 (Figure 6-3). Conductivity ranged from 33 µS (BG18) to 1602 µS (McC01). Conductivity at tributary stations was more variable; averages were higher at four tributary stations in the early season and lower at the other four tributaries. Averages at tributary stations were generally higher than their adjacent mainstem stations, particularly during the early season.

Park Creek and McCormick Creek were the only stations with average conductivity values over 1000 µS, with maximum values of 1108 µS and 1602 µS, respectively. Four of ten values from both Park Creek and McCormick Creek were above 1000 µS. The two canyon stations (BG18 and LG22) had the lowest conductivity, both of which were under 100 µS for all samples.

Figure 6-3. 2018 Average Conductivity by Site and Sample Period



There is no standard for specific conductivity in the state of Wyoming; however, because conductivity is highly dependent on the number of dissolved solids, high values could be a concern for agricultural operations related to crop/hay 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, 2005b). Conductivity is not directly proportional to the TDS concentration, but it can be used to estimate the relative concentration of TDS.

Overall, average 2018 conductivity in both the early and late season was lower in 2018 than in 2001 (Table 6-5). Early season conductivity at mainstem stations decreased from 2001 to 2009, increased in 2012, decreased in 2015, and increased slightly at the majority of mainstem stations in 2018. Late season averages were generally down from late season averages in 2015. Conductivity averages at most sites were higher in the late season than in the early season. The stations in the canyons were the most consistent among years and between seasons with values ranging from 53-103 µS at BG18 and 58-83 µS at LG22. Yearly comparisons among tributary stations are more difficult because values were more variable.

USGS Station 06304500 (Little Goose Creek at Sheridan) reported conductivity values between 156 µS and to 709 µS from November 2015-June 2016.

Table 6-5. 2001-2018 Average Conductivity (µs) Comparisons by Site and Sample Period

Site	May-June/July							July/August-September						
	2001 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day	**2001** 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day
GC01	658	631	338	260	423	294	372	984	813	682	580	778	745	657
GC02	649	612	334	249	395	277	347	827	743	649	540	713	705	618
Soldier	1062	1389	821	694	547	608	596	1512	1303	640	602	657	817	575
BG01/02[A]	519	533	282	198	273	203	261	930	770	680	492	727	773	608
Beaver	1074	958	709	568	673	NS	424	936	916	617	571	803	NS	732
BG10	304	377	203	134	192	134	189	595	669	681	407	737	675	444
Park[B]	862	867	NS	NS	811	858	1034	NS	NS	NS	NS	989	844	765
BG14	207	247	NS	NS	143	105	158	422	660	NS	NS	752	603	358
Rapid	222	603	237	244	273	207	185	270	540	493	438	473	521	384
BG18	90	103	71	63	60	55	53	87	96	102	81	81	86	77
LG02	918	666	313	244	536	282	444	1058	806	594	535	696	634	599
LG08	549	438	234	190	421	217	344	654	617	515	512	630	555	509
McCormick	819	1037	1105	938	568	1205	1266	630	1146	583	668	783	857	701
Kruse	649	626	607	643	631	572	474	644	582	436	440	545	555	469
LG13	427	332	192	166	347	188	303	492	475	449	410	584	484	456
Jackson	586	505	537	539	575	584	566	688	539	603	571	712	678	587
Sackett	485	466	563	559	616	647	574	395	522	418	464	428	765	617
LG22	67	83	72	60	58	60	65	63	60	63	60	58	72	65

[NS] Site not sampled during season and/or year

[A] Includes values from BG01 in 2001, 2002, 2012, 2015 and 2018 and values from BG02 in 2005 and 2009

[B] Park Creek was dry in August 2001 and 2002. Park Creek was dry in late September 2018; therefore, the late season average was calculated on 4 out of 5 samples

6.2.5 Dissolved Oxygen

All sites met the minimum instantaneous dissolved oxygen concentration standard of 5.0 mg/L for early life stages and 4.0 mg/L for other life stages. Two mainstem stations and five tributary stations (Table 6-6) returned at least one measurement below the 8.0 mg/L water column concentration recommended to achieve the 5.0 mg/L inter-gravel concentration for early life stages. All measurements on Park Creek were below 8.0 mg/L with one exception; on May 22, dissolved oxygen at Park Creek was 8.81 mg/L.

Values on tributary stations ranged from 5.49-11.45 mg/L, with the minimum value on Park Creek and the maximum value on Jackson Creek. Dissolved oxygen values at mainstem stations ranged from 6.46 mg/L at GC01 to 11.93 mg/L at BG10. The lowest dissolved oxygen values were reported on July 18 at most of stations on Goose Creek and Big Goose Creek. Dissolved oxygen values were more variable across Little Goose Creek mainstems and tributaries. At all stations the highest dissolved oxygen values occurred on May 22 and September 25, the first and last sampling days of the season.

Table 6-6. 2018 Dissolved Oxygen Ranges and Number of Samples Below 8.0 mg/L

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)
GC01	4	6.46-9.80	Soldier	2	7.70-10.34
GC02	0	8.43-11.01	Beaver	0	8.27-10.79
BG01	1	7.85-10.73	Park	8	5.49-8.81
BG10	0	8.63-11.93	Rapid	0	8.73-10.46
BG14	0	9.14-11.40	McCormick	0	8.54-10.56
BG18	0	8.68-11.64	Kruse	2	7.55-10.08
LG02	0	8.45-13.94	Jackson	1	7.45-11.45
LG08	0	8.96-11.36	Sackett	6	6.84-9.10
LG13	0	8.91-11.63			
LG22	0	8.55-11.36			

Average dissolved oxygen values were relatively consistent across the watershed among years (Table 6-7). Typically, average dissolved oxygen values were higher in the early season than in the late season across all years. Dissolved oxygen was generally lower in 2018 than in 2015 at both mainstem and tributary stations, apart from one mainstem site (LG02) during the early season and several mainstem sites during the late season (GC02, BG02, BG10, LG02 and LG13). Early season dissolved oxygen values were lower in 2018 than in 2001 at most mainstem and tributary stations, whereas late season averages were higher in 2018 than in 2001 at most stations. Park Creek dissolved oxygen averages remain the lowest across all years, ranging from 4.67 to 7.75 mg/L.

USGS Station 06304500 (Little Goose Creek at Sheridan) reported dissolved oxygen values between 9.4 mg/L and 13.7 mg/L from November 2015-June 2016.

Table 6-7. 2001-2018 Average Dissolved Oxygen (mg/L) by Site and Sample Period

Site	May-June/July							July/August-September						
	2001 30 day	2002 30 day	2005 30 day	2009 30 day	2012 30 day	2015 60 day	2018 60 day	2001 30 day	2002 30 day	2005 30 day	2009 30 day	2012 30 day	2015 60 day	2018 60 day
GC01	9.26	8.87	10.22	8.96	7.85	9.15	8.29	7.23	7.86	8.22	7.84	6.56	8.43	8.12
GC02	10.56	10.72	10.64	9.99	9.19	9.70	9.63	10.44	8.96	9.11	8.81	7.82	8.88	9.21
Soldier	8.76	9.14	9.46	8.90	8.28	8.71	8.49	6.81	7.40	9.13	8.22	6.90	8.53	8.93
BG01/02[A]	8.04	10.10	10.42	9.77	9.10	9.43	9.32	6.89	7.68	8.80	8.16	8.56	9.01	9.18
Beaver	10.37	11.11	10.20	9.77	9.36	NS	9.12	9.51	9.14	10.07	9.03	8.82	NS	9.69
BG10	10.15	11.44	10.78	10.69	10.11	10.36	9.88	9.34	9.04	9.61	9.41	8.64	9.43	9.75
Park[B]	6.23	7.71	NS	NS	7.75	7.00	6.33	NS	NS	NS	NS	4.67	7.32	6.74
BG14	10.45	10.43	NS	NS	9.45	10.37	9.86	9.39	9.29	NS	NS	9.73	10.15	10.14
Rapid	9.78	9.86	10.37	10.18	9.54	10.17	9.63	8.74	8.62	9.13	8.75	8.37	8.92	9.39
BG18	10.09	10.38	10.59	11.13	10.30	10.63	9.85	8.56	8.79	8.58	9.23	8.63	10.15	9.99
LG02	8.62	9.78	9.95	10.34	10.83	10.09	10.61	7.67	7.19	9.54	10.46	9.16	10.46	10.96
LG08	9.25	10.76	11.22	10.65	9.75	10.23	9.78	8.58	8.21	11.26	9.83	9.65	10.46	10.45
McCormick	9.36	10.60	10.44	9.98	9.40	9.25	9.22	9.33	8.95	8.74	8.52	8.53	9.58	9.36
Kruse	8.92	10.28	10.10	9.41	8.87	8.65	8.31	8.60	8.25	8.32	8.06	8.00	10.44	8.89
LG13	10.35	11.31	11.43	10.83	9.87	10.17	9.77	9.45	8.90	10.49	10.64	9.03	10.34	10.75
Jackson	8.58	8.72	10.94	9.68	8.42	9.37	8.67	6.14	7.54	9.99	8.62	10.46	11.17	9.94
Sackett	8.82	10.20	9.91	8.20	7.86	8.05	7.46	8.68	8.15	8.19	7.86	7.29	8.61	8.14
LG22	9.75	10.38	10.22	10.82	10.27	10.27	9.73	8.38	8.59	7.80	8.74	8.40	9.93	9.57

[NS] Site not sampled during season and/or year

[A] Includes values from BG01 in 2001, 2002, 2012, 2015, and 2018 and values from BG02 in 2005 and 2009

[B] Park Creek was dry in August 2001 and 2002. Park Creek was dry in late September 2018; therefore, the late season average was calculated on 4 out of 5 samples

6.3 DISCHARGE

SCCD used calibrated staff gauges to estimate discharge during water sampling events (Appendix Tables C3-C20). High precipitation and run-off in late May and early June 2018 resulted in submersion and/or damage to some gauges, which were repaired or replaced as necessary.

Most mainstem stations reported the highest flows on June 6, followed by May 22 (Table 6-8). Flows were more variable at tributary sites; most reported the highest discharge measurements during May and June, while discharge measurements at McCormick Creek and Kruse Creek were higher later in the season. The lowest discharge observed at most mainstem sites occurred on August 14, followed by September 12. The lowest discharge measurements occurred during the same dates for most tributary sites, apart from McCormick Creek and Kruse Creek. For several sites, discharge was not calculated for all dates because the gauge was submerged, out of water, or because of gauge calibration issues.

Table 6-8. 2018 Highest and Lowest Instantaneous Discharge Measurements

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								
GC01	6/6	741.43	5/22	508.78	8/14	47.14	9/12	64.46
GC02	FLOW DATA DISCARDED				FLOW DATA DISCARDED			
BG01	6/6	SUB	5/22	382.03	8/14	10.46	9/12	24.97
BG10	6/6	SUB	5/22	SUB	8/14	13.47	9/12	20.74
BG14	6/6	164.61	7/30	50.47	7/2	0.22	6/20	6.69
BG18	6/6	511.61	5/22	SUB	8/14	22.64	7/18	25.89
LG02	6/20	460.75	7/30	353.24	7/18	20.8	8/14	21.94
LG08	6/6	BENT	5/22	290.16	7/18; 8/14	16.53	9/12	16.53
LG13	7/30	4.42	8/30	2.4	8/14	1.08	9/12	1.17
LG22	6/6	420.43	5/22	267.14	9/12	7.11	9/25	17.06
TRIBUTARY SITES								
Soldier Creek	6/6	28.54	5/22	19.26	8/14	5.76	9/12	5.86
Beaver Creek	6/6	OUT	5/22	OUT	9/12	2.23	8/14	2.88
Park Creek	FLOW DATA DISCARDED				FLOW DATA DISCARDED			
Rapid Creek	6/20	34.54	7/2	33.75	9/12	1.66	8/14	1.74
McCormick Creek	7/30	62.53	9/25	9.054	6/20	0.406	6/6	0.453
Kruse Creek	8/30	14.56	7/2 and 7/30	13.82	5/22	7.98	8/14	8.45
Jackson Creek	5/22	5.22	6/6	3.3	9/12	0.13	8/14	0.31
Sackett Creek	6/6	1.22	5/22	0.97	9/12	0.12	8/30; 9/25	0.21

Late season discharge measurements in 2018 were generally higher at most sites than those from late season 2015 (Table 6-9). Early season discharge in 2018 was more variable; sites lower in the watershed generally had higher discharge than in 2015, whereas sites higher in the watershed generally had lower discharge than in 2015. Average discharge on Little Goose, Big Goose, and Goose Creeks were typically highest in early season 2009; however, some sites in early season 2018 reported higher discharge than in 2009 (Soldier Creek, Rapid Creek, BG18, LG08, Kruse Creek and LG22). Early season 2018 discharge on Soldier Creek, Beaver Creek, BG18, LG08 and Kruse Creek were higher than in all other years; late season 2018 discharge on Soldier Creek, BG10, BG14, Rapid Creek, LG02, McCormick Creek and Kruse Creek were also higher than in all other years.

Table 6-9. 2001-2018 Average Instantaneous Discharge (cfs) by Site and Sample Period

Site	May-June/July							July/August-September						
	2001 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day	**2001** 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day
GC01	34.7	64.1	502.8	511.2	141.1	187.5	370.3	14.6	27.2	60.8	120.5	24.8	52.5	80.6
GC02	ND	69.2	38.9	450.3	185.8	149.8	ND	ND	27.1	61.1	73.7	22.4	61.5	ND
Soldier	1.4	1.1	10.7	8.0	8.8	12.6	16.1	0.2	0.4	2.6	4.1	0.9	1.7	6.9
BG01/02[A]	28.0	35.8	204.5	344.3	128.0	ND	203.8	4.7	7.1	20.9	39.3	27.1	ND	35.5
Beaver	1.2	2.0	8.19	17.6	8.9	NS	25.8	2.6	2.6	14.6	15.5	3.6	NS	3.7
BG10	70.0	29.5	22.6	288.5	115.6	172.0	97.4	10.3	7.9	11.4	34.6	6.8	15.2	54.2
Park[B]	0.0	0.0	NS	NS	0.0	1.2	ND	NS	NS	NS	NS	0.0	0.5	ND
BG14	73.1	23.5	NS	NS	105.0	75.6	53.6	9.8	6.0	NS	NS	5.5	7.6	22.2
Rapid	2.2	1.2	7.3	13.3	6.8	62.5	26.5	1.1	1.0	1.5	2.7	1.1	1.4	2.8
BG18	86.2	26.7	75.0	202.0	93.2	71.4	210.7	26.7	23.9	18.9	63.1	25.1	24.5	35.0
LG02	8.3	63.7	26.8	325.8	45.1	72.0	203.9	3.6	5.3	29.4	44.6	13.0	29.3	96.9
LG08	11.5	32.8	13.0	57.8	32.5	94.6	115.4	6.4	13.4	21.5	36.1	10.7	22.0	27.5
McCormick	1.8	5.6	2.9	5.9	2.5	49.8	1.7	1.6	0.1	4.2	3.2	0.9	2.3	17.9
Kruse	1.6	2.9	4.5	2.7	2.0	4.5	10.4	0.6	3.5	5.8	6.6	3.0	7.7	11.3
LG13	3.3	16.1	19.8	66.6	15.8	80.7	ND	1.4	2.6	6.6	19.3	2.2	8.3	2.2
Jackson	0.7	0.9	1.6	3.1	1.9	4.5	2.8	0.4	0.9	4.3	0.5	0.7	1.3	0.4
Sackett	0.8	3.1	5.6	1.0	0.5	7.6	0.9	0.6	0.3	0.4	0.6	0.8	0.1	0.3
LG22	47.6	46.4	166.1	166.5	86.6	201.1	173.0	33.4	29.6	39.0	80.8	49.4	54.2	43.8

[ND] Problems with gauge calibration prevented estimation of discharge at GC02 in 2001 and 2018; BG01 in 2015; Park Creek in 2018; and LG13 in 2018

[NS] Site not sampled during season and/or year

[A] Includes values from BG01 in 2001, 2002, 2012, 2015 and 2018 and values from BG02 in 2005 and 2009

One USGS gauge collected hydrologic information during the sampling period. *Station 06305700 Goose Creek near Acme*, which is near GC01, reported "real-time" discharge information beginning in February 2018 (Appendix Figure C-9). Higher flow values measured at GC01 in May and June of 2018, and lower flow values measured from mid-August to the end of September, correspond to similar instantaneous and historical discharge measurements recorded by the USGS. Historical hydrologic information was also available from *Station 06302000 Big Goose near Sheridan*, which corresponds to site BG18 (Appendix Figure C-10).

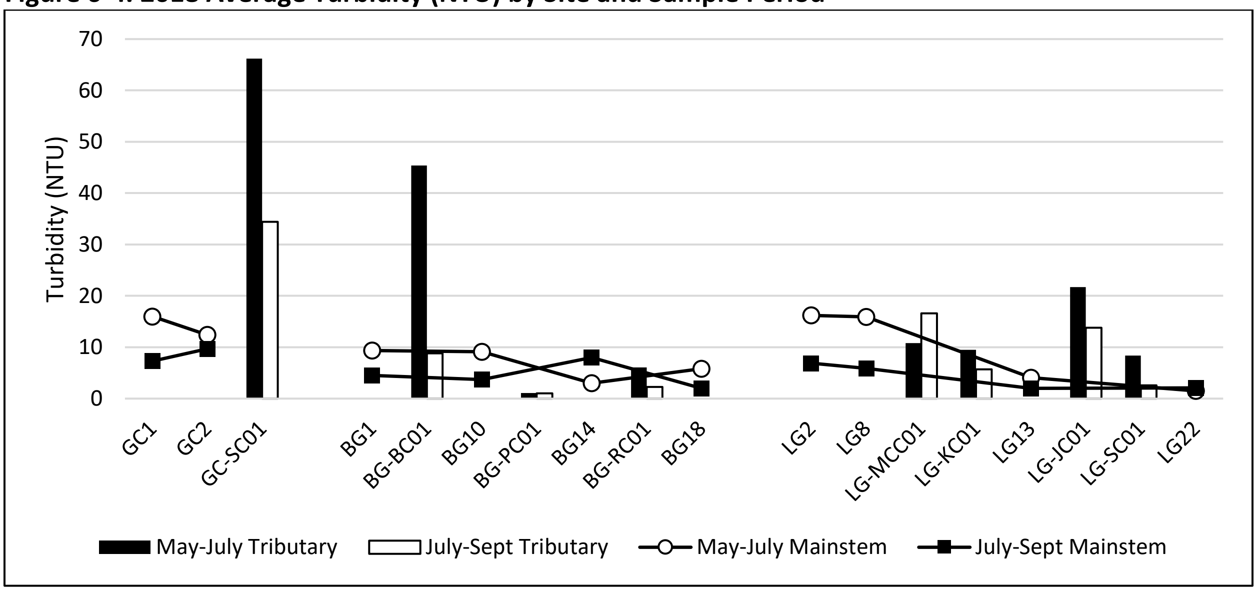
High flow values at BG18 in May 2018 correspond to historical mean daily flow measurements from the USGS, as do lower flow measurements taken in August and September 2018.

6.4 TURBIDITY

Turbidity generally increased from upstream to downstream (Figure 6-4); however, decreases in turbidity were recorded during the late season from GC02 to GC01 and from BG14 to BG10. Samples collected during the early season of 2018 generally had higher turbidity than those collected during the late season, apart from BG14, McCormick Creek and LG22. Tributary stations were typically higher than adjacent mainstem sites during both seasons, except for Park Creek which was lower during all occasions, Rapid Creek which was lower than BG14 during the late season, and McCormick Creek which was lower than LG08 during the early season.

The highest turbidity value reported from a mainstem site was 57.6 NTUs at LG08 on June 22; the lowest mainstem value was 0.8 NTUs at LG22 on July 2. The highest turbidity value reported from a tributary site was 117 NTUs at Beaver Creek on June 6; the lowest tributary value was 0.5 NTUs at Park Creek on August 14.

Figure 6-4. 2018 Average Turbidity (NTU) by Site and Sample Period



Average turbidity on mainstem stations during the early season was generally lower than in 2015, except on LG02, LG08, BG10, and BG18 (Table 6-10). Turbidity on tributary stations was more variable, with early season turbidity remaining relatively consistent at Soldier Creek, Park Creek, and Rapid Creek, increasing from 2015 to 2018 at Sackett Creek, and decreasing from 2015 to 2018 at McCormick Creek, Jackson Creek and Kruse Creek. Generally, average turbidity during the late season increased from 2015 to 2018 at mainstem stations. However, late season averages decreased from 2015 to 2018 at LG22, and averages at GC01 and LG02 remained the same from 2015 to 2018. Late season turbidity averages increased from 2015 to 2018 at all tributaries, except for Park Creek, which decreased slightly. Changes in turbidity averages across other years and timeframes were more variable.

Table 6-10. 2001-2018 Average Turbidity (NTU) by Site and Sample Period

Site	May-June/July							July/August-September						
	2001 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day	**2001** 30 day	**2002** 30 day	**2005** 30 day	**2009** 30 day	**2012** 30 day	**2015** 60 day	**2018** 60 day
GC01	9.3	12.7	30.2	9.7	19.6	18.9	16.0	2.4	3.9	8.4	12.8	3.4	7.3	7.3
GC02	9.0	7.5	19.8	12.0	17.4	15.5	12.4	2.7	2.6	8.1	12.0	5.0	9.0	9.7
Soldier	8.1	14.7	80.1	15.7	39.1	65.0	66.2	10.5	25.6	38.6	47.3	33.1	12.9	34.4
BG01/02[A]	9.3	5.3	16.1	15.4	16.2	10.0	9.4	4.7	4.8	8.2	8.2	6.3	7.3	4.5
Beaver	4.5	7.9	22.3	21.2	28.6	NS	45.4	4.8	5.9	22.9	23.0	13.0	NS	8.8
BG10	13.7	2.4	7.1	6.6	7.3	6.9	9.1	1.0	1.8	3.3	3.7	3.2	3.0	3.7
Park[B]	8.1	13.6	NS	NS	1.5	1.2	1.1	NS	NS	NS	NS	4.6	1.8	1.0
BG14	8.4	3.0	NS	NS	5.4	4.3	3.0	1.3	1.2	NS	NS	3.5	2.3	8.0
Rapid	8.3	0.9	7.8	3.7	7.3	6.1	6.1	2.0	1.2	2.0	2.3	1.1	0.9	2.3
BG18	2.6	1.7	4.1	3.3	2.0	4.7	5.8	1.6	1.1	1.1	1.3	1.0	1.2	2.0
LG02	2.3	9.9	13.4	7.1	11.3	9.7	16.2	1.1	2.1	7.7	11.3	6.0	6.9	6.9
LG08	8.5	9.8	7.8	5.6	8.6	8.1	15.9	11.6	10.0	7.0	7.9	4.8	3.1	5.9
McCormick	11.8	33.0	14.9	24.2	21.3	12.6	10.8	20.6	9.5	21.8	23.4	18.3	12.4	16.6
Kruse	21.6	20.7	20.4	9.4	7.3	12.4	9.4	11.7	19.7	21.3	9.1	10.3	3.4	5.7
LG13	2.6	2.8	5.2	5.0	3.6	4.9	4.1	1.2	2.7	1.6	4.8	2.4	1.5	2.0
Jackson	62.5	89.4	53.8	14.5	17.0	24.0	21.7	23.2	34.2	5.2	12.2	5.2	2.1	13.8
Sackett	7.9	5.5	5.2	4.9	7.6	4.8	8.4	3.2	4.6	2.9	4.2	3.8	1.7	2.6
LG22	1.5	0.8	3.5	2.0	1.7	2.2	1.5	2.1	3.4	1.5	2.2	2.0	2.4	2.1

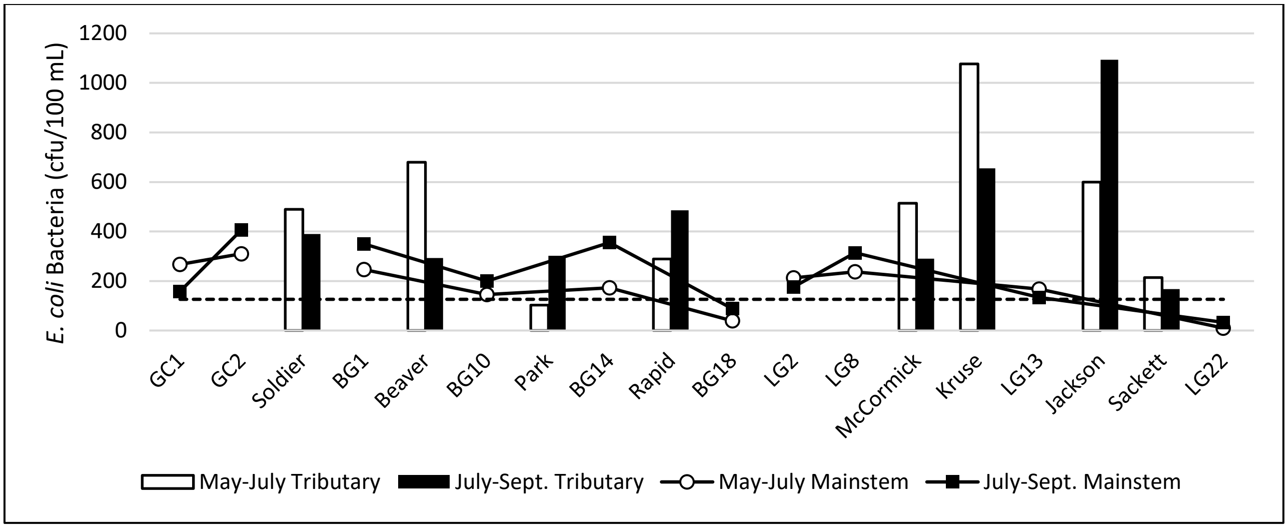
[NS] Site not sampled during season and/or year
[A] Includes values from BG01 in 2001, 2002, 2012, 2015 and 2018 and values from BG02 in 2005 and 2009
[B] Park Creek was dry in August 2001 and 2002. Park Creek was dry in late September 2018; therefore, late season average was calculated on 4 out of 5 samples

6.5 BACTERIA

In 2018, ten *E. coli* bacteria samples were obtained from 17 of the 18 stations from May to September (Appendix Tables C3-C20). Geometric means were calculated for each site from five early season (May 22-July 18) samples and five late season (July 30-September 25) samples. A mid-season (June 20-August 14) geometric mean was also calculated. Park Creek was dry on September 25; therefore, the late season geometric mean for this site was only calculated on four samples.

Geometric mean bacteria concentrations exceeded the Wyoming water quality standard at all sites during all seasons except for Park Creek, BG18, and LG22. Park Creek did not exceed the standard during the early season and BG18 and LG22 reported concentrations that remained below the standard across the entire monitoring season. Geometric mean bacteria concentrations were typically lower in the early season than in the late season at Goose Creek and Big Goose Creek sites (Figure 6-5). The opposite was true for bacteria concentrations at Little Goose Creek sites. Five out of eight sites were higher in the early season than in the late season, whereas, LG08, Jackson Creek, and LG22 were lower. Mainstem sites typically had lower bacteria concentrations than tributary sites. Bacteria concentrations at tributaries may have contributed to increases in bacteria concentrations at some adjacent downstream stations.

Figure 6-5. 2018 Goose Creek Watershed *E. Coli* Bacteria Geometric Means by Site and Sample Period



For samples collected in 2001-2012, geometric means were calculated on five samples collected within two separate 30-day periods. In 2015, SCCD collected samples within two separate 60-day periods to correspond to changes in WDEQ methodology (WDEQ, 2017). 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 the early season and the late season conditions.

The number of comparable mainstem sites with geometric means that exceeded the standard increased from 2001 to 2018 in both the early and late season (Table 6-11). The number of tributary stations that exceeded the standard in August has remained consistent since 2002.

Table 6-11. Number of Comparable Sites Exceeding Bacteria Standards from 2001-2018

Description	2001	2002	2005	2009	2012	2015	2018
Goose Creek May-June (2 sites)	0	2	2	2	2	1	2
Big Goose May-June (4 sites)	0	0	0	1	2	1	3
Little Goose May-June (4 sites)	0	0	1	0	2	2	3
Tributaries May-June (8 sites)	3	1	5	2	5	5	7
Total Sites May-June/July	***3***	***3***	***8***	***5***	***11***	***9***	***15***
Goose Creek August-September (2 sites)	1	1	2	2	1	2	2
Big Goose August-September (4 sites)	1	0	2	2	2	2	3
Little Goose August-September (4 sites)	2	2	2	3	3	3	3
Tributary August-September (8 sites)	5	6	6	6	6	6	8
Total Sites July/August-September	***9***	***9***	***12***	***13***	***12***	***13***	***16***

An increase in bacteria concentrations from 2001 to 2018 was observed at every comparable mainstem site for both the early and late seasons (Figures 6-6 through 6-8). For samples collected during the early season, most mainstem stations show an increase from 2001 to 2009 or 2012 that is followed by a decrease in 2015, and then an increase again from 2015 to 2018. For the late season, fluctuations among years are more variable. GC01, GC02, LG08, LG13, and BG01 follow a similar pattern throughout the years as they did in the early season. Both canyon sites, LG22 and BG18, have been showing a slight increase across the years during the late season. For the most part, concentrations decreased from 2015 to 2018 during the late season (except for at BG14 and BG18); opposite of what was observed at mainstem sites during the early season.

Tributary stations are more variable; however, most stations appear to have an increase in 2005 or 2012 that are followed by subsequent decreases (Figures 6-9 through 6-11). Concentrations at Soldier Creek increase during the early season from 2015 to 2018 but decreased during the late season. The opposite is true for Park Creek. Rapid Creek concentrations increase during the early and late season from 2015 to 2018; concentrations at Beaver Creek decreased during both seasons since it was last sampled in 2012. Early season bacteria concentrations at all Little Goose tributaries have been increasing since 2009. Overall, late season concentrations at Little Goose tributaries have been more variable than the early season, but all increased from 2015 to 2018, apart from Sackett Creek.

Bacteria concentrations increased by 20-82% from 2015 to 2018 at all mainstem stations during the early season except for LG22, where concentrations decreased by 42% (Table 6-11). The opposite was observed during the late season; concentrations decreased by 10-78% at all but two mainstem sites from 2015 to 2018. BG14 and B18 increased by 17% and 20%, respectively.

Concentrations at tributaries increased from 2015 to 2018 at most stations during both the early and late season. Early season concentration increases ranged from 33-84%; late season concentration increases ranged from 8-54%. Park Creek decreased by 34% in the early season; late season concentrations decreased at Soldier Creek and Sackett Creek 40% and 128% respectively.

Overall, bacteria concentrations have increased at mainstem and tributary sites across the monitoring season between 2001 and 2018. Park Creek early season concentrations decreased during this time, as did late season concentrations at Soldier Creek, McCormick Creek, and Sackett Creek. Increases in concentrations between 2001 and 2018 range from 9-1850%, with the largest mainstem increase observed between early season data at BG18. However, BG18 concentrations remain well within water quality standards, increasing from 2 cfu/100 mL to 39 cfu/100 mL. The largest increase observed at a tributary site from 2001 to 2018 between early season data was at Kruse Creek, which increased from 118 cfu/100 mL to 1077 cfu/100 mL. Changes among other seasons and years has been more variable.

Bacteria deposits from livestock, humans, wildlife, and other sources can be transported from upland areas to streams through overland run-off. 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.

Table 6-12. 2001-2018 Bacteria Geometric Means and Percent Change

	Site	May-June/July *E. coli* Geometric Means (cfu/100 mL)							Percent Change					
		2001 [A]	2002 [A]	2005	2009	2012	2015	2018	2001-2018	2002-2018	2005-2018	2009-2018	2012-2018	2015-2018
Mainstem Sites	GC01	55	127	303	309	335	124	267	385%	52%	-13%	-16%	-25%	54%
	GC02	96	135	275	391	329	142	310	223%	56%	11%	-26%	-6%	54%
	BG01 [B]	113	55	107	285	223	163	246	118%	78%	57%	-16%	9%	34%
	BG10	38	6	41	102	267	76	149	292%	96%	73%	32%	-79%	49%
	BG14	21	3	NS	NS	415	92	173	724%	98%			-140%	47%
	BG18	2	1	9	6	9	7	39	1850%	97%	76%	85%	77%	82%
	LG02	43	102	242	119	215	169	212	393%	52%	-14%	44%	-1%	20%
	LG08	54	73	56	66	165	140	237	339%	69%	76%	72%	30%	41%
	LG13	20	18	40	48	118	94	167	735%	89%	76%	71%	29%	44%
	LG22	1	2	4	2	9	14	10	900%	80%	63%	81%	12%	-42%
Tributary Sites	Soldier	246	197	1286	133	461	163	489	99%	60%	-163%	73%	6%	67%
	Beaver	166	45	400	405	999	NS	679	309%	93%	41%	40%	-47%	
	Park	139	468	NS	NS	58	138	103	-26%	-354%			44%	-34%
	Rapid	67	36	35	66	637	109	289	331%	88%	88%	77%	-120%	62%
	McCormick	143	119	139	108	249	335	514	259%	77%	73%	79%	51%	35%
	Kruse	118	80	261	69	101	177	1077	813%	93%	76%	94%	91%	84%
	Jackson	246	14	177	317	508	352	600	144%	98%	71%	47%	15%	41%
	Sackett	33	7	238	48	129	144	214	548%	97%	-11%	78%	40%	33%
	Site	July/Aug-Sept *E. coli* Geometric Means (cfu/100 mL)							Percent Change					
		2001 [A]	2002 [A]	2005	2009	2012	2015	2018	2001-2018	2002-2018	2005-2018	2009-2018	2012-2018	2015-2018
Mainstem Sites	GC01	99	38	174	186	69	194	158	60%	76%	-10%	-18%	56%	-23%
	GC02	374	156	343	319	299	495	406	9%	62%	15%	21%	26%	-22%
	BG01 [B]	310	122	386	308	246	453	350	13%	65%	-10%	12%	30%	-29%
	BG10	80	53	141	165	278	263	199	149%	73%	29%	17%	-40%	-32%
	BG14	69	111	NS	NS	521	294	355	414%	69%			-47%	17%
	BG18	20	4	11	37	42	70	88	340%	95%	87%	58%	52%	20%
	LG02	133	184	278	219	257	222	176	32%	-5%	-58%	-24%	-46%	-26%
	LG08	220	326	302	235	285	427	314	43%	-4%	4%	25%	9%	-36%
	LG13	44	73	122	186	132	238	134	205%	46%	9%	-39%	1%	-78%
	LG22	7	7	7	18	20	36	33	371%	78%	77%	47%	39%	-10%
Tributary Sites	Soldier	2548	420	655	446	480	545	390	-85%	-8%	-68%	-14%	-23%	-40%
	Beaver	167	157	375	769	408	NS	293	75%	46%	-28%	-162%	-39%	
	Park	NS	NS	NS	NS	147	264	302					51%	13%
	Rapid	65	129	326	216	526	223	485	646%	73%	33%	56%	-8%	54%
	McCormick	303	219	546	289	789	162	290	-4%	24%	-88%	0%	-172%	44%
	Kruse	155	150	776	297	585	601	655	323%	77%	-19%	55%	11%	8%
	Jackson	219	206	568	462	1686	584	1094	400%	81%	48%	58%	-54%	47%
	Sackett	237	179	228	161	148	382	167	-30%	-7%	-37%	4%	12%	-128%

[A] *E. coli* values for May 2001, May 2002, and August 2001 were calculated based on fecal coliform values

[B] Includes values from BG01 in 2001, 2002, 2012, 2015 and 2018 and values from BG02 in 2005 and 2009

[NS] Site not sampled during season and/or year

Figure 6-6. 2001-2018 *E. coli* Bacteria Geometric Means on Goose Creek Mainstem Stations

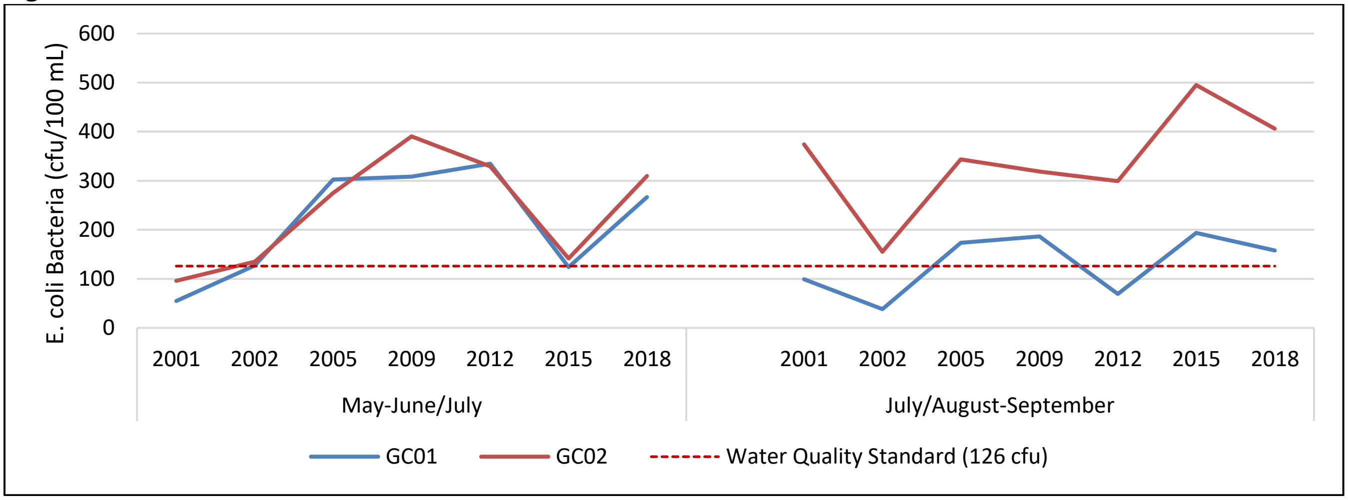


Figure 6-7. 2001-2018 *E. coli* Bacteria Geometric Means on Big Goose Creek Mainstem Stations

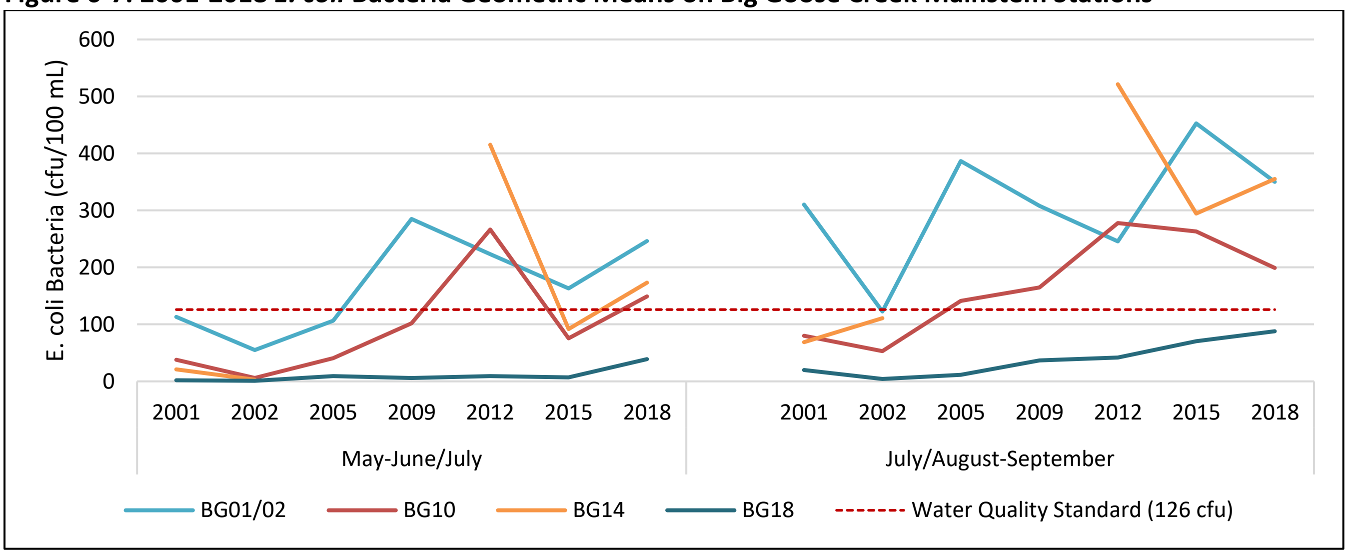


Figure 6-8. 2001-2018 *E. coli* Bacteria Geometric Means on Little Goose Creek Mainstem Stations

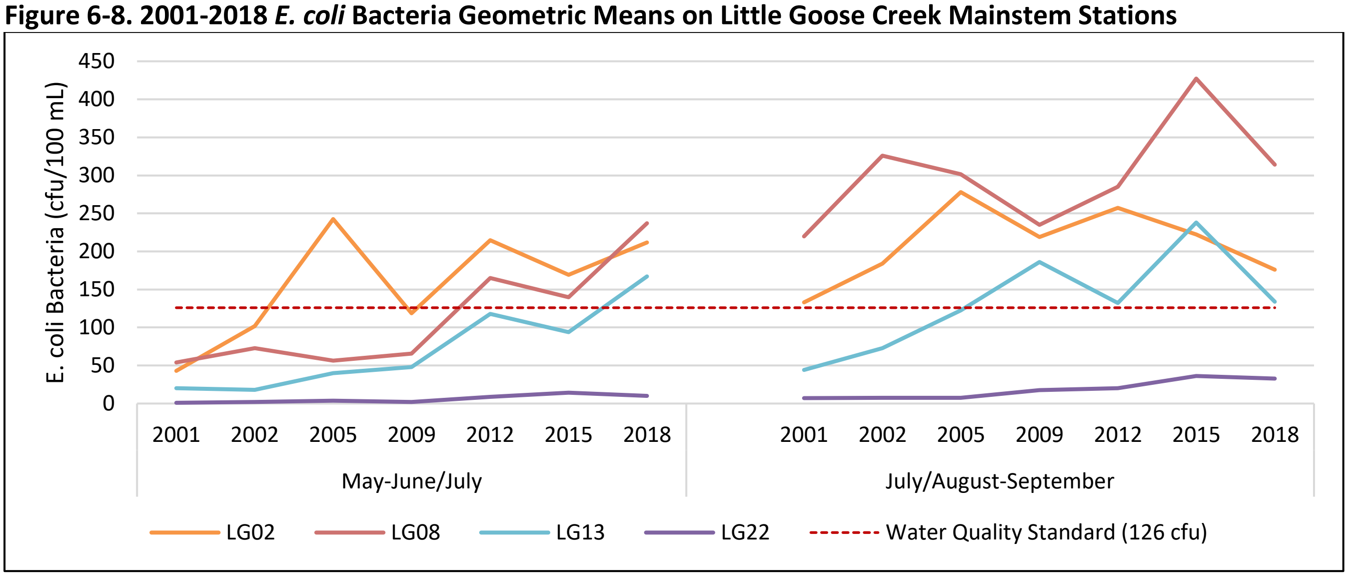


Figure 6.9—2001-2018 *E. coli* Bacteria Geometric Means on Goose Creek Tributaries

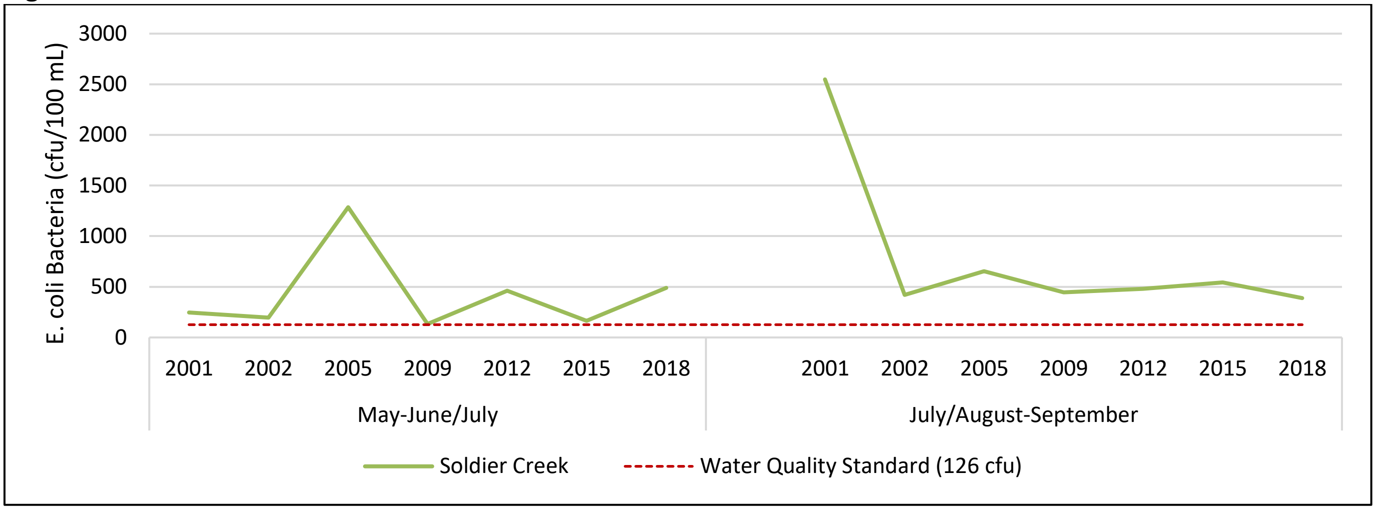


Figure 6.10—2001-2018 *E. coli* Bacteria Geometric Means on Big Goose Creek Tributaries

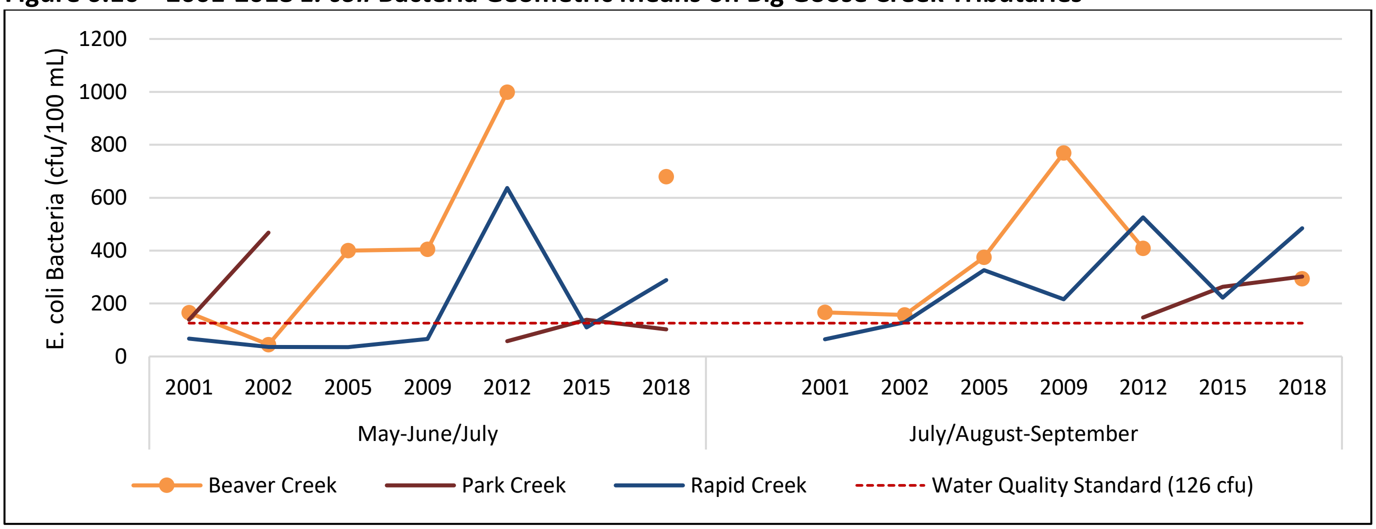
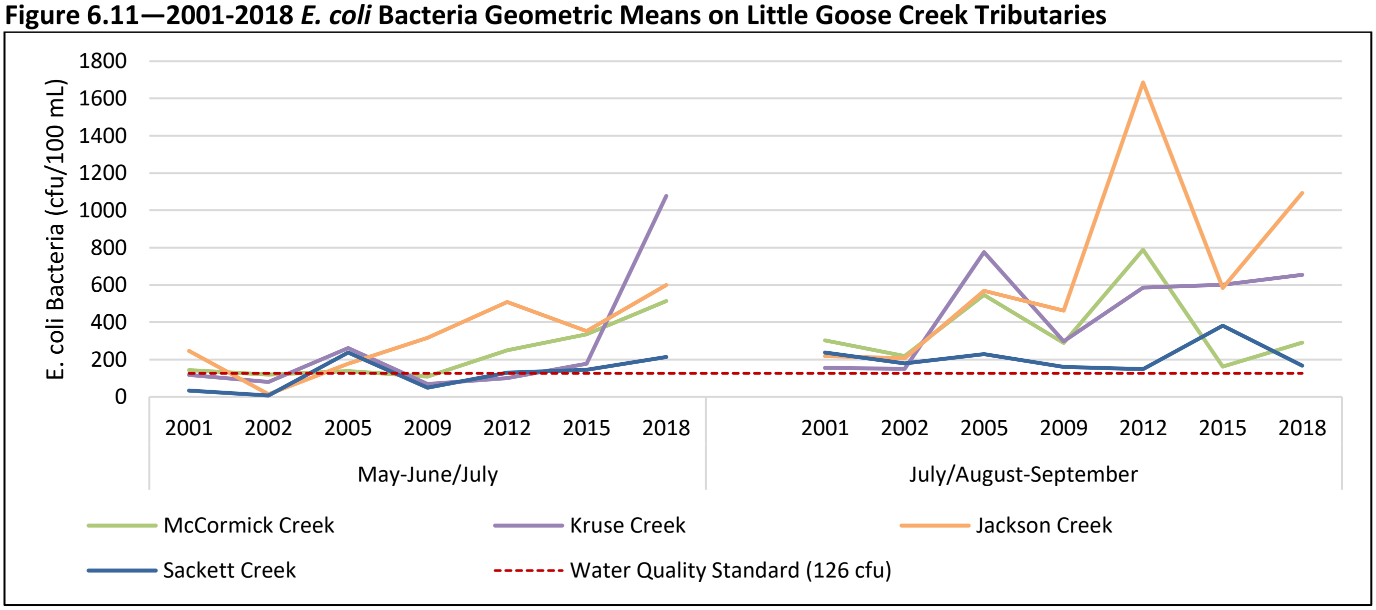


Figure 6.11—2001-2018 *E. coli* Bacteria Geometric Means on Little Goose Creek Tributaries



6.6 METEOROLOGICAL DATA AND SUPPORTING INFORMATION

Mean daily air temperatures were above average by 2-6°C from May-July, but below average by 1-3°C from August-October (Table 6-13 and Appendix FigureC-11). National Weather Service data at the Sheridan County Airport show normal mean daily air temperatures from May through October average 59.4°F while 2018 mean daily air temperatures averaged 60.0°F.

Cumulative precipitation through October 2018 was 15.3 inches, which was 3 inches higher than the normal precipitation for the same period (Table 6-13 and Appendix Figure C-12). This increase is primarily attributed to high precipitation in May and August, which were 1.8 and 2.6 inches higher than normal, respectively. Monthly precipitation for other months in 2018 was either the same or lower than normal.

Table 6-13. 2018 Precipitation and Air Temperature Data Collected by the National Weather Service from the Sheridan County Airport

Months	Average Monthly Air Temperature (°F)		Average Monthly Precipitation (inches)			
	2018	Normal	2018	Normal	2018 Cumulative	Normal Cumulative
January-April					5.5	3.7
May	58	52	0.12	0.08	6.7	4.9
June	63	62	0.05	0.07	9.8	7.2
July	72	70	0.04	0.04	10.7	8.8
August	67	69	0.04	0.02	12.3	9.7
September	57	58	0.04	0.05	13.2	10.7
October	43	46	0.05	0.05	15.3	12.3

6.7 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates reside in and on the bottom substrate of streams and provide a valuable tool for the assessment of water quality in the Goose Creek 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, 2018c) 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, 2018c).

6.7.1 Previous Benthic Macroinvertebrate Sampling

The historic benthic macroinvertebrate data collected in the Goose Creek watershed through 2002 were presented and discussed in the *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003). Subsequent benthic macroinvertebrate data collected by WDEQ in 2004 and SCCD in 2005 in the Goose Creek watershed were presented and discussed in the *2005 Goose Creek Watershed Monitoring Project Final Report* (SCCD, 2006). Benthic macroinvertebrate data collected by SCCD in 2009 in the Goose Creek watershed were presented and discussed in the *2009 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2011). Further, the benthic macroinvertebrate data collected by SCCD in 2012 were presented and discussed in the *2012 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2014). Benthic macroinvertebrate samples collected in 2015 were presented in the *2015 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2017). No benthic macroinvertebrate samples were collected in the Goose Creek watershed by SCCD during 2003, 2006, 2007, 2008, 2010, 2011, 2013, 2016 and 2017. WDEQ collected duplicate macroinvertebrate samples at Little Goose Creek station MRC 38 (SCCD station LG22) during 2014.

During 2001 and 2002, a total of twenty-one samples were collected each year by SCCD from nineteen stations (SCCD, 2003). A total of seven benthic macroinvertebrate samples were collected by SCCD in 2005 from six stations (SCCD, 2006). WDEQ collected ten benthic macroinvertebrate samples at nine stations in the Goose Creek watershed during 2004. The WDEQ benthic macroinvertebrate sampling occurred in and near Sheridan as part of the Goose Creeks storm water project. The purpose of the storm water project was to identify and assess significant potential water quality problems related to storm water discharges within the Goose Creek watershed, identify sources of pollutants in storm water runoff, and assess the impacts of storm water runoff on receiving waters (WDEQ, 2005a). Apart from four of the WDEQ benthic macroinvertebrate sampling stations assessed in 2004, all samples were collected at stations previously established in the Goose Creek watershed. SCCD collected a total of seven benthic macroinvertebrate samples from six stations in the Goose Creek watershed in 2009 and a total of nine samples from eight stations in 2012. Macroinvertebrate sampling and habitat assessments were performed at six stations in October of 2015.

6.7.2 *Benthic Macroinvertebrate Sampling In 2018*

Macroinvertebrate sampling and habitat assessments were performed at eight stations in October of 2018 (Appendix A-1). Benthic macroinvertebrate samples were collected from two Goose Creek stations (station GC01 and station GC02), four samples were collected from three Big Goose Creek stations (station BG02, station BG10 and station BG18), and three samples were collected from three Little Goose Creek stations (station LG2A, station LG10 and station LG22). Included in the total number of samples was a duplicate sample collected at Big Goose Creek station BG02. The duplicate sample was used only for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results.

The number of sampling stations and the number of samples collected by SCCD in 2018 differed slightly to the number of stations sampled and number of samples collected in 2005, 2009, 2012 and 2015. Big Goose Creek upstream control station BG18 and Little Goose Creek upstream control station LG22 added to the 2012 and 2018 benthic macroinvertebrate sampling schedule were not sampled during 2015. However, the overall reduced number of sample stations and samples collected during 2005, 2009, 2012, 2015 and 2018 when compared to the sampling regime in 2001 and 2002 precluded a complete evaluation of the benthic macroinvertebrate communities between years and the comparison of biological condition at each station in the Goose Creek watershed.

Field benthic macroinvertebrate sample collection methods and laboratory analytical methods employed by SCCD in 2001, 2002, 2005, 2009, 2012 and 2015 were the same as those used for sampling in 2018. In addition, WDEQ benthic macroinvertebrate sampling methods for samples collected in 1994, 1998, 2004 and 2014 were identical to those used by SCCD resulting in comparable benthic macroinvertebrate data. Macroinvertebrate samples collected in 2018 were sorted by Aquatic Assessments, Inc. in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon. Previous benthic macroinvertebrate samples collected by WDEQ in in 1994 and 1998 were analyzed by ABA. Samples collected by WDEQ in 2004 and 2014 were analyzed by Rhithron Associates, Inc. in Missoula, MT.

6.7.3 *Benthic Invertebrate Taxa*

Taxa lists for benthic macroinvertebrate samples collected in the Goose Creek watershed in 2018 are presented in Appendix D, Tables D-1 through D-9. The cumulative list of macroinvertebrate taxa identified from samples collected in the Goose Creek watershed from 2001 through 2018 is presented in Appendix D, Table D-10. The list of benthic macroinvertebrate metrics for samples collected in 1994, 1998, 2001, 2002, 2004, 2005, 2009, 2012, 2015 and 2018 is presented in Appendix D, Tables D-11 through D-16.

A total of 259 benthic macroinvertebrate taxa have been identified since 2001 from a total of 91 samples collected during the project (Appendix Table D-10). Fourteen new taxa were identified during 2018 including the water mite genera *Protzia* and *Hygrobates*, the Chironomidae genera *Hydrobaenus*, *Orthocladius (Euorthocladius*), and *Paraphaenocladi*us, the worm taxa *Limnodrilus udekemianus*, *Rhyacodrilus*, *Eiseniella tetraedra* and *Lumbriculus*, the stonefly genus *Pteronarcys*, the Amphipod genus *Crangonyx*, the riffle beetle taxa *Heterlimnius corpulentus* and *Narpus concolor*, the mayfly genus *Neoleptophlebia* and the gastropod *Physella*.

No threatened or endangered benthic macroinvertebrate taxa or fish species (incidentally captured during macroinvertebrate sampling) were identified. The generally widespread occurrence of the freshwater shrimp genera *Gammarus, Hyalella*, *Crangonyx,* and the freshwater shrimp species group *Hyalella azteca* (commonly used in laboratory toxicity tests) in the Goose Creek watershed indicated that water in Goose Creek, Big Goose Creek and Little Goose Creek contained no toxic substances in sufficient concentration to prevent the establishment and survival of these organisms.

The worm genus *Tubifex* has not been identified in the Goose Creek watershed. This is encouraging because the presence of *Tubifex* in streams is of concern since T*ubifex tubifex* (a species of worm) is implicated in the occurrence of whirling disease. Whirling disease is caused by a destructive parasite that may decimate trout populations. *T. tubifex* 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. The lack of the genus *Tubifex* in the watershed indicates the low potential occurrence of *T. tubifex*. Continued monitoring for this organism is suggested not only as an environmental indicator, but as an indicator of future health of trout populations in the Goose Creek watershed. Whirling disease has not been identified in the Goose Creek watershed or the nearby Tongue River and Prairie Dog Creek watersheds. However, whirling disease has been identified in the Clear Creek watershed east, and adjacent to the Prairie Dog Creek watershed.

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 Goose Creek watershed or the nearby Tongue River and Prairie Dog Creek watersheds.

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 southeast Wyoming. Historic benthic macroinvertebrate sampling and current monitoring by SCCD have not identified the New Zealand Mudsnail or the Asian clam in the Goose Creek watershed or the nearby Tongue River and Prairie Dog Creek watersheds.

Turbellaria flatworms (subclass Trepaxonemata) were most common in the Goose Creek watershed and occurred in 92% of the total samples collected (Appendix Table D-10). Acari (water mites) (88%), the riffle beetle genus *Microcylloepus* (88%), the Chironomidae midge fly genera *Cricotopus* (87%) and *Rheotanytarsus* (79%), and the blackfly genus *Simulium* (77%) were common in samples collected since 2001.

Chironomidae, Coleoptera and Ephemeroptera were present in 100 percent of samples collected in the Goose Creek watershed since 2001. The Diptera family Chironomidae (midges) had the greatest number of taxa in the project area (N = 63 taxa), followed by the order Ephemeroptera (N = 41 mayfly taxa), the order Trichoptera (N = 38 caddisfly taxa), the class Oligochaeta (N = 23 worm taxa), the order Plecoptera (N = 14 stonefly taxa), the Diptera family Tipulidae (N = 10 cranefly taxa) and the Coleopteran family Elmidae (N = 10 riffle beetle taxa) (Appendix Table D-10).

6.8 BIOLOGICAL CONDITION

Biological condition scores were determined using the Wyoming Stream Integrity Index (WSII) initially developed by Jessup and Stribling (2002), updated by Hargett and ZumBerge (2006) and revised by Hargett, 2011. The WSII is based on the analysis of 1,488 benthic macroinvertebrate monitoring data collected by WDEQ from 1993 through 2009 from multiple 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. Biological condition scoring criteria developed for the High Valleys bioregion were used to evaluate biological condition for streams in the Goose Creek watershed within the project area. Table 6-14 lists the WSII metrics and metric formulae used to determine biological condition for benthic macroinvertebrate communities in the High Valleys bioregion.

Table 6-14. Wyoming Stream Integrity Index (WSII) metrics and scoring criteria for benthic macroinvertebrate communities in the High Valleys bioregion (from Hargett, 2011)

Macroinvertebrate Metric	Metric Scoring Formulae	5th/25th or 95th/75th %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

The calculated biological condition value was then 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 aquatic community is stressed by 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. Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII); (from Hargett, 2011) in the High Valleys bioregion of Wyoming.

Rating of Biological Condition (Aquatic Life Use Support)	High Valleys bioregion
Full Support	>48.77
Indeterminate Support	32.51 – 48.76
Partial/ (Non - Support)	0 – 32.50

Table 6-16 lists other select macroinvertebrate metrics that may be evaluated when assessing biological condition since their expected response to water quality and habitat change is relatively well known. Biological condition for each station sampled through 2018 is presented in Table 6-17.

Table 6-16. 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 not 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

Table 6-17. Biological condition score and rating for comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations sampled in 2018; based on the Wyoming Stream Integrity Index (WSII) for the High Valleys bioregion (from Hargett, 2011).

Sampling Station	Sampling Year	Sampling Group	Score	Support Rating
Goose Creek GC01	2018	SCCD	38.9	Indeterminate
	2015	SCCD	33.3	Indeterminate
	2012	SCCD	27.7	Partial/ (Non - Support)
	2009	SCCD	36.9	Indeterminate
	2005	SCCD	36.4	Indeterminate
	2005 - Duplicate	SCCD	38.7	Indeterminate
	2002	SCCD	38.9	Indeterminate
	2001	SCCD	36.1	Indeterminate
	1998	WDEQ	45.2	Indeterminate
Goose Creek GC02	2018	SCCD	39.1	Indeterminate
	2015	SCCD	23.0	Partial/ (Non - Support)
	2012	SCCD	21.7	Partial/ (Non - Support)
	2009	SCCD	30.9	Partial/ (Non - Support)
	2005	SCCD	36.1	Indeterminate
	2002	SCCD	21.3	Partial/ (Non - Support)
	2002 - Duplicate	SCCD	21.1	Partial/ (Non - Support)
	2001	SCCD	15.6	Partial/ (Non - Support)
	1998	WDEQ	32.7	Indeterminate
Big Goose Creek BG02	2018	SCCD	50.2	Full
	2018 - Duplicate	SCCD	46.9	Indeterminate
	2015	SCCD	32.2	Partial/ (Non - Support)
	2012	SCCD	36.5	Indeterminate
	2012 - Duplicate	SCCD	37.6	Indeterminate
	2009	SCCD	36.3	Indeterminate
	2009 - Duplicate	SCCD	44.8	Indeterminate
	2005	SCCD	32.5	Partial/ (Non - Support)
	2004	WDEQ	40.9	Indeterminate
	2002	SCCD	43.7	Indeterminate
	2001	SCCD	44.5	Indeterminate
	1998	WDEQ	56.0	Full
	1994	WDEQ	33.6	Indeterminate
Big Goose Creek BG10	2018	SCCD	35.3	Indeterminate
	2015	SCCD	45.7	Indeterminate
	2015 - Duplicate	SCCD	52.5	Full
	2012	SCCD	32.2	Partial/ (Non - Support)
	2009	SCCD	48.1	Indeterminate
	2005	SCCD	40.0	Indeterminate

Table 6-17. (continued)

Sampling Station	Sampling Year	Sampling Group	Score	Rating
Big Goose Creek BG10	2002	SCCD	41.1	Indeterminate
	2001	SCCD	61.7	Full
Big Goose Creek BG18	2018	SCCD	36.1	Indeterminate
	2012	SCCD	64.1	Full
	2002	SCCD	63.6	Full
	2001	SCCD	65.6	Full
	1998	WDEQ	74.0	Full
Little Goose Creek LG2A	2018	SCCD	38.7	Indeterminate
	2015	SCCD	39.3	Indeterminate
	2012	SCCD	30.4	Partial/ (Non - Support)
	2009	SCCD	35.7	Indeterminate
	2005	SCCD	44.6	Indeterminate
	2004	WDEQ	36.7	Indeterminate
	2002	SCCD	25.7	Partial/ (Non - Support)
	2001	SCCD	26.3	Partial/ (Non - Support)
	1998	WDEQ	28.7	Partial/ (Non - Support)
	1997	WEST *	32.7	Indeterminate
	1994	WDEQ	21.9	Partial/ (Non - Support)
Little Goose Creek LG10	2018	SCCD	25.9	Partial/ (Non - Support)
	2015	SCCD	31.5	Partial/ (Non - Support)
	2012	SCCD	25.7	Partial/ (Non - Support)
	2009	SCCD	25.3	Partial/ (Non - Support)
	2005	SCCD	23.9	Partial/ (Non - Support)
	2002	SCCD	35.3	Indeterminate
	2001	SCCD	43.6	Indeterminate
	2001 - Duplicate	SCCD	37.5	Indeterminate
	1998	WDEQ	39.6	Indeterminate
	1998 - Duplicate	WDEQ	37.6	Indeterminate
Little Goose Creek LG22	2018	SCCD	62.3	Full
	2014	WDEQ	79.9	Full
	2014 - Duplicate	WDEQ	80.2	Full
	2012	SCCD	62.1	Full
	2002	SCCD	76.4	Full
	2001	SCCD	80.3	Full
	1998	WDEQ	81.5	Full
	1996	WDEQ	70.4	Full

* = Sample collected by Western EcoSystems Technology, Inc., Cheyenne, Wyoming.

6.8.1 *Goose Creek Biological Condition*

Biological condition at Goose Creek station GC01 was indeterminate for all years except for 2012 when it was partial/non-supporting (Table 6-17). Biological condition has declined since 1998 at station GC01 as evidenced by the slightly negative trend line shown in Figure 6.10. Biological condition at the lowermost Goose Creek station GC01 was better than biological condition at the upper Goose Creek station GC02 during each sampling year. This observation was in contrast to a general decline in biological condition from upstream to downstream stations noted at Big Goose Creek and Little Goose Creek stations.

Biological condition at Goose Creek station GC02 was partial/non-supporting each year except for 1998, 2005 and 2018 when biological condition was indeterminate (Table 6-17). The slight improvement in biological condition at GC02 noted from 2001 to 2005 was not observed in 2009, 2012 or 2015. Biological condition has increased since 1998 as evidenced by the slightly positive trend line shown in Figure 6-12. Reduced biological condition at GC02 when compared to GC01 is probably related to the location of GC02 just downstream of the Sheridan Wastewater Treatment Facility (WWTF). Biological communities at GC02 are exposed to treated effluent discharged from the Sheridan WWTF as well as numerous upstream storm water discharges and urban land use effects. Station GC01 is located several stream miles downstream of GC02 and is not directly affected by Sheridan WWTF effluent, storm water discharges and urban land use effects. The predominant land use upstream of station GC01 is irrigated pasture/hayland, livestock and wildlife grazing, and some rural residential development.

Figure 6-6 shows that since 2001 mean monthly *E. coli* concentrations were generally reduced from upstream station GC02 to station downstream station GC01. The reduction in *E. coli* concentrations was most apparent during the July/August to September sampling period.

Continued sampling should be conducted at station GC01 and station GC02 and at all original Goose Creek stations, if possible, to determine if the changes observed in biological condition through 2018 continue. The generally low biological condition scores continue to indicate indeterminate or partial/non-support of the narrative WDEQ water quality standard for aquatic life use. Planning and implementation of remedial measures to restore full aquatic life use support in Goose Creek should continue.

6.8.2 *Big Goose Creek Biological Condition*

Biological condition was fully supporting at Big Goose Creek station BG02 during the most recent sampling event in 2018 (Table 6-17). Biological condition has varied at this station from full support in 1998 and 2018 to partial/non-supporting in 2005 and 2015. Biological condition increased from 1994 to 1998, then gradually declined from 1998 to 2005. A slight increase in biological condition was observed from 2005 to 2012 with a subsequent slight decrease from 2012 to 2015. Biological condition increased from 2015 to 2018 when full support was observed. However, the overall trend in biological condition has declined slightly since 1998 at station BG02 as evidenced by the negative trend line shown in Figure 6-12.

Biological condition at BG10 has been variable since sampling began in 2001. Biological condition was fully supporting in 2001 with a subsequent decline to Indeterminate support from 2002 to 2009. The biological condition increase noted in 2009 then decreased to partial/non-supporting in 2012 with an increase to Indeterminate support in 2015 and 2018 (Figure 6-10).

Big Goose Creek station BG18 was last sampled for benthic macroinvertebrates and biological condition in 2012. Station BG18 is the most upstream sampling location on Big Goose Creek for water quality, macroinvertebrates and stream habitat. The station represents the control, or least impacted station with which to determine change in water quality, biological condition or habitat at downstream Big Goose Creek stations.

Initial benthic macroinvertebrate sampling at station BG18 in 1998 by WDEQ in 2001 found biological condition was fully supporting (Table 6-17). Subsequent sampling by SCCD in 2001, 2002, and 2012 found that biological condition was also fully supporting. Sampling in 2018 showed a reduction in biological condition from full support to indeterminate support. The reduction in biological condition did not appear to be related to a reduction in water quality, but to an increase in sand in the stream substrate starting in 2012. Sand comprised 33 percent of the stream substrate in 2012 and 27 percent of stream substrate in 2018 (Appendix Table E-4). Chutter (1969) reported that the amount of silt and sand in the stream substrate are detrimental to trout egg survival and maintenance of healthy benthic macroinvertebrate populations that provide food for trout. Tiziano et. al. (2007) found the abundance of macroinvertebrates and the number of taxa were inversely related to the total amount of sand. Nuttall (1972) found that the poor occurrence of macroinvertebrates and plants in the Camel River were associated with the unstable shifting nature of the sand deposits. He found that sand deposition accounted for the low diversity of macroinvertebrate species below a tributary that was a source of sand which resulted in the elimination of several species which were frequent upstream of the tributary. The literature is consistent in that the greater amount of sand in stream substrate, the lower number of macroinvertebrate abundance and the number of macroinvertebrate taxa. Sand is unstable and shifts with changes in stream water velocity resulting in an abrasive and grinding action on organisms. The increase in sand at station BG18 suggested that upstream disruption occurred in the watershed resulting in the increased contribution of sand to the stream channel. The amount of sand in the stream substrate at station BG 18 should continue to be tracked to determine if the sand deposition increases.

The overall trend in biological condition has declined since 1998 at station BG18 as evidenced by the negative trend line shown in Figure 6-12. As indicated beforehand, the reduction in biological condition appeared to be related to deposition of sand in the stream substrate and not to declining water quality.

It was not possible to determine change in benthic macroinvertebrate communities through the entire length of Big Goose Creek within the project area because only three stations (BG02, BG10 and BG 18) of the total seven benthic macroinvertebrate stations established at Big Goose Creek in 2001 have been consistently sampled. Whether biological condition has improved or declined at the other Big Goose Creek stations is unknown since they were not sampled.

Continued macroinvertebrate sampling should be conducted at Big Goose Creek stations BG02, BG10 and BG18, and at all original Big Goose Creek stations, if possible, to track changes in biological condition.

6.8.3 Little Goose Creek Biological Condition

Biological condition at station LG2A has been variable since sampling by WDEQ began in 1994 (Table 6-17). Since 1994, biological condition was Indeterminate during 55 percent of samples collected and partial/non-supporting during 45 percent of samples collected. The trend in biological condition has improved since 1994 at station LG2 as evidenced by the positive trend line shown in Figure 6-12. This is an important observation since other than Goose Creek station GC02, no other station sampled in 2015 or 2018 in the Goose Creek watershed exhibited an improving trend in biological condition. Station LG2A is located downstream of a large storm drain outfall that likely discharged highly variable quantity and quality of storm drain effluent. The improvement in biological condition suggested that pollutants from the storm drain were reduced over the years. In addition, there appears to be no negative remnant effects on the benthic macroinvertebrate community caused by an oil spill at station LG2A in the early 2000's.

Biological condition at station LG10 was Indeterminate from 1998 to 2002 and decreased to partial/non-supporting from 2005 to 2018 (Table 6-17). Pollution tolerant taxa have increased over the years and the percent composition of silt and sand in the stream substrate have generally increased over the years (Appendix Table E-5). As indicate previously in this report, the abundance of macroinvertebrates and the number of taxa will be reduced with an increase in the total amount of sand in the stream substrate.

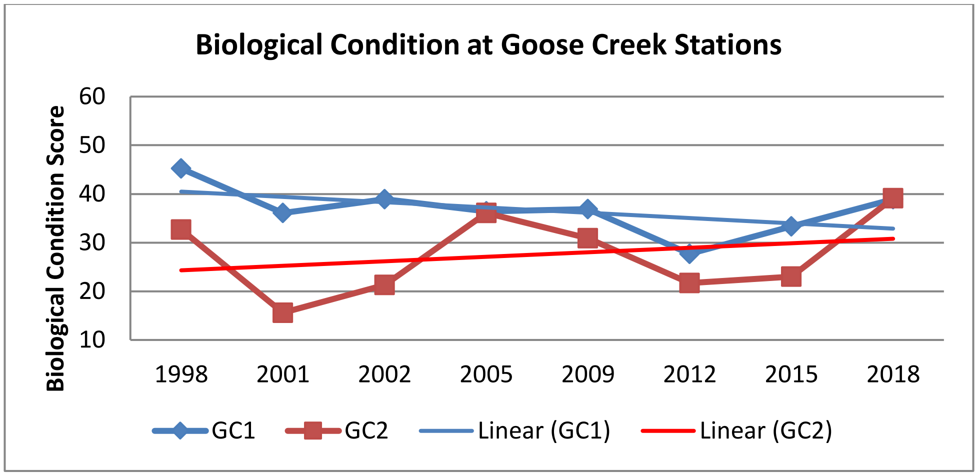
Little Goose Creek station LG22 was last sampled for benthic macroinvertebrates and biological condition in 2014 by WDEQ. Station LG22 is the most upstream sampling location on Little Goose Creek for water quality, macroinvertebrates and stream habitat. The station represents the control, or least impacted station with which to determine change in water quality, biological condition or habitat at downstream Little Goose Creek stations.

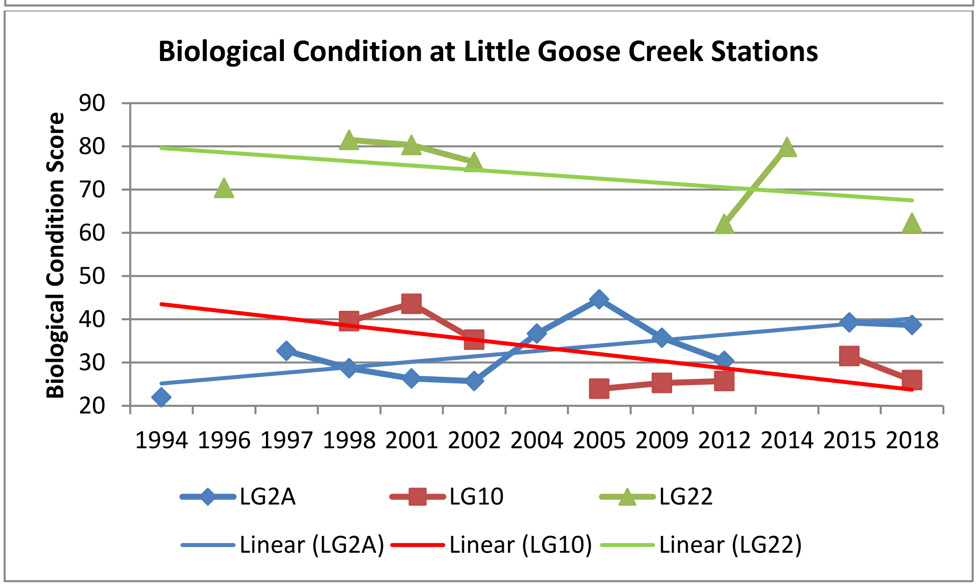
Biological condition at Little Goose Creek reference station LG22 was fully supporting from 1996 to 2018 (Table 6-17). However, the trend in biological condition at station LG22 was similar to the trend in biological condition at the Big Goose Creek reference station BG18 in that both stations have exhibited a slight decline in biological condition since 1998.

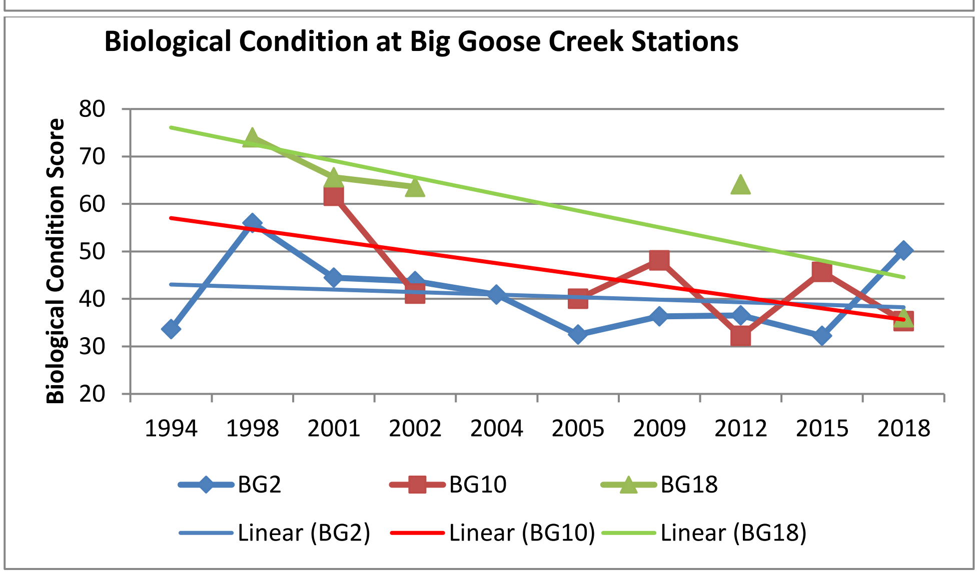
Change in the benthic macroinvertebrate communities through the entire length of Little Goose Creek within the project area could not be determined because only three stations (LG2A, LG10, and LG22) were sampled out of the total seven benthic macroinvertebrate stations established in 2001. Whether biological condition has improved or declined at the other Little Goose Creek stations since 2002 is unknown since they were not sampled.

Continued sampling should be conducted at all Little Goose Creek stations as funding allows to track potential changes in biological condition with special consideration toward monitoring the apparent upward trend in biological condition noted at station LG2A. Planning and implementation of remedial measures to restore full aquatic life use support in Little Goose Creek should continue.

Figure 6-12. Biological condition trends at select stations in the Goose Creek Watershed. Note the solid trendline shown for each station.







6.9 HABITAT ASSESSMENTS

6.9.1 PREVIOUS HABITAT ASSESSMENTS

The historic habitat assessment data collected in the Goose Creek watershed through 2002 were presented and discussed in the *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003). Subsequent limited habitat assessment data collected by WDEQ in 2004 in the Goose Creek watershed were presented and discussed in the *2005 Goose Creek Watershed Monitoring Project* (SCCD, 2006). Habitat assessment data collected by SCCD in 2009 in the Goose Creek watershed were presented and discussed in the *2009 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2011). No habitat assessments were conducted in the Goose Creek watershed during 2003, 2006, 2007 and 2008. Further habitat assessment data collected by SCCD in 2012 were presented and discussed in the *2012 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2014). The number of stations assessed by SCCD in 2012 was slightly higher than the number of stations assessed in both 2005 and 2009. Big Goose Creek upstream control station BG18 and Little Goose Creek upstream control station LG22 were added to the 2012 sampling schedule. Habitat assessment data collected in 2015 were presented in the *2015 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2016). Big Goose Creek BG18 and Little Goose Creek station LG22 were not included in the 2015 sampling schedule. WDEQ collected duplicate macroinvertebrate samples at Little Goose Creek station MRC 38 (SCCD station LG22) during 2014 but did not collect comparable habitat assessment data to that collected by SCCD and thus, was not included in this report.

6.9.2 HABITAT ASSESSMENTS IN 2018

A total of nine habitat assessments were conducted by SCCD in 2018 from eight stations. One habitat assessment was conducted from two Goose Creek stations (station GC01 and station GC02), four habitat assessments were conducted from three Big Goose Creek stations (station BG02, station BG10 and station BG18) and three habitat assessments were conducted from three Little Goose Creek stations (station LG2A, station LG10 and station LG22). Included in the total number of habitat assessments was a duplicate assessment collected at Big Goose Creek station BG02. The duplicate assessment was used only for QA/QC purposes and for general discussion of habitat assessment results.

The reduced number of stations assessed during 2005, 2009, 2012, 2015 and 2018 when compared to the initial project sampling regime in 2001 and 2002 precluded a complete evaluation of the habitat assessments between years and the comparison of habitat assessments at each station in the Goose Creek watershed.

Field habitat assessment methods employed by SCCD in in 2001, 2002, 2005, 2009 and 2015 were the same as those used in 2018.

The habitat assessments over the years were conducted in September or October. Habitat assessments at a station were generally conducted on sampling dates within ± two (2) weeks of one another each year. Results from the habitat assessments conducted during 2018 are presented in Appendix E. Because the habitat assessments were qualitative, SCCD used caution by providing a conservative interpretation of data. Although several elements of the habitat assessments were subjective, the habitat data when combined with photo points, may identify general habitat quality change among sample stations, between sample stations over time, and identify differences in habitat components such as stream channel and riparian zone characteristics, substrate composition and silt deposition.

6.9.3 Goose Creek Habitat Assessments

There was no large change in habitat at Goose Creek stations GC01 or GC02 from 1998 to 2012. The total habitat score at station GC01 varied little between those years ranging from a total score of 121.5 in 2001 to a total score of 131 in 2012 (Appendix Table E-1). Habitat assessment values increased at station GC01 during 2015 (158) and 2018 (155.5). The enhanced habitat assessment score at station GC01 was due to lower embeddedness (amount of sand and silt surrounding or covering cobble, coarse and find gravel substrate) and increased instream cover (Appendix E-1). The total habitat score at station GC02 also varied little between 1998 to 2012 ranging from a total score of 99.5 in 2012 to a total score of 132 in 2015 (Appendix Table E-1 and E-2). Habitat assessment values slightly increased at station GC02 during 2015 (132) and 2018 (140.5).

Stream substrate composition at station GC01 and station GC02 generally improved since 2001 with an increase in percent cobble and percent coarse gravel, and a decrease in sand. A mixture of substrate of different sizes was present and provided good microhabitat for the establishment and maintenance of a diverse benthic macroinvertebrate community which serves as a food source for fish. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) was variable at station GC01 and station GC02 since 2001.

6.9.4 Big Goose Creek Habitat Assessments

Habitat quality scores at Big Goose Creek station BG02 have been variable from 1994 to 2018 (Appendix Table E-2 and Table E-3). The habitat quality at station BG10 declined from 2001 to 2005, then improved in 2009 and decreased in 2012 and 2015. The habitat quality increased in 2018 (Appendix Table E-4). The habitat at upstream control station BG18 was relatively consistent during the period from 1998 through 2018 (Appendix Table E-4). The habitat assessment scores ranged from 146 in 2002 to 167 in 2001. The habitat assessments conducted over the years at Big Goose Creek stations consistently found that station BG18 exhibited the highest habitat quality when compared to the other downstream stations.

The composition of stream substrate was dominated by cobble at stations BG02, BG10 and BG18 since monitoring began in 1994. Of concern was the occasional high occurrence of sand at certain Big Goose Creek stations over the years. As previously indicated in Section 6.8.2, sand and silt in stream substrate are concerning since they are detrimental to trout egg survival and the maintenance of healthy benthic macroinvertebrate populations that provide food for trout.

From 1994 to 2018, the composition of sand at station BG02 varied from 0 percent in 1998 to 31 percent in 1994. The majority of readings for the composition for sand in the stream substrate ranged from 14 percent to 26 percent composition (Appendix Table E-2 and Table E-3). Stream substrate composition for sand was generally low and stable at station BG10 from 2001 to 2018 ranging from 4 percent in 2002 to 16 percent in 2015. The average percent composition of sand at station BG10 from 2001 to 2018 was 8 percent. The composition of sand at BG18 previously mentioned in Section 6.8, found that sand was relatively low from 1998 to 2002 (averaging 10 percent), but increased to 33 percent of the stream substrate in 2012 and 27 percent of stream substrate in 2018 (Appendix Table E-4).

6.9.5 Little Goose Creek Habitat Assessments

Habitat quality has remained low at Little Goose Creek station LG2A since sampling began by WDEQ in 1994 (Appendix Table E-4 and Table E-5). The lowest habitat score (77) at station LG2A during 2012 was due primarily to channelization of Little Goose Creek for flood control in Sheridan that reduced undercut banks, the number of pools, instream cover for fish, and the riparian zone. The channelization for flood control isolated the stream from the normal floodplain affecting the dynamics of stream flow and disrupting stream habitat at and downstream from the immediate channelized reaches. The habitat quality at station LG2A ranked 2nd lowest among all stations assessed in the Goose Creeks watershed during 2001-2002 (SCCD, 2003). Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 18 percent of the stream substrate from 1994 to 2018 which was considered moderate.

There were no large changes in habitat at Little Goose Creek station LG10 from 2001 to 2018 (Appendix E-5). The range in habitat assessment scores ranged from 126.5 during 2001 to 152.5 during 2002. The average total habitat assessment score since 2001 at LG10 was 138 compared to an average total habitat assessment score of 72 at station LG2A. Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 19 percent of the stream substrate since 2001, which was considered moderate.

Upstream control station LG22 exhibited the best habitat. Total habitat scores ranged from 150 in 2012 to 172 in 1998 (Appendix Table E-6). The average habitat quality score from 1996 to 2018 was 160. The stream substrate at station LG22 was dominated by cobble ranging from 50 percent in 2002 to 72 percent in 1998. In 1996 and 2012, the cobble substrate at station LG22 was 69 percent. Mean coarse gravel, fine gravel and sand comprised 10 percent, 10 percent, and 14 percent of the total stream substrate, respectively. The mean weighted embeddedness value (amount of silt covering and surrounding cobble and gravels) was 91 indicating that about 88 percent of cobble and gravels were free of silt.

6.9.6 Relation Of Habitat Assessments To Biological Condition

Good stream habitat is critical for the establishment and maintenance of good fishery, benthic macroinvertebrate populations and other aquatic life. Habitat quality is directly related to biological condition at streams in the Goose Creek watershed (see Figure 8-99 in *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003)). The relationship between habitat quality and biological condition was strong and significant (Correlation Coefficient =

0.7235; p<0.99). This relationship is important because improvement in habitat quality, in the absence of effects due to water quality, will result in improved biological condition. Those Goose Creek, Big Goose Creek and Little Goose Creek stations exhibiting Indeterminate Support or Partial/ Non - Support of aquatic life use may be improved by enhancing habitat quality.

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Chapter 7 Conclusions and Recommendations

Instantaneous water temperatures exceeded the 20°C standard at most of the lower and mid-watershed stations and at several tributaries on various dates from June-August. Continuous water temperatures exceeded the standard at all stations during the same time period except for the uppermost station in Little Goose Canyon. All stations were within the standard for pH. Conductivity was within the expected range at all stations, with the occasional measurement over 1000 µs. Two mainstem stations and several tributary stations reported at least one measurement that did not meet the standard for dissolved oxygen. High discharge from late May to early June corresponds with above average precipitation for that period. Turbidity values were considered normal for the watershed with occasional high values occurring during late spring, early summer precipitation and run-off events.

Bacteria concentrations were typically lower in the early season than in the late season at Goose Creek and Big Goose Creek stations. Concentrations at Little Goose Creek stations were more variable between the early and late season. Most stations reported 60-day averages that exceeded the standard apart from the two canyon sites. Early season concentrations increased at most stations from 2015 to 2018 but decreased during the late season. An overall increase in concentrations was observed at every station from 2001 to 2018 except for a few tributaries.

Benthic macroinvertebrate sampling was conducted at eight stations in October 2018. Biological condition at the lowermost Goose Creek station GC01, was indeterminate for all years except for 2012 when it was partial/non-supporting. Biological condition has generally declined since 1998. However, biological condition at the lower Goose Creek station GC01 was better than biological condition at the upper Goose Creek station GC02. This observation was in contrast to a general decline in biological condition from upstream to downstream stations noted at Big Goose Creek and Little Goose Creek stations.

Biological condition was fully supporting at Big Goose Creek station BG02 during 2018. Biological condition varied at this station from full support in 1998 and 2018 to partial/non-supporting and indeterminate supporting from 2001 to 2015. Biological condition at Big Goose Creek station BG10 has been variable since sampling began in 2001. Biological condition was fully supporting in 2001 with a subsequent decline to indeterminate support from 2002 to 2009. Biological condition increased in 2009, decreased to partial/non-supporting in 2012, and increased to indeterminate support in 2015 and 2018. Benthic macroinvertebrate sampling at the uppermost control station BG18 in 1998 by WDEQ, and subsequent sampling by SCCD in 2001, 2002, and 2012 found that biological condition was fully supporting. Sampling in 2018 showed a reduction in biological condition from full support to indeterminate support. The reduction in biological condition did not appear to be related to a reduction in water quality, but to an increase in sand in the stream substrate starting in 2012.

The biological condition at Little Goose Creek station LG2A has been variable since sampling by WDEQ began in 1994. The trend in biological condition at station LG2 has improved since 1994 at station LG2. This is an important observation since other than Goose Creek station GC02, no other station sampled in 2018 in the Goose Creek watershed exhibited an improving trend in biological condition. Biological condition at station LG10 was Indeterminate from 1998 to 2002, then decreased to partial/non-supporting from 2005 to 2018. Although biological condition decreased from the 1998-2002 period to the 2005-2015 period, biological condition was generally similar during each sampling event from 2005 to 2018.

Biological condition at the uppermost Little Goose Creek control station LG22 was fully supporting from 1996 to 2018. However, the trend in biological condition at station LG22 was similar to the trend in biological condition at the Big Goose Creek reference station BG18 in that both stations have exhibited a decline in biological condition since 1998.

Continued benthic macroinvertebrate sampling is recommended at current Goose Creek, Big Goose Creek, and Little Goose Creek stations, and at all original Goose Creek watershed stations as funding allows, to track changes in biological condition. Planning and implementation of remedial measures should continue to restore full aquatic life use support in streams in the Goose Creek watershed.

The positive effects that improvement projects have on water quality may not be immediately determined due to the factors such as the bacteria storage capacity of bed sediment, which is normally suspended during seasonal high 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 in the 2001-2002 assessment and subsequent interim monitoring indicate the need for additional improvement projects as well as continued future monitoring to create and measure positive water quality changes.

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. Nonetheless, each improvement project implemented in the watershed certainly induces positive water quality changes, whether they are immediately evident or not.

The Goose Creek Watershed effort has increased local awareness about several important resource issues and has led to more public interest in the watershed. Continued monitoring can provide information on water quality changes over the long-term. SCCD will continue to monitor water quality in the Goose Creek watershed on a three-year rotation, pending available funding sources.

CHAPTER 8 REFERENCES CITED

American Public Health Association (APHA), American Water Works Association, Water Environment Federation, 1998. Standard methods for the examination of water and wastewater, 20th ed., Eaton, A.D., L.S. Clesceri and A.E. Greenburg, eds., Washington, DC.

American Public Health Association (APHA), American Water Works Association, Water Environment Federation, 2005. Standard methods for the examination of water and wastewater, 21st ed., Washington, DC.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates, and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency: Office of Water; Washington, D.C.

Chutter, F.M. 1969. The effects of sand and silt on the invertebrates and fauna of streams and rivers. Hydrobiologia 34: 57-76.

Federal Register, 2012. Volume 77, Number 97; May 18, 2012. Code of Federal Regulations, Title 40: Protection of Environment, Chapter 1, Subchapter D, Part 136: Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Analysis and Sampling Procedures; Final Rule.

Friedman, L.C. and D.E. Erdmann. 1982. Quality assurance practices for the chemical and biological analyses of water and fluvial sediments. Techniques of water-resources investigations of the United States Geological Survey. Book 5, Laboratory analysis; Chapter A6. Washington, D.C.

Gilbert, R.O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold Press. New York, NY.

Hargett, E.G. and J. R. ZumBerge. 2006. Redevelopment of the Wyoming Stream Integrity Index (WSII) for assessing the biological condition of wadeable streams in Wyoming. Wyoming Department of Environmental Quality Water Quality Division. Cheyenne, WY. 70pp.

Hargett, E.G. 2011. The Wyoming Stream Integrity Index (WSII) – multimetric Indices for assessment of wadeable streams and large rivers in Wyoming. Wyoming Department of Environmental Quality, Water Quality Division. Cheyenne, WY.

Jessup, B.K. and J.B. Stribling. 2002. Further evaluation of the Wyoming Stream Integrity Index, considering quantitative and qualitative reference site criteria. Report to U.S. EPA Region 8, Denver, CO. by Tetra Tech, Inc. Owings Mills, MD.

King, K.W. 1990. Effects of oil field produced water discharges on pond zooplankton populations. Wyoming Department of Environmental Quality Water Quality Division. Cheyenne, WY. 85pp.

King, K.W. 1993. A bioassessment method for use in Wyoming stream and river water quality monitoring. Wyoming Department of Environmental Quality Water Quality Division. Cheyenne, WY. 85pp.

Nuttall, P.M. 1972. The effects of sand deposition upon the macroinvertebrate fauna of the River Camel, Cornwall. Freshwater Biology 2(3): 181-186.

Rasmussen, Patrick. 2003. Comparison and Continuous Estimates of Fecal Coliform and *Escherichia Coli* bacteria in Selected Kansas Streams, May 1999 Through April 2002. USGS 03-4056.

Rosenberg, D.M., and V.H. Resh. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates, pp. 1-9. *In* Rosenberg, D.M., and V.H. Resh, (editors), Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York. 488pp.

Sawyer, C.N. 1960. Chemistry for sanitary engineers. McGraw-Hill, New York, NY.

Sheridan County Conservation District. 2003. Goose Creek Watershed Assessment 2001-2002, Final Report. Sheridan, WY.

Sheridan County Conservation District. 2004. Goose Creek Watershed Management Plan. Sheridan, WY.

Sheridan County Conservation District. 2006. 2005 Goose Creek Watershed Monitoring Project Final Report. Sheridan, WY.

Sheridan County Conservation District. 2011. 2009 Goose Creek Watershed Interim Monitoring Report. Sheridan, WY.

Sheridan County Conservation District. 2012. 2012 Goose Creek Watershed Improvement Effort Implementation Strategy 2012-2015. Sheridan, WY.

Sheridan County Conservation District. 2014. 2012 Goose Creek Watershed Interim Monitoring Report. Sheridan, WY.

Sheridan County Conservation District. 2017. 2015 Goose Creek Watershed Interim Monitoring Report. Sheridan, WY.

Sheridan County Conservation District. 2018a. 2018 Goose Creek Watershed Monitoring Project Sampling Analysis Plan. Sheridan, WY.

Sheridan County Conservation District. 2018b. Water Quality Monitoring Program Quality Assurance Project Plan 2018 Update. Sheridan, WY.

Stephenson, G.R. and R.C. Rychert. 1982. Bottom Sediment: A Reservoir of *Escherichia coli* in Rangeland Streams. Journal of Range Management. 35:119-123.

Stribling, J.B., B.K Jessup and J. Gerritsen. 2000. Development of biological and physical habitat criteria for Wyoming streams and their use in the TMDL process. Report to U.S. EPA Region 8, Denver, CO prepared by Tetra Tech, In., Owings Mills, MD.

SWCA Environmental Consultants. 2010. Goose Creek Watershed TMDLs. Prepared for Wyoming Department of Environmental Quality. Sheridan, WY.

Tiziano, B., F. Stefano, M. Giorgio and P. Massimo. 2007. Effects of clogging on stream macroinvertebrates: An experimental approach. Limnologica 37(2): 186-192.

U.S. Department of Agriculture, Natural Resources Conservation Service. 1986. Soil Survey for Sheridan County Area, Wyoming.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2003. National Water Quality Handbook, Part 614 & 615. Washington, D.C.

U. S. Environmental Protection Agency. 1980. Interim guidelines and specifications for preparing quality assurance project plans. QAMS-005/80. Office of Monitoring Systems and Quality Assurance, Office of Research and Development. Washington, D.C.

U.S. Environmental Protection Agency. 1983. Methods for chemical analysis of water and wastes. 600/4-79-020. Environmental Monitoring and Support Lab., Cincinnati, OH.

U.S. Environmental Protection Agency. 1990. Biological criteria: national program guidance for surface waters. Office of Water. EPA/440/5-90-004. Washington, D.C.

U.S. Environmental Protection Agency. 1995. Generic quality assurance project plan guidance for programs using community-level biological assessment in streams and wadeable rivers. EPA 841-B-95-004. Office of Water, Washington, D.C.

United States Geological Survey. 1985. Geologic map of Wyoming. Sheets 1, 2 and 3. Reston, VA. G85136.

Wyoming Department of Environmental Quality. 2005a. Goose Creeks storm water report. Water Quality Division, Cheyenne, WY. 52pp.

Wyoming Department of Environmental Quality. 2005b. Water Quality Rules and Regulations Chapter VIII, Quality standards for Wyoming groundwaters. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2013a. Wyoming Surface Water Classification List. Water Quality Division, Surface Water Standards. Cheyenne, WY.

Wyoming Department of Environmental Quality 2013b. Wyoming Nonpoint Source Management Plan 2013 Update. Document # 13-0035. Water Quality Division. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2017. Wyoming's Methods for Determining Surface Water Quality Condition. Document #17-0865. Water Quality Division. Watershed Program. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2018a. Manual of Standard Operating Procedures for Sample Collection and Analysis. Water Quality Division. Watershed Program. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2018b. Quality Assurance Program Plan for Watershed Protection Program Water Quality Monitoring. Water Quality Division, Watershed Program. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2018c. Water Quality Rules and Regulations, Chapter 1, Quality standards for Wyoming surface waters. Cheyenne, WY

Wyoming Department of Environmental Quality. 2018d. Wyoming's 2016/2018 Integrated 305(b) and 303(d) Report. Document #18-0111. Water Quality Division. Cheyenne, WY.

APPENDICES

APPENDIX A

GOOSE CREEK WATERSHED
2018 MAPS

APPENDIX B

GOOSE CREEK WATERSHED
2018 QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION

APPENDIX C

GOOSE CREEK WATERSHED
2018 WATER QUALITY DATA

APPENDIX D

GOOSE CREEK WATERSHED
2018 BENTHIC MACROINVERTEBRATE DATA

APPENDIX E

GOOSE CREEK WATERSHED
2018 HABITAT ASSESSMENT DATA

APPENDIX F

GOOSE CREEK WATERSHED
2018 PHOTOS