2015 GOOSE CREEK WATERSHED INTERIM MONITORING PROJECT

FINAL REPORT

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EXECUTIVE SUMMARY

The Goose Creek Watershed encompasses 267,520 acre (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. 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 located in the upper portion of the Goose Creek watershed.

Accessible to over 27,000 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, 2013). 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 of the 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, and in 2015 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, which included goals and objectives to address bacteria and other watershed issues. The watershed committee also included recommendations and activities the group felt would achieve the 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 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. The Goose Creek Watershed TMDL and associated watershed plans 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 2015 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.
The specific objectives of this project were to use water quality monitoring information/trends:

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

In 2015, SCCD monitored water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli* at 17 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 six stations. Of the 17 stations, there were two sites on Goose Creek, four on Big Goose Creek, four on Little Goose Creek, and one each on Soldier Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek. The landowner on Beaver Creek chose not to allow access in 2015; that site was not monitored nor included in the discussion of results.

Instantaneous water temperature measurements were recorded above the maximum 20°C at the lower mainstem stations and on five tributaries during 2015. Continuous temperature loggers reported temperatures that exceeded 20°C at all but the uppermost canyon stations (BG18 and LG22). For the most part, pH and conductivity were within the expected ranges with two pH values above 9.0 SU in Little Goose Canyon and two tributary stations (Park Creek and McCormick Creek) with conductivity values above 1000 µS. With one exception, all sites met the minimum dissolved oxygen concentration for early and other life stages. Three mainstem stations and four tributary stations returned at least one dissolved oxygen measurement below the water column concentration recommended to achieve the intergravel concentration for early life stages. High discharge in early June corresponds 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. Tributary stations typically had higher turbidity than adjacent mainstem sites, except for Park Creek.

Bacteria concentrations were typically lower in May-June than in August-September; with the exception of McCormick Creek. Mainstem sties typically had lower bacteria concentrations than tributary sites. Most stations had at least one geometric mean that exceeded Wyoming Water Quality Standards in 2015, including six mainstem stations and six tributaries in May-June and eight mainstem stations and seven tributaries in August-September. The only stations that were below the standards for the entire season were BG18 and LG22.

A decrease in bacteria concentrations was observed from 2012-2015 at all but one of the mainstem stations in May-June. At the station in Little Goose Canyon (LG22) bacteria concentrations increased, but were still well within water quality standards. For August-September, however, bacteria concentrations increased at some stations. All but two of the tributary stations had higher bacteria concentrations in May-June 2015 than in 2012. During the late season, the percent change from 2012-2015 among tributary stations was less consistent, with four tributaries showing increases and three showing decreases. From 2001 to 2015, an increase in bacteria concentrations was observed at every comparable site and sampling period, except for Soldier Creek during the early season and Soldier Creek and McCormick Creek during the late season.

Benthic macroinvertebrate sampling was conducted at six stations in October of 2015. Biological condition at Goose Creek station GC1 was indeterminate for all years except for 2012 when it was partial/non-supporting. Biological condition has declined since 1998. However, biological condition at the lower Goose Creek station GC1 was better than biological condition at the upper Goose Creek station GC2. 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 partial/non-supporting at Big Goose Creek station BG2 during 2015. Biological condition varied at this station from full support in 1998 to partial/non-supporting in 2005 and 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.

The biological condition at Little Goose Creek station LG2A has been variable since sampling by WDEQ began in 1994. Since 1994, biological condition was Indeterminate during 50 percent of samples collected and partial/non-supporting during 50 percent of samples collected. The trend in biological condition has improved since 1994 at station LG2. This is an important observation since no other station sampled in 2015 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 2015. Although biological condition decreased from the 1998-2002 period to the 2005-2015 period, biological condition gradually increased during each sampling event from 2005 to 2015.

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, especially when comparing water quality data that has been collected during season 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. Bacteria concentrations, in particular, are known to vary in response to a number of different factors, including changes in water temperatures, water quantity, and suspended sediment loads.

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 actually 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 acre (418 square miles) in Sheridan County located in north-central Wyoming (Appendix A-1). The watershed is identified by hydrologic unit code (HUC) 100901-01-02. 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, with the majority of the sample stations, is in the 14-16" precipitation zones (Appendix A-2). Precipitation in the upper watershed, within the BNF, ranges from 20-36 inches. All of the sampling stations are in precipitation zones that are less 20 inches. 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 Bighorn 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 located in the upper portion of the Goose Creek watershed.

Accessible to over 27,000 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.

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.

1.3 STREAM CLASSIFICATIONS AND BENEFICIAL USES

The Wyoming Department of Environmental Quality (WDEQ) is charged with implementing the policies of the Clean Water Act and providing for the "highest possible water quality" for activities on a waterbody (WDEQ, 2013). Chapter 1 of the Wyoming Water Quality Rules and Regulations (WDEQ, 2013) describes the surface water classes, and designated uses, and the water quality standards that must be achieved for a Wyoming waterbody to support its designated uses. Stream classifications are assigned by WDEQ and identified on the Wyoming Surface Water Classification List (WDEQ, 2013a) or in subsequent reports. 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, 2013a)

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.

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, 2013). 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.

Table 1.2—Goose Creek Watershed Stream Classifications and Beneficial Uses

Class 2AB Stream Classifications	Associated Beneficial Uses
Goose Creek	Drinking Water
Soldier Creek	Game Fish
Big Goose Creek	Non-Game Fish
Beaver Creek	Fish Consumption
Park Creek	Other Aquatic Life
Rapid Creek	Recreation
Little Goose Creek	Wildlife
McCormick Creek	Agriculture
Kruse Creek	Industry
Jackson Creek	Scenic Value
Sackett Creek	

1.4 STREAM IMPAIRMENTS AND LISTINGS

States are required to summarize water quality conditions in the state through section 305(b) of the Clean Water Act; this report is commonly known as the 305(b) report. 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 is published every two years. If a waterbody exceeds narrative or numeric water quality standards, it is considered to be "impaired" or not meeting its designated uses. Big and Little Goose Creeks 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.

Currently, impaired waterbodies are first included on the Wyoming 303(d) list of Waters Requiring TMDLS under Category 5 (WDEQ, 2014). Once a TMDL is completed, a waterbody is moved from Category 5 to Category 4, which includes the list of waterbodies with TMDLs. With the completion of the Goose Creek Watershed TMDL in September 2010, all of the impaired segments (including tributaries) were included as Category 4 waters in the Wyoming 2014 Integrated Report (Table 1.3).

Table 1.3—Impaired Stream Segments in the Goose Creek Watershed (from WDEQ, 2014)

Name	List Date	Location	Miles	Uses	Causes
Goose Creek (tributary to Tongue River)	2000	From the confluence with Little Goose Creek downstream to the Tongue River	12.7	Recreation	Fecal Coliform
Goose Creek (tributary to Tongue River)	2006	From the confluence with Little Goose Creek downstream to the Tongue River	12.7	Aquatic life, cold-water fish	Habitat Alterations, Sediment
Soldier Creek (tributary to Goose Creek)	2000	From the confluence with Goose Creek 3.1 miles upstream	3.1	Recreation	Fecal Coliform
Soldier Creek* (tributary to Goose Creek)	2010	From 3.1 miles upstream from the confluence with Goose Creek 17.1 miles upstream	17.0	Aquatic life, cold-water fish	Flow Alterations
Big Goose Creek (tributary to Goose Creek)	1996	From the confluence with Little Goose Creek upstream to the confluence with Rapid Creek	19.2	Recreation	Fecal Coliform
Beaver Creek (tributary to Big Goose Creek)	2000	From the confluence with Big Goose Creek to the confluence with Apple Run	6.5	Recreation	Fecal Coliform
Park Creek (tributary to Big Goose Creek)	2000	From the confluence of Big Goose Creek 2.8 miles upstream	2.8	Recreation	Fecal Coliform
Rapid Creek (tributary to Big Goose Creek)	2000	From the confluence with Big Goose Creek 3.2 miles upstream	3.2	Recreation	Fecal Coliform
Little Goose Creek (tributary to Goose Creek)	1996	From the confluence of Big Goose upstream to Brundage Lane in the City of Sheridan	3.5	Recreation	Fecal Coliform
Little Goose Creek (tributary to Goose Creek)	2006	From the confluence of Big Goose upstream to Brundage Lane in the City of Sheridan	3.5	Aquatic life, cold-water fish	Habitat Alterations, Sediment
McCormick Creek (tributary to Little Goose Creek)	2004	From the confluence with Little Goose Creek 2.2 miles upstream	2.2	Recreation	Fecal Coliform
Kruse Creek (tributary to Little Goose Creek)	2000	From the confluence with Little Goose Creek upstream to East Fork Kruse Creek	2.5	Recreation	Fecal Coliform
Jackson Creek (tributary to Little Goose Creek)	2000	From the confluence with Little Goose Creek to a point 6.4 miles upstream	6.4	Recreation	Fecal Coliform
Sackett Creek (tributary to Little Goose Creek)	2000	From the confluence with Little Goose Creek to East Fork Sackett Creek	3.1	Recreation	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, 2014)." 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, 2014)."

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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 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.

The Goose Creek Watershed Assessment, which was initiated in April 2001, included collecting 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 similar to the monitoring in 2001 with a few exceptions. All of the 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 upstream 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; interim monitoring evaluated 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 only 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 similar to 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 and 2012 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 2012. 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.

With the exception of canyon sites, biological condition at Goose Creek, Big Goose Creek and Little Goose Creek stations sampled in 2009 and 2012 were partial/non-supporting based on the evaluation of the stream benthic macroinvertebrate communities. The partial/non-support classification indicates the aquatic communities are stressed and water quality or habitat improvements are required to restore the stream to full support for the narrative WDEQ standard for aquatic life use. The site in Big Goose Canyon has been fully supporting, though it decreased through 2012 and may not fully support aquatic life in the future if the trend continues. The site in Little Goose Canyon decreased from full support to indeterminate support in 2012.

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 the Sheridan County Planning Commission.

The Goose Creek Watershed Management Plan included goals and objectives to address bacteria and other watershed issues identified by meeting participants. The watershed committee also included recommendations and activities the group felt would achieve the 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. SCCD has provided assistance on 55 improvement projects including 16 livestock related projects, 21 septic system replacements, four stream channel stabilization segments, three irrigation diversion replacements, and 11 willow planting sites within the watershed (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 pathogens in highly used areas. The City of Sheridan implemented a storm drain stenciling program to educate local 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;
- Workshops on pathogens, animal feeding operations, and septic systems; and
- Various articles/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 2015 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 2015 monitoring is within a three monitoring rotation currently conducted by SCCD on the Tongue River, Goose Creek, and Prairie Dog Creek watersheds and is funded through the Sheridan County Watershed Improvements #4 Project funded by WDEQ through Section 319 of the Clean Water Act.

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

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

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CHAPTER 3 HISTORICAL AND CURRENT DATA

Historical data, for the purposes of this project, are defined as data greater than five years old from the start of the 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 to the 2001-2002 Final Report. These data are not repeated in this document.

USGS collected water quality and/or hydrologic information from three sites in the Goose Creek Watershed from 2012-2015 (Table 3.1). Much of the hydrologic and water quality data previously collected by USGS have been discontinued due to funding availability except for USGS Station 06305500 (Goose Creek below Sheridan), Station 06305700 (Goose Creek near Acme), and Station 06304500 (Little Goose Creek at Sheridan), which only collects field/lab water-quality samples and instantaneous discharge.

Table 3.1—Active USGS Stations in the Goose Creek Watershed in 2012-2015

Site ID	Drainage Area (miles^2)	"Real-time: Observations	Field Lab Water Quality Samples	Daily/Monthly/ Annual Statistics
06304500 Little Goose Cr at Sheridan	159	NA	3/1979-11/2015	NA
06305500 Goose Creek below Sheridan, WY	392	NA	8/1959-7/2014 Field Discharge 9/1983-8/2000	Discharge 10/1941-9/1984
06305700 Goose Creek near Acme, WY	413	Discharge 6/19/2015-Current	10/1983-8/2008 Field Discharge 5/1984-12/2015	Discharge 5/1984-9/2015

Station 06305700 (Goose Creek near Acme) has intermittently collected hydrologic information since 1983; "real-time" flow observations began again in June of 2015 and extended through the remainder of the sample season. Hydrologic information from station 06305500 has not been collected since 1984 apart from some instantaneous field discharge measurements from 1983 to 2000. SCCD instantaneous discharge measurements were compared to hydrographs developed for each of these stations, which correspond to SCCD stations GC01 and GC02.

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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 in the Project

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

4.2 MONITORING PARAMETERS

Water quality parameters monitored in 2015 included: water temperature, pH, conductivity, dissolved oxygen, discharge, turbidity, and *E. coli*. Water quality monitoring was performed at 17 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 six 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 *2015 Goose Creek Watershed Monitoring Project Sampling Analysis Plan* (SCCD, 2015), the *SCCD Water Quality Monitoring Program Quality Assurance Project Plan 2015 Update* (SCCD, 2015a), Natural Resources Conservation Service *National Handbook of Water Quality Monitoring* (USDA-NRCS, 2003), and WDEQ sampling procedures (WDEQ, 2015) according to accepted analytical methods (Table 4.2). Water quality and macro-invertebrate samples were obtained from representative sample riffles.

Table 4.2—Standard Field and Laboratory Methods Applicable to 2015 Monitoring

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

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

Sample sites were equipped with a staff gauge for flow measurements. During site reconnaissance, staff gauges were inspected, surveyed, and replaced if needed. Upon installation and/or inspection, gauges were surveyed and compared with a permanent bench mark. Staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter using the mid-section method (WDEQ, 2015). The resulting stage-discharge relationships were used to estimate flow during sampling events.

Grab samples for *E. coli* and turbidity were collected within two separate 60 day periods in May-July and July-September. Gauge height, pH, conductivity, dissolved oxygen, and instantaneous water temperature were also measured during these sampling events. Continuous temperature data were collected by anchoring the data loggers near the bottom of 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 of the 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.

Table 4.3—Sample Site Descriptions and Information for 2015 Goose Creek Watershed Interim Monitoring

Site	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (feet)	Land Use(s)
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	100901010301 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; creek is channelized/ straightened through this section.
GC02	On Goose Creek approximately 200 yards downstream of Sheridan WWTP	0344758E, 4965129N	44° 49.368' N 106° 57.819'W	100901010301 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	100901010301 Goose Creek	3,705	In the Downer Addition in the City of Sheridan. Rural properties upstream.
BG01	On Big Goose Creek off of 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	100901010209 Lwr Big Goose	3,735	Urban / residential. Adjacent to hill side below Sheridan Junior High School.
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	100901010209 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	100901010205 Up Big Goose	4060	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	100901010205 Up Big Goose	4060	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands. An animal feeding operation is to the northwest.
BG-RC01	On Rapid Creek approximately 25 yards downstream of the County Road crossing	0330489E, 4954616N	44° 43.492' N 107° 08.431'W	100901010205 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	100901010205 Up Big Goose	4,505	Primarily wildlife habitat. Cattle and horse grazing does occur. The BNF boundary is about 1 mile upstream. The Alliance Ditch intake is ~50 yards downstream.
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	100901010209 Lwr Little Goose	3,725	Urban – mostly business with some light industrial and residential areas. Railroad tracks are adjacent to the east bank.

Table 4.3 (continued) —Sample Site Descriptions and Information for 2015 Goose Creek Watershed Interim Monitoring

Site	Sample Site Description	UTM Zone 13 (NAD83)	Latitude Longitude	HUC	Elevation (feet)	Land Use(s)
LG08	On Little Goose Creek approximately ¼ mile downstream from McCormick Creek	0345473E, 4953671N	44° 43.181' N 106° 57.062'W	100901010209 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	100901010209 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	100901010209 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	100901010208 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	100901010208 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	100901010208 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	100901010208 Mid Little Goose	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BNF boundary is approximately 3 miles upstream.
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	100901010301 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	100901010301 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	100901010209 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	100901010209 Lwr Big Goose	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated haylands.
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	100901010209 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	100901010209 Lwr Little Goose	3,915	Small acreage properties with cattle grazing, wildlife habitat, and irrigated haylands.

Historically, SCCD requested and documented verbal permission to collect water quality samples and publish the data in a report. On July 1, 2012, changes to the Wyoming Public Records Act (W.S. 16-4-291 through 16-4-205) required written permission to release any information collected on agricultural operations. In addition, Wyoming Statute W.S. 6-3-414 through the 2015 Enrolled Act #61 (The Trespass Bill), requires written permission to access for the purpose of collecting data. Signed consent forms were maintained for all sample sites; all sites were accessed using public highways/roads or private driveways/parking areas where consent forms had been received. One landowner chose not to allow access in 2015; that site was not included in the SAP and was not monitored nor included in the discussion of results.

4.5 Monitoring Schedule

The 2015 monitoring schedule included sampling to determine the geometric means of *E. coli*, based on 5 samples collected within a 60-day period in May-June and 5 samples collected within a 60-day period in August-September (Table 4.4). A total of ten water quality samples were scheduled for collection at each site. High stream flows and road flooding prevented access to one sample site in early June, resulting in only nine samples being collected from that site.

Sample dates were based on random numbers generated for Monday-Thursday due to lab availability and sampling holding times. Continuous temperature data loggers were deployed to measure instream temperatures from May 5th through October 19th. Macroinvertebrate collections and habitat assessments were completed in October.

Table 4.4—Sample Schedule for 2015 Goose Creek Watershed Monitoring

<table>
<tr><th>Date(s)</th><th>Sites</th><th>Parameters</th></tr>
<tr><td>May 5 – October 19</td><td>GC01, BG01, BG10, BG18, LG02, LG08, LG22</td><td>Continuous Temperature</td></tr>
<tr><td>May 5</td><td rowspan="5">GC01, GC02, GC-SC01, BG01, BG10, BG-PC01, BG14, BG-RC01, BG18, LG02, LG08, LG-McC01, LG-KC01, LG13, LG- JC01, LG-SC01, LG22</td><td rowspan="5">Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/ Discharge, Turbidity, and E. coli</td></tr>
<tr><td>May 21</td></tr>
<tr><td>June 2</td></tr>
<tr><td>June 15</td></tr>
<tr><td>June 30</td></tr>
<tr><td>August 6</td><td rowspan="5">GC01, GC02, GC-SC01, BG01, BG10, BG-PC01, BG14, BG-RC01, BG18, LG02, LG08, LG-McC01, LG-KC01, LG13, LG- JC01, LG-SC01, LG22</td><td rowspan="5">Instantaneous temperature, pH, Conductivity, Dissolved Oxygen, Stage Height/ Discharge, Turbidity, and E. coli</td></tr>
<tr><td>August 18</td></tr>
<tr><td>September 3</td></tr>
<tr><td>September 17</td></tr>
<tr><td>September 30</td></tr>
<tr><td>October</td><td>GC01, GC02, BG02, BG10, LG2A, LG10, LG22</td><td>MACRO, HAB, Photo</td></tr>
</table>

CHAPTER 5 QUALITY ASSURANCE/QUALITY CONTROL

5.1 FUNCTION OF QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance (QA) may be defined as an integrated system of management procedures designed to evaluate the quality of data and to verify that the quality control system is operating within acceptable limits (Friedman and Erdmann, 1982; USEPA, 1995). Quality control (QC) may be defined as the system of technical procedures designed to ensure the integrity of data by adhering to proper field sample collection methods, operation and maintenance of equipment and instruments. Together, QA/QC functions to ensure that all data generated is 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, 2015) and the SCCD QAPP (SCCD, 2015a).

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). NRCD Field office staff and interns provided assistance with site set-up, surveys, discharge measurements, water quality monitoring, and macroinvertebrate collection. During monitoring activities, SCCD personnel collected the samples/measurements, while the other staff recorded the information on the appropriate data sheets. Assisting personnel were under the direct supervision of SCCD staff. The SAP defined all necessary field protocols and was available to the sampling team for every sampling event.

Table 5.1—SCCD Sampling Personnel and Qualifications

Personnel	Qualifications
Carrie Rogaczewski District Manager	M.S. University of Wyoming in Rangeland Ecology and Watershed Management with an emphasis in Water Resources; BKS Environmental; 16+ years of experience with the SCCD; WACD Water Quality training
Amy Doke Program Specialist	B.A. University of Wyoming in Environment and Natural Resources with an emphasis in international studies and ecology; 9+ years of experience with SCCD, assisting in other watershed efforts

5.3 SAMPLE COLLECTION, PRESERVATION, ANALYSIS, AND CUSTODY

Accepted referenced methods for the collection, preservation and analysis of samples were adhered to as described in the SAP. In addition to field data sheets, samplers carried a field log book to document conditions, weather, and other information for each sample day and/or site. Calibration logs were completed for each instrument every time a calibration was performed. Project field measurements were recorded on field data sheets. Water samples requiring laboratory analysis were immediately preserved (if required), placed on ice, and hand delivered to the 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, specific 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, used throughout the project, did not require a calibration solution. 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, to include battery replacement and monthly replacement of the DO meter membrane cap, was performed according to the SAP and manufacturer's instructions. All maintenance activities were documented on the maintenance log.

The Marsh-McBirney flow meter was factory calibrated and did not require field calibration; however, SCCD conducted a "zero check" in the beginning of the field season using a five-gallon plastic 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 beginning of the season to validate the loggers' accuracy.

Equipment used for benthic macroinvertebrate sample collection and reach level habitat assessments did not require calibration; however, surber sampler nets and other equipment were checked for damage prior to entering the field.

5.5 Summary of Quality Assurance/Quality Control

Data Quality Objectives (DQO's) are qualitative and quantitative specifications used by water quality monitoring programs to limit data uncertainty to an acceptable level. DQO's were established for each monitoring parameter for precision, accuracy, and completeness at levels sufficient to allow SCCD to realize project goals and objectives (Table 5.2). SCCD evaluated collected data according to the DQOs in the Project SAP (SCCD, 2015) and WDEQ protocols (WDEQ, 2015).

Table 5.2—Data Quality Objectives for 2015 Goose Creek Watershed Monitoring (SCCD, 2015)

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

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

5.5.1 *Comparability*

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

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

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

Prior to 2014, *E. coli* standards were based on a geometric mean of 5 samples collected within a 30 day period. SCCD collected water quality parameters on the same schedule as the *E. coli* samples; 5 sample geometric means were calculated for all water quality parameters for the 30 day periods. During revisions to water quality standards and methods in 2014, WDEQ changed the basis for the *E. coli* standard to a geometric mean of 5 of more samples collected within a 60 day period (WDEQ, 2014. As a result, SCCD incorporated 60 day geometric means into the 2015 schedule. Comparisons among years are still valuable for evaluating water quality trends; both the 30 day geometric means and the 60 day geometric means capture samples collected during early season (May-June/July) and late season (July-August/September) conditions.

5.5.2 Continuous Temperature Data Loggers

Onset's HOBO Pendent Temperature 64 Data Loggers were deployed at GC01, BG01, BG14, BG18, LG02, LG08, and LG22 to record water temperature during the 2015 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. The pre-season ice bath temperature on 5/4/2015 was reported to be between 0.01-0.232°C (Appendix Table B-5).

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 was used outside of this range and returned the expected results in the crushed ice tests. All of the temperature loggers were considered to have maintained their accuracy and to have provided valid water temperature data for the 2015 monitoring project.

5.5.3 Stage-Discharge Relationships

The relationship between stage height and discharge for a given location yields an equation that allows the calculation of discharge at various stage heights recorded on a staff gauge. 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, 2015) 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 the height of the gauge and the height of the benchmark were compared to verify gauge stability (Table 5.3).

Table 5.3—Summary of 2015 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	2.02	2.02	0.00	0.999
GC02	3.71	3.70	0.01	0.973
GC-SC01	7.95	7.95	0.00	0.995
BG01	8.34	8.39	0.05	ND-DISCARD
BG10	7.87	7.87	0.00	0.996
BG-PC01	0.48	0.42	0.06	1.000
BG14	4.05	4.01	0.04	0.996
BG-RC01	4.50	4.60	0.10	0.994
BG18	2.06	2.06	0.00	0.997
LG02	1.57	1.55	0.02	1.000
LG08	0.99	1.03	0.04	0.986
LG-McC01	2.26	2.25	0.01	1.000
LG-KC01	1.62	1.68	0.06	0.991
LG13	0.76	0.75	0.01	0.992
LG-JC01	0.40	ND	ND	0.940
LG-SC01	5.97	5.98	0.01	1.000
LG22	3.04	3.04	0.00	0.999

ND= No data for the site

The R^2 value for Jackson Creek (LG-JC01) was below the DQO value of 0.95 with a value of 0.940. This site had low late season flows, which could have impacted the discharge measurements. Because this value approached the DQO and presented the only flow information available for this site, discharge measurements were used in the calculation of summary statistics and in the development of load estimates, where appropriate.

All discharge information for the lower most station on Big Goose Creek (BG01) was discarded. Discharge measurements for gauge calibration resulted in a negative stage discharge relationship. Flow measurements were likely affected by a hill slide just downstream from the sample location. The slide and subsequent repair work narrowed the channel and backed-up flows into and upstream of the sample location.

Three of the gauge surveys resulted in differences greater than 0.05 between the pre-season and post-season surveys. The surveys from Park Creek (BG-PC01) and Kruse Creek (LG-KC01) were 0.06, which was close to 0.05. The bench marks at those sites were located adjacent to fences and trees, which may have affected survey measurements. The survey from Rapid Creek (BG-RC01) was 0.10; field notes indicated that the post-season survey was difficult because of high winds and leaves/branches that made reading the rod difficult. The post-season survey at Jackson Creek (LG-JC01) could not be completed, because the bench mark had been washed out or removed during high water. Discharge measurements for these sites were retained because gauges appeared stable and the flow data is used only for pollutant load comparisons and not for regulatory decision making.

5.5.4 Blanks

Trip blanks were prepared to determine whether samples might be contaminated by the sample container, preservative, or during transport and storage conditions. One *E. coli* and turbidity trip blank per cooler was 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*. Two blanks detected turbidity levels of 0.1 NTU (Table 5.4 and Appendix Table B-4). The turbidity data were considered acceptable because they were at the minimum detection limit value of 0.1 NTU. Because there was only one cooler per sample trip after 5/5/2015, SCCD did not fully meet the requirement of one blank for every 10 samples. However, because there was a trip blank in every cooler and trip blanks did not indicate any issues with sample transport, SCCD assumed the data were valid.

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. No field blanks prepared during the project contained detectable levels of *E. coli*; two samples had turbidity values reported as 0.1 NTU and one had a value of 0.2 NTU (Table 5.4 and Appendix Table B-4).

Table 5.4—Turbidity Detections in Blanks for 2015 Goose Creek Watershed Monitoring

Field Blanks				Trip Blanks		
Sample ID	**Site Prepared**	**Sample Date**	**Turbidity (NTU)**	**Sample ID**	**Sample Date**	**Turbidity (NTU)**
FB01	BG18	9/3/2015	0.1	TB01	9/17/15	0.1
FB01	GC01	9/17/15	0.1	TB01	9/30/15	0.1
FB01	GC01	9/30/15	0.2			

5.5.5 Sample Holding Times

All 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 *E. coli* samples were analyzed within their required 8-hour holding time and all turbidity samples were analyzed within the required 48 hour holding time. All water quality field samples were analyzed on-site immediately following sample collection. Benthic macroinvertebrate samples were preserved on-site upon sample collection; there is no holding time for benthic macroinvertebrate samples.

5.5.6 *Duplicates*

The project SAP specified that duplicate chemical, physical, biological, and habitat samples be obtained for at least 10% of all field samples. Duplicate water quality samples were obtained by collecting consecutive water quality samples from a representative stream riffle. Duplicate macroinvertebrate samples were collected by two field samplers, each equipped with a surber net, collecting samples simultaneously and adjacent to one another. 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 5.5).

Table 5.5—Summary of Duplicates Collected for 2015 Goose Creek Watershed Monitoring

Parameter	No. of samples	No. of Duplicates	% Duplicated	DQO (%)
Water Quality Samples in 2015 (17 sites X 10 samples)	170	20*	11.76%	10%
Macroinvertebrate Samples in 2015	6	1	16.67%	10%
Habitat Assessments in 2015	6	1	16.67%	10%

*Note: An error with the dissolved oxygen meter resulted in 18 duplicates being collected for that parameter, which was still within the DQO of 10%.

5.5.7 *Precision*

Precision was defined as the degree of agreement of a measured value as the result of repeated application under the same condition. The Relative Percent Difference (RPD) statistic was used, because the determination of precision is affected by changes in relative concentration for certain chemical parameters. Precision was determined for water quality samples by conducting duplicate samples at 10 percent of the sample sites. With few exceptions, all samples met the DQOs for precision (Table 5.6).

All temperature, pH, and dissolved oxygen duplicate samples met the appropriate DQO for precision. In addition to meeting the DQO of 5% RPD from the Project SAP, all pH sample duplicates were within ±0.3 SU as required by WDEQ. One conductivity measurement exceeded 10% RPD at 10.2, which was only slightly above the DQO. Three turbidity samples exceeded the 20% RPD with values of 21.7, 22.9 and 24.2. Because turbidity values can be relatively low, small variations can result in high RPDs. Four *E. coli* samples exceeded the SCCD precision DQO of 50%. Two of the samples, occurring on 5/5/15 at LG22 and 9/3/15 at LG02, were calculated on reported values that were less than 100. According to WDEQ requirements, the DQO of 50% would not apply to these samples. The RPD for the other two samples, which were both collected from GC02 on 5/21/15 and 9/30/15, was 74.0 and 81.3. The RPD for the other conductivity, turbidity, and *E. coli* duplicate samples collected on the same sample day were within the DQOs. As a result, all of the data for those samples were accepted.

Table 5.6 —Precision of 2015 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 (%)	E. coli RPD (%)	TURB RPD (%)
SCCD DQO Relative Percent Difference:			**10**	**5**	**10**	**20**	**20**	**50**	**20**
WDEQ DQO Relative Percent Difference or Other:			**10**	**±0.3SU**	**10**	**10**	**10**	**50 if >100 NA if <100**	**20**
5/5/15	Dup1	GC01	0.7	1.5	1.3	0.10	1.3	18.2	***21.7***
	Dup2	LG22	1.7	1.3	3.1	2.23	2.0	***66.7(<100)***	7.4
5/21/15	Dup1	GC02	1.1	1.2	0.3	0.64	0.4	***74.0 (>100)***	***22.9***
	Dup2	LG-SC01	2.2	0.9	0.7	2.05	1.4	41.7	8.9
6/2/15	Dup 1	GC-SC01	0.6	0.2	0.3	0.37	0.2	18.2	4.0
	Dup2	LG-JC01	1.4	1.2	1.6	2.28	2.2	31.0	4.2
6/15/15	Dup 1	BG01	0.0	1.8	***10.2***	1.83	3.1	10.3	19.4
	Dup 2	LG13	1.9	2.6	5.3	1.36	1.3	28.9	9.3
6/30/15	Dup 1	BG10	0.0	0.7	0.5	6.51	6.6	16.6	4.7
	Dup 2	LG-KG01	0.0	0.5	0.9	2.88	2.9	19.5	13.1
8/6/15	Dup 1	BG-PC01	0.6	1.3	0.4	1.61	1.3	7.3	5.7
	Dup 2	LG-McC01	1.1	0.4	1.8	3.62	3.5	0.0	5.5
8/18/15	Dup 1	BG14	0.0	0.6	0.0	0.57	0.5	39.3	12.5
	Dup 2	LG08	0.6	0.0	1.4	1.46	2.4	0.0	***24.2***
9/3/15	Dup 1	BG-RC01	0.0	1.6	1.0	1.52	2.0	12.3	13.3
	Dup 2	LG02	0.5	0.2	1.4	1.69	1.6	***79.3 (<100)***	2.9
9/17/15	Dup 1	BG18	0.0	1.3	0.0	0.09	0.0	19.3	7.4
	Dup 2	LG22	0.0	0.2	1.3	2.94	2.9	37.0	0.0
9/30/15	Dup 1	GC02	0.0	0.8	0.1	ND	ND	***81.3(>100)***	2.4
	Dup 2	LG08	0.7	0.3	0.9	ND	ND	21.2	0.0
AVERAGE RPD FOR ALL SAMPLES			**0.6**	**0.9**	**1.6**	**1.9**	**2.0**	**31.1**	**9.5**

Duplicate samples were collected at 10% 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 21.5% and the RPD for total taxa was 1.2% (Table 5.7). Precision for each parameter was within the established DQO. The RPD for the duplicate intra-crew habitat assessment at station BG10 was 3.8%, which was also within the established DQO of 15%.

Table 5.7—Precision of 2015 Macroinvertebrate and Habitat Assessment Data

Parameter	Dup 1 (#)	Dup 2 (#)	Precision (%-RPD)	DQO (%)
Total Abundance	4042	6254	21.5	50
Total Taxa	42	41	1.2	15
Intra-Crew Habitat Assessments	102.5	110.5	3.8	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. There are no current laboratory methods to determine the accuracy of biological samples; therefore, the accuracy of *E. coli* samples could not be determined. Accuracy could not be determined for macroinvertebrate samples and habitat assessment since the true or actual value for macroinvertebrate populations or habitat parameters was unknown. Precision served as the primary QA check for *E. coli* bacteria, turbidity, benthic macroinvertebrates, and habitat assessments.

5.5.9 Completeness

Completeness refers to the percentage of measurements determined to be valid and acceptable compared to the number of samples scheduled for collection. This DQO is achieved by avoiding loss of samples due to accidents, inadequate preservation, failure to meet holding times, and proper access to sample sites for collection of samples as scheduled. DQOs for most parameters were met with the exception of dissolved oxygen and discharge measurements (Table 5.8).

Completeness values for all parameters were affected by flood conditions that prevented access to LG13 on 6/2/15. On 9/30/2015, problems associated with the calibration of the dissolved oxygen meter resulted in no measurements being collected on that day. Gauges that were submerged, broken, or otherwise unusable because of high flows also affected completeness values for discharge. Issues with gauge calibration at BG01 resulted in all of the discharge values being discarded for that site.

Table 5.8—Completeness of 2015 Monitoring Data

Parameter	% 2015 Completeness	DQO (%)
Water Temperature	99	95
pH	99	95
Conductivity	99	95
Dissolved Oxygen	89	95
Discharge	81	90
Turbidity	99	95
E. coli	99	95
Marcroinvertebrates	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 and all holding times were met. 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, 2015). With the exception of blanks, no lab results were reported below the detection limits in 2015.

High flows caused six gauges 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. A total of 15 gauge heights were adjusted; adjusted heights were used for discharge calculations and summary statistics.

Three discharge measurements were unreasonably high for the site conditions and were determined to be outside of the calibrated range of the staff gauge. These measurements, which included one each on Soldier Creek and BG14 on 6/15/15 and one on Sackett Creek on 6/2/15, were discarded and not used in the calculation of summary statistics.

Gauge calibration measurements for site BG01 were affected by a hill slide just downstream from the sample location. Discharge measurements for gauge calibration resulted in a negative stage discharge relationship. As a result, all of the discharge calculations were discarded.

Two *E. coli* values were reported as >2419.6 col/100mL. These samples were collected from Soldier Creek on 6/30/15 and Kruse Creek on 8/18/2015. SCCD used 2420 col/100mLfor calculation of summary statistics.

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 decided to continue 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 and maintenance logs were documented on the appropriate forms and are maintained on file in the SCCD office. Photographs and photograph descriptions were organized by station, maintained on file in the SCCD office.

Water quality and supporting QA/QC data were received electronically and in hard copy format 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 SCCD database on the SCCD server in Sheridan, Wyoming.

5.8 DATABASE CONSTRUCTION AND DATA REDUCTION

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

After data validation and database construction, data were statistically summarized for the following calculations (Appendix Table C-20):

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

These statistics and analyses provided insight for temporal and spatial water quality changes within the watershed. Microsoft Excel® was used to generate the statistical tables, geometric means, and graphics for this report. Geometric means were calculated for all of the water quality parameters using the ten sampling dates and then separately for the five samples collected in May-July and in July-September. 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 or excursions 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 will also be available.

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

CHAPTER 6 DISCUSSION OF RESULTS

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 2015 monitoring (Table 6.1).

Table 6.1—Numeric and Narrative Water Quality Standards Applicable for Waters in the 2015 Goose Creek Watershed Monitoring Project (WDEQ, 2013)

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)	High Valleys Bioregion: Score >48.77 for full support; Score 32.51-48.76 for indeterminate support; and score 0-32.50 for partial/non-support.
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.

6.1 FIELD WATER CHEMISTRY AND PHYSICAL PARAMETERS

Water quality data were collected in May-June and August-September, 2015 at 17 stations (Appendix Tables C-3 through C-19). Summary statistics and geometric mean values for the two periods were calculated for all sites on accepted data (Appendix Table C-20). In addition to samples collected by SCCD, USGS collected water quality data from two stations from 2013-2015, including station 06304500 (Little Goose Creek at Sheridan) and 06305500 (Goose Creek Below Sheridan). Among other things, the USGS collected temperature, pH, dissolved oxygen, conductivity, discharge, and bacteria. Only data similar in scope to the parameters collected by the SCCD are presented (Appendix Tables C-21 and C-22).

6.2.1 Instantaneous Water Temperature

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at 9 stations on 6/30/15 (Table 6.2). Temperatures above 20°C were also observed on other occasions at GC01 and LG02, including 8/6/15 and 9/3/15 (LG02). The maximum instantaneous temperature was observed on Kruse Creek (22.6°C) on 6/30/15. Instantaneous water temperature measurements collected during 2015 did not necessarily represent daily minimum, maximum, or average water temperature.

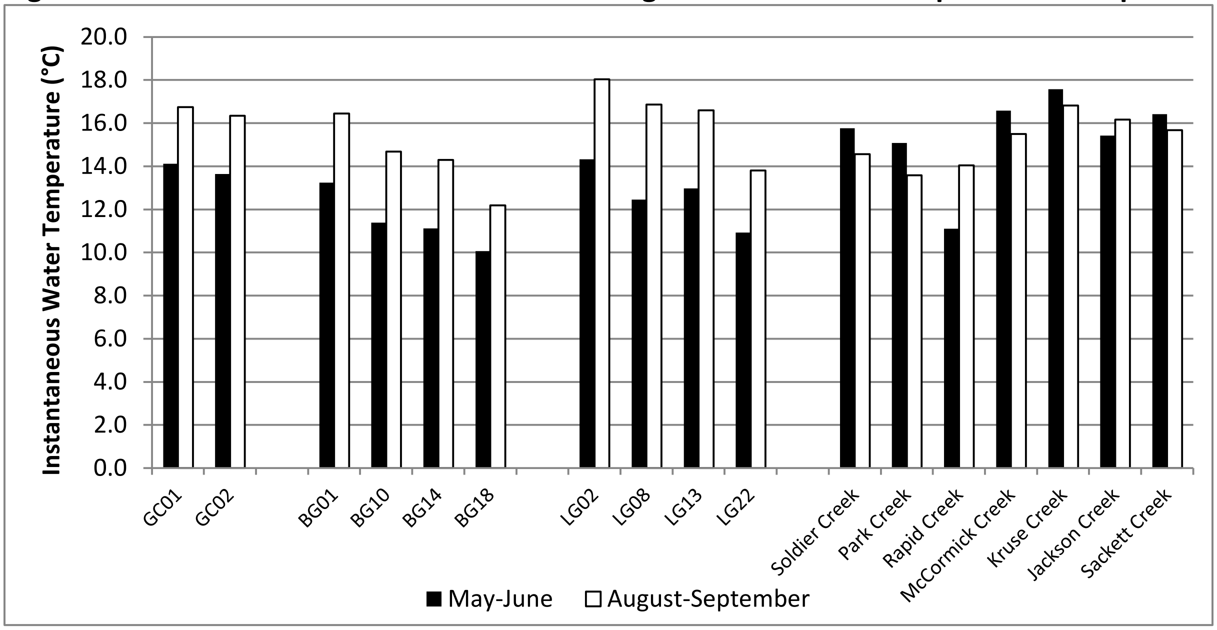
Table 6.2—Instantaneous Water Temperatures above 20°C during the 2015 Goose Creek Watershed Interim Monitoring

Site	Date	Temperature (°C)
GC01	6/30/15	21.4
	8/6/15	20.2
GC02	6/30/15	21.0
Soldier	6/30/15	21.9
BG01	6/30/15	21.0
Park	6/30/15	20.4
LG02	6/30/15	20.9
	8/6/15	21.0
	9/3/15	20.2
McCormick	6/30/15	21.6
Kruse	6/30/15	22.6
Jackson	6/30/15	21.6

Average instantaneous temperature was lower in May-June than in August-September at most stations, including all mainstem sites (Figure 6.1). However, early season (May-June) water temperatures were higher than in the late season on all but two tributary sites. The tributaries with warmer instantaneous water temperatures in May-June include: Soldier Creek, Park Creek, McCormick Creek, Kruse Creek, and Sackett Creek.

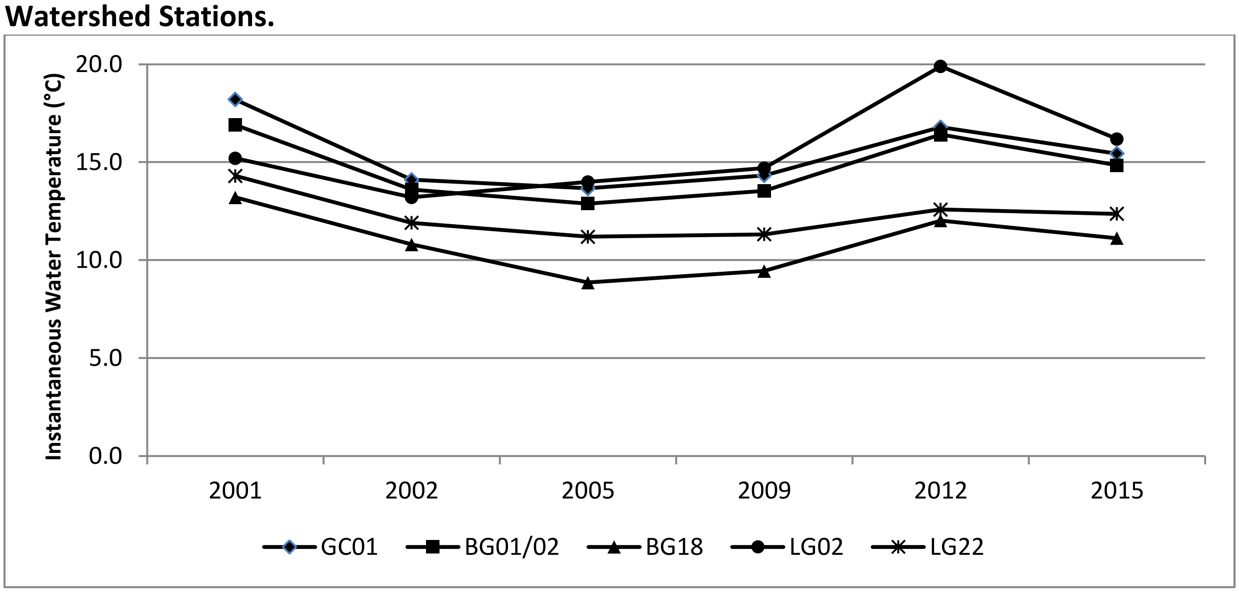
For mainstem sites on Big Goose Creek and Little Goose Creek, instantaneous temperatures generally decrease from downstream to upstream. The tributary stations in the Little Goose Creek subwatershed generally had higher temperatures than the tributaries in the Goose Creek and Big Goose Creek subwatersheds.

Figure 6.1—2015 Goose Creek Watershed Average Instantaneous Temperature Comparisons



Changes in annual average instantaneous water temperatures were relatively consistent among mainstem stations. In 2015, average annual temperatures were similar or slightly higher than in 2005. Annual averages of comparable periods were highest in 2001 and 2012 than in other sampling years. This could be attributed to higher than normal air temperatures and lower than normal precipitation. However, direct comparisons among years are difficult because of variations in water quantity and air temperatures.

Figure 6.2— Average Annual Instantaneous Water Temperature at Select Goose Creek Watershed Stations.



USGS Stations 06304500 (Little Goose Creek at Sheridan) and 06305500 (Goose Creek Below Sheridan) both reported instantaneous temperatures above 20° C in July of 2013 and 2014. No measurements were reported above 20°C in 2015 from USGS Stations 06304500 (Little Goose Creek at Sheridan). USGS Station 06305500 (Goose Creek Below Sheridan) did not report any data in 2015.

6.2.2 *Continuous Water Temperature*

Onset's HOBO Pendent Temperature 64 Data Loggers were used at seven stations from 5/5/15 through 10/19/15 (Appendix Figures C-1 through C-7). There was one station on Goose Creek (GC1) and three each on Big Goose Creek (BG01, BG14, and BG18) and Little Goose Creek (LG02, LG08, and LG22). The logger at LG08 appeared to have been out of the water or on the bank for the period between 8/6/2015 and 8/13/2015. Temperatures for this period ranged from 13.27°C to 38.16°C. These data were discarded and were not included in summaries of daily maximums, minimums and average temperatures.

All of the loggers reported temperatures over 20°C except for the stations located at the uppermost stations in Big Goose and Little Goose canyons (Table 6.3). The lowermost stations (GC1, BG01, and LG02) had days where the daily average and minimum temperature was also above 20°C. Maximum reported temperatures ranged from 18.2°C at LG22 to 29°C at BG01.

Table 6.3—Daily Maximum, Average, and Minimum Temperatures Recorded by Continuous Temperature Data loggers in the Goose Creek Watershed in 2015.

Site	# of Days Maximum Temp >20°C	# of Days Average Temp >20°C	# of Days Minimum Temp >20°C	Maximum Temp (°C)	Average Temp (°C)	Minimum Temp (°C)
GC01	69	49	23	26.7	18.6	9.0
BG01	65	44	17	29.0	18.2	8.5
BG14	62	11	0	26.7	17.1	5.6
BG18	0	0	0	19.7	13.4	3.9
LG02	62	36	1	25.6	18.2	8.2
LG08*	42	11	0	23.9	16.8	7.6
LG22	0	0	0	18.2	13.2	5.1

* Data from LG08 between 8/6/15 and 8/13/15 were discarded because of questionable values.

Temperatures at the lower stations (GC01, BG01, and LG02) had extended periods from the middle of June through August where daily maximum temperatures exceeded 20°C. In addition, the stations at GC01 and BG01 had extended periods where the minimum daily temperature was above 20°C. Sites in the middle part of the watershed (BG14, and LG08) also had temperatures above 20°C, but the periods were not as long and there were no days where the minimum temperatures were also above 20°C. The logger at LG08 did not have a complete dataset; reported temperatures may not reflect the actual maximum, minimum, or average temperatures for that site.

Yearly comparisons from GC01 showed that mean daily water temperatures for 2015 were similar to previous years with some exceptions (Appendix Figure C-8). Temperatures in 2015 were generally more similar to temperatures in 2012 than in other years, with temperatures from 2001-2002 typically being higher and temperatures from 2005-2009 typically being lower. From May through July, 2015 temperatures were lower than the 2001-2002 average mean daily temperatures but higher than the 2005-2009 average. Mean daily temperatures from August-October 2015 were higher than all other years by as much as 5°C or more on some days.

6.2.3 PH

Ranging from 7.54 to 9.06 SU, all but two pH measurements were within the Wyoming water quality standard of 6.5-9.0 SU. The station at LG22 reported pH values of 9.04 SU and 9.07 SU on 6/15/15 and 9/30/15, respectively. When averaged for the sampling season, pH was within standards for all stations; the same is true for all sampling years (Table 6.4).

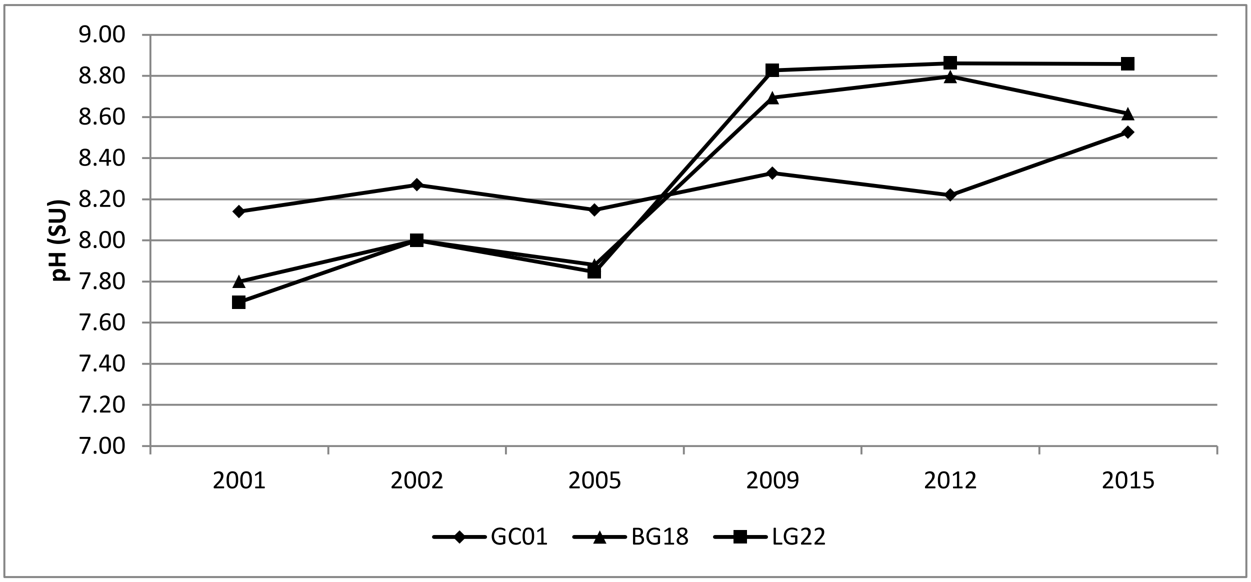
Table 6.4—Average pH for stations within the Goose Creek watershed from 2001-2015

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

[A] Includes values from BG01 in 2001, 2002, 2012, and 2015 and values from BG02 in 2005 and 2009
[B] Park Creek and BG14 were not sampled in 2005 and 2009
[C] Means for 2001 and 2002 on Park Creek are for May only; Park Creek was dry in August of 2001 and 2002

Average pH increased at all stations from 2005-2009. Sharp increases were observed at both canyon stations (Figure 6.3), especially when compared to increases at stations in the lower part of the watershed. USGS stations reported similar pH values, which ranged from 8.1 to 8.6 SU from 2013 through 2015 at Station 06304500 (Little Goose Creek at Sheridan) and between 7.8 to 8.7 SU at 06305500 (Goose Creek Below Sheridan) in 2013 and 2014.

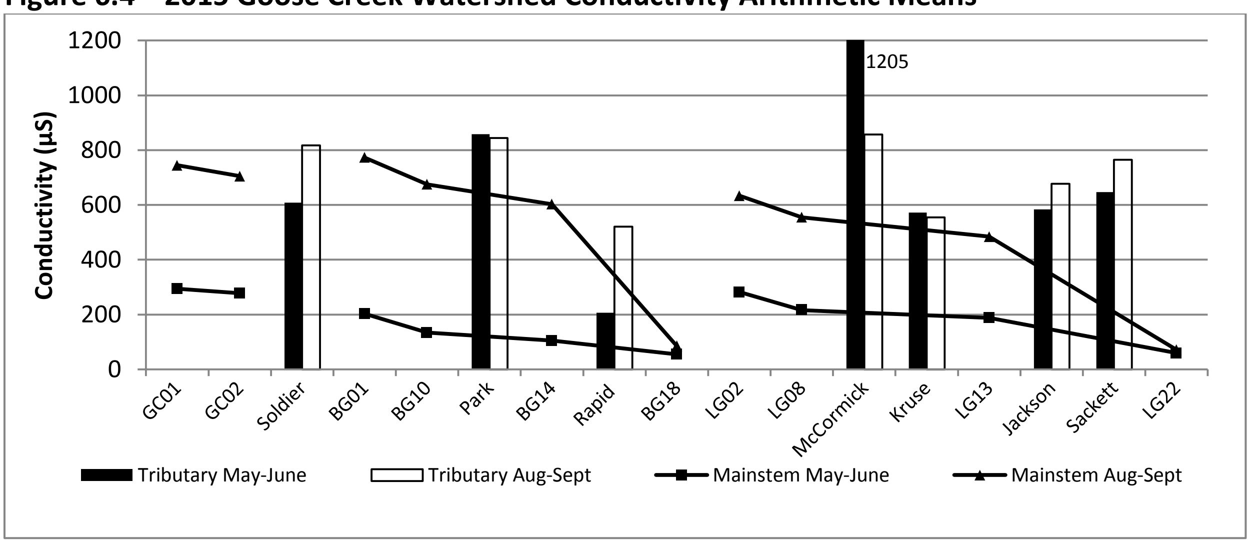
Figure 6.3—Average Annual pH Comparison at Select Goose Creek Watershed Stations



6.2.4 *CONDUCTIVITY*

The average conductivity at mainstem stations in 2015 increased from upstream to downstream in Little Goose, Big Goose, and Goose Creek (Figure 6.4). Conductivity ranged from 34 µS (BG18) to 1558 µS (McC01). At mainstem stations, average conductivity was lower in May-June than in August-September, but only slightly so at the two canyon stations.

Figure 6.4—2015 Goose Creek Watershed Conductivity Arithmetic Means



Park Creek and McCormick Creek were the only stations with conductivity values over 1000 µS, with maximum values of 1019 µS and 1558 µS, respectively. Six of 10 values in McCormick Creek were above 1000 µS. The two stations in the canyons (BG18 and LG22) had the lowest conductivity, both of which were under 100 µS.

There is no standard for specific conductivity in the state of Wyoming; however, because conductivity is highly dependent on the amount of dissolved solids (such as salts), high values could become a concern for agricultural operations related to crop/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, 2005). While conductivity is not directly proportional to the TDS concentration, conductivity can be used to estimate the relative concentration of TDS.

For the most part, May-June conductivity at mainstem stations decreased from 2001 to 2009, increased in 2012 and decreased again in 2015 (Table 6.5). August-September conductivity was higher than May-June at all mainstem stations. Yearly comparisons among tributary stations were more difficult because values were more variable. The stations in the canyons were the most consistent among years and between seasons with values ranging from 55-103 µS at BG18 and 58-83 µS at LG22.

Table 6.5—Yearly Comparisons for Conductivity (µS) Arithmetic Means 2001-2015

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

[A] Includes values from BG01 in 2001, 2002, 2012, and 2015 and values from BG02 in 2005 and 2009
[B] Park Creek and BG14 were not sampled in 2005 and 2009
[C] Park Creek was dry in August of 2001 and 2002

USGS Station 06304500 (Little Goose Creek at Sheridan) reported conductivity values between 219 µS and to 806 µS from 2013-2015; conductivity ranged from 176 µS to 792 µS at USGS station 06305500 (Goose Creek below Sheridan) from 2013-2014. Low conductivity values reported by USGS stations corresponded to high discharge measurements in May and June 2014, respectively.

6.2.5 *Dissolved Oxygen*

All sites met the minimum instantaneous dissolved oxygen water quality standards, with one exception. One sample from Park Creek, which occurred on 6/30/15, was 4.24 mg/L and was the only sample below the early life stage standard of 5.0 mg/L. WDEQ recommends a water column concentration standard of 8.0 mg/L to achieve the 5.0 mg/L intergravel concentrations (WDEQ, 2013). Three mainstem stations and four tributary stations returned at least one measurement below the recommendation of 8.0 mg/L (Table 6.6). With one exception, all of the measurements on Park Creek were below 8.0 mg/L; on 5/21/15, dissolved oxygen at Park Creek was 9.02 mg/L.

Table 6.6—Dissolved Oxygen Ranges and Number of Samples Below 8.0 mg/L in 2015

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	1	7.37-10.06	Soldier	2	6.99-9.88
GC02	1	7.77-10.95	Park	7	4.24-9.02
BG01	1	7.54-10.79	Rapid	0	8.37-11.36
BG10	0	8.55-11.78	McCormick	1	7.77-10.97
BG14	0	8.58-12.00	Kruse	0	8.14-12.31
BG18	0	8.85-12.11	Jackson	0	8.24-12.15
LG02	0	8.45-11.54	Sackett	4	6.74-10.90
LG08	0	8.69-11.58			
LG13	0	8.69-12.28			
LG22	0	8.72-11.73			

Values on tributary stations ranged from 4.24 – 12.31 mg/L, with the minimum value on Park Creek and the maximum value on Kruse Creek. On mainstem stations, dissolved oxygen ranged from 7.37 mg/L at GC01 to 12.28 at LG13. The lowest dissolved oxygen values were reported on 6/30/15 at all but two stations. The sites at BG10 and LG22 returned the lowest dissolved oxygen measurements on 9/3/15. All but three mainstem stations and three tributary stations returned their highest dissolved oxygen measurement on 5/21/15; all of the exceptions were within the Little Goose Subwatershed. The stations at LG02, LG13, LG22, Kruse Creek, Jackson Creek, and Sackett Creek returned the highest dissolved oxygen measurements on 9/17/15.

Average dissolved oxygen values were relatively consistent across the watershed among years (Table 6.7). For the most part, average dissolved oxygen values in August-September were lower than in May-June. Average dissolved oxygen values in 2015 were higher than in 2012 at most stations; however, 2015 values were not necessarily higher than other years. Across all years, Park Creek had the lowest average dissolved oxygen, ranging from 4.67 to 7.75 mg/L.

Table 6.7—Yearly Comparisons for Dissolved Oxygen (mg/L) Arithmetic Means 2001-2015

	May-June						August-September					
	2001	2002	2005	2009	2012	2015	2001	2002	2005	2009	2012	2015
GC01	9.26	8.87	10.22	8.96	7.85	9.2	7.23	7.86	8.22	7.84	6.56	8.4
GC02	10.56	10.72	10.64	9.99	9.19	9.7	10.44	8.96	9.11	8.81	7.82	8.9
Soldier	8.76	9.14	9.46	8.90	8.28	8.71	6.81	7.40	9.13	8.22	6.90	8.53
BG01/02[A]	8.04	10.10	10.42	9.77	9.10	9.43	6.89	7.68	8.80	8.16	8.56	9.01
BG10	10.15	11.44	10.78	10.69	10.11	10.36	9.34	9.04	9.61	9.41	8.64	9.43
Park	6.23	7.71	ND[B]	ND[B]	7.75	7.00	ND[C]	ND[C]	ND[B]	ND[B]	4.67	7.32
BG14	10.45	10.43	ND[B]	ND[B]	9.45	10.37	9.39	9.29	ND[B]	ND[B]	9.73	10.15
Rapid	9.78	9.86	10.37	10.18	9.54	10.17	8.74	8.62	9.13	8.75	8.37	8.92
BG18	10.09	10.38	10.59	11.13	10.30	10.63	8.56	8.79	8.58	9.23	8.63	10.15
LG02	8.62	9.78	9.95	10.34	10.83	10.09	7.67	7.19	9.54	10.46	9.16	10.46
LG08	9.25	10.76	11.22	10.65	9.75	10.23	8.58	8.21	11.26	9.83	9.65	10.46
McCormick	9.36	10.60	10.44	9.98	9.40	9.25	9.33	8.95	8.74	8.52	8.53	9.58
Kruse	8.92	10.28	10.10	9.41	8.87	8.65	8.60	8.25	8.32	8.06	8.00	10.44
LG13	10.35	11.31	11.43	10.83	9.87	10.17	9.45	8.90	10.49	10.64	9.03	10.34
Jackson	8.58	8.72	10.94	9.68	8.42	9.37	6.14	7.54	9.99	8.62	10.46	11.17
Sackett	8.82	10.20	9.91	8.20	7.86	8.05	8.68	8.15	8.19	7.86	7.29	8.61
LG22	9.75	10.38	10.22	10.82	10.27	10.27	8.38	8.59	7.80	8.74	8.40	9.93

[A] Includes values from BG01 in 2001, 2002, 2012, and 2015 and values from BG02 in 2005 and 2009
[B] Park Creek and BG14 were not sampled in 2005 and 2009
[C] Park Creek was dry in August of 2001 and 2002

Dissolved oxygen values reported by USGS Station 06304500 (Little Goose Creek at Sheridan) ranged from 8.0 mg/L to 15.5 mg/L from 2013-2015 and from 8.1 mg/L and 16.8 mg/L from Station 06305500 (Goose Creek Below Sheridan) through 2014. Low dissolved oxygen values at both stations were observed in July 2013.

6.2 Discharge

SCCD used calibrated staff gauges to estimate discharge during water sampling events. Heavy precipitation and run-off in early June 2015 resulted in submersion and/or damage to some gauges. The site at LG13 was inaccessible on 6/2/15 because of road closures due to flooding.

One USGS gauge collected hydrologic information during a portion of the sampling period. Station 06305700 Goose Creek near Acme, which is near GC01, reported "real-time" discharge information beginning in June of 2015 (Appendix Figure C-9). Historical hydrologic information was also available from Station 06305500 (Goose Creek Below Sheridan), which corresponds to site GC02 (Appendix Figure C-10).

The majority of stations reported the highest flows on 6/2/15 followed by 6/15/15 (Table 6.8). For many of these sites, discharge was not able to be calculated because staff gauges were submerged or the gauge height was outside of the calibrated range. The lowest discharge observed on most sites occurred on 9/3/15. Tributaries were more variable; however, the highest discharge for all tributary sites was on 6/2/15.

Table 6.8—2015 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	6/2/15	SUB	6/15/15	SUB	9/3/15	36.73	9/17/15	43.48
GC02	6/2/15	SUB	6/15/15	SUB	9/3/15	33.23	9/17/15	53.68
BG01	ALL FLOW DATA DISCARDED							
BG10	6/2/15	SUB	6/15/15	SUB	9/3/15	8.53	9/30/15	9.47
BG14	6/2/15	SUB	6/15/15	OUT	9/3/15	2.10	9/30/15	2.95
BG18	6/2/15	SUB	6/15/15	SUB	9/30/15	17.86	9/17/15	18.91
LG02	6/2/15	SUB	6/15/15	SUB	9/3/15	18.83	9/30/15	27.33
LG08	6/2/15	SUB	6/15/15	162.64	9/30/15	13.11	9/17/15	19.27
LG13	6/2/15	ND-Flood	6/15/15	SUB	9/3/15	4.25	9/30/15, 9/17/15, 8/6/15	9.12
LG22	6/2/15	639.26	6/15/15	350.02	9/17/15	27.57	9/30/15	44.69
TRIBUTARY SITES								
GC-SC01	6/2/15	SUB	6/15/15	OUT	9/3/15	0.92	8/18/15	1.13
BG-PC01	6/2/15	4.89	8/6/15	1.71	9/30/15	0.003	9/17/15	0.009
BG-RC01	6/2/15	155.40	5/21/15	54.24	9/30/15	0.65	9/17/15	0.69
LG-McC01	6/2/15	160.30	6/15/15	85.36	5/5/15	0.002	5/21/15	0.03
LG-KC01	6/2/15	SUB	6/30/15	12.21	5/21/15	1.04	5/5/15	1.41
LG-JC01	6/2/15	8.95	5/21/15	5.65	9/3/15	1.00	9/17/15	1.27
LG-SC01	6/2/15	OUT	5/21/15, 6/15/15	14.33	9/3/15	0.03	9/30/15	0.05

High discharge corresponds to an increase in precipitation or snowmelt, which were both higher than normal for this period during 2015 (Appendix Figure C-11). Average discharge on Little Goose, Big Goose, and Goose Creeks were typically lower than in 2009, but higher than other years (Table 6.9). The same pattern was observed on most tributary stations. May 2015 discharge on McCormick Creek, Rapid Creek, and Soldier Creek were higher than in all other years and seasons.

Table 6.9—Instantaneous Discharge (cfs) Arithmetic Means Yearly Comparisons 2001-2015

	May-June						August-September					
	2001	2002	2005	2009	2012	2015	2001	2002	2005	2009	2012	2015
GC01	34.7	64.1	502.8	511.2	141.1	187.5	14.6	27.2	60.8	120.5	24.8	52.5
GC02 [A]	ND [A]	69.2	38.9	450.3	185.8	149.8		27.1	61.1	73.7	22.4	61.5
Soldier	1.4	1.1	10.7	8.0	8.8	12.6	0.2	0.4	2.6	4.1	0.9	1.7
BG01/02[B]	28.0	35.8	204.5	344.3	128.0	ND [A]	4.7	7.1	20.9	39.3	27.1	ND [A]
BG10	70.0	29.5	22.6	288.5	115.6	172.0	10.3	7.9	11.4	34.6	6.9	15.2
Park	0.04	0.02	ND[C]	ND[C]	0.00	1.20	ND[D]	ND[D]	ND[C]	ND[C]	0.00	0.5
BG14	73.1	23.5	ND[C]	ND[C]	105.0	75.6	9.8	6.0	ND[C]	ND[C]	5.5	7.6
Rapid	2.2	1.2	7.3	13.3	6.8	62.5	1.1	1.0	1.5	2.8	1.1	1.4
BG18	86.2	26.7	75.0	202.0	93.2	71.4	26.7	23.9	19.0	63.1	25.1	24.5
LG02	8.3	63.8	26.8	325.8	45.1	72.0	3.6	5.3	29.4	44.6	13.0	29.3
LG08	11.5	32.8	13.0	57.8	32.5	94.6	6.4	13.4	21.5	36.1	10.7	22.0
McCormick	1.8	5.6	3.0	5.9	2.5	49.8	1.6	0.1	4.2	3.2	0.9	2.3
Kruse	1.6	2.9	4.5	2.7	2.0	4.5	0.6	3.5	5.8	6.6	3.1	7.7
LG13	3.3	16.1	19.8	66.6	15.8	80.7	1.4	2.6	6.6	19.3	2.2	8.3
Jackson	0.7	0.9	1.6	3.1	1.9	4.5	0.4	0.9	4.3	0.5	0.7	1.3
Sackett	0.8	3.1	5.6	1.0	0.5	7.6	0.6	0.3	0.4	0.6	0.8	0.1
LG22	47.6	46.4	166.1	166.5	86.6	201.1	33.4	29.6	39.0	80.8	49.4	54.2

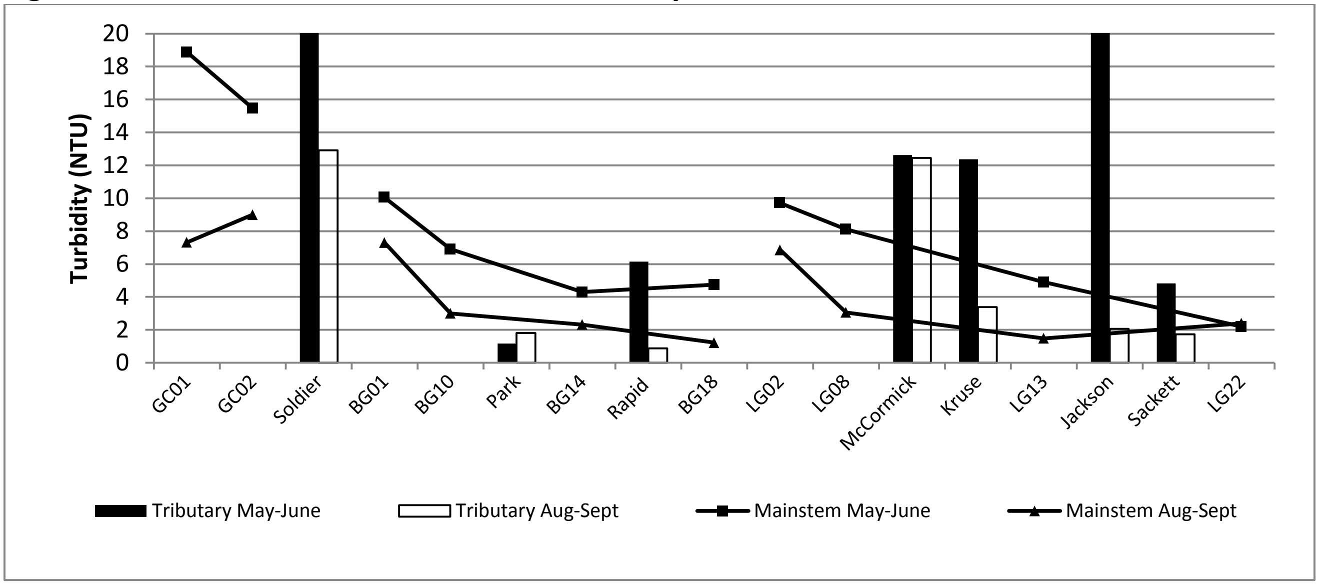
[A] Problems with gauge calibration prevented estimation of discharge at GC02 in 2001 and BG01/02 in 2015
[B] Includes values from BG01 in 2001, 2002, 2012, and 2015 and values from BG02 in 2005 and 2009
[C] Park Creek and BG14 were not sampled in 2005 and 2009
[D] Park Creek was dry in August of 2001 and 2002

6.3 TURBIDITY

There is no turbidity standard for surface waters in the State of Wyoming except when it relates to point source discharges. Turbidity generally increased from upstream to downstream (Figure 6.5); with a decrease in August-September from GC02 to GC01. Samples collected in May-June 2015 had higher turbidity than samples collected in August-September at nearly all stations, except on Park Creek and the station in Little Goose Canyon (LG22). Tributary stations were typically higher than adjacent mainstem sites, except for Park Creek.

The highest turbidity value reported from a mainstem site was 24.0 NTUs at GC02 on 6/2/15; the lowest mainstem value was 0.9 NTU at BG18 on 8/18/15. The highest turbidity value reported from a tributary station was 102.0 NTUs on Soldier Creek on 6/2/15; the lowest tributary value was 0.4 NTU on Park Creek on 9/3/15. Sometime between 6/2/15 and 6/15/15, the small reservoir just upstream of the staff gauge on Kruse Creek washed through the embankment, which may have affected the turbidity on 6/15/15, which increased from 10.1 NTUs on 6/2/15 to 30.7 NTUs on 6/15/15. The embankment was not repaired through the remainder of the sample season.

Figure 6.5—2015 Goose Creek Watershed Turbidity Arithmetic Means



Average turbidity on mainstem stations for May-June 2015 was slightly lower than in 2012, except on upper stations (BG18, LG13, and LG22),which had slight increases. For August-September averages, turbidity increased from 2012 to 2015 on the Goose Creek stations. Changes in turbidity at other stations and other years were more variable.

Table 6.10—Yearly Comparisons for Turbidity (NTU) Arithmetic Means 2001-2015

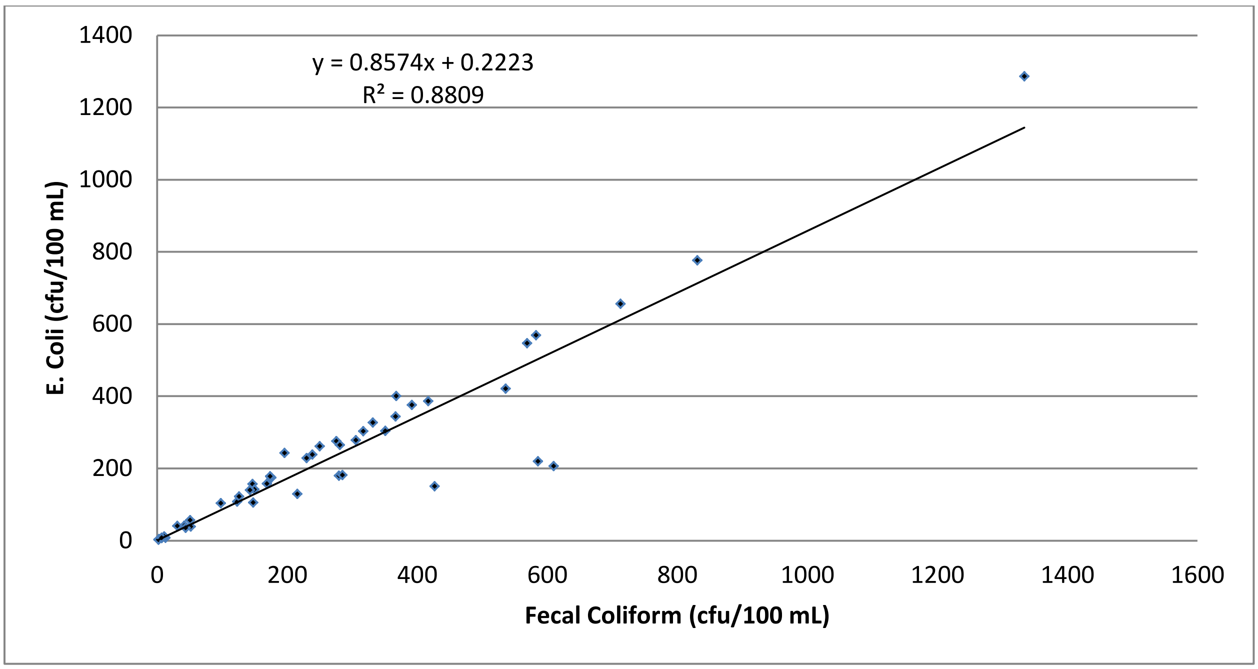
	May-June						August-September					
	2001	**2002**	**2005**	**2009**	**2012**	**2015**	**2001**	**2002**	**2005**	**2009**	**2012**	**2015**
GC01	9.3	12.7	30.2	9.7	19.6	18.9	2.4	3.9	8.4	12.8	3.4	7.3
GC02	9.0	7.5	19.8	12.0	17.4	15.5	2.7	2.6	8.1	12.0	5.0	9.0
Soldier	8.1	14.7	80.1	15.7	39.1	65.0	10.5	25.6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

[A] Includes values from BG01 in 2001, 2002, 2012, and 2015 and values from BG02 in 2005 and 2009
[B] Park Creek and BG14 were not sampled in 2005 and 2009
[C] Park Creek was dry in August of 2001 and 2002

6.4 Bacteria

In 2001, 2002, and 2005, fecal coliform bacteria were the indicator for pathogens under Wyoming Water Quality Standards. However, during the revision of Chapter 1 in 2007, *E. coli* became the indicator for determination of recreational use support. In anticipation of this change, SCCD collected both *E. coli* and fecal coliform at a select number of sites in 2002 and at all stations in 2005 so that *E. coli* samples could be compared to fecal coliform data from previous years. While there is no standard conversion from fecal coliform to *E. coli*, it is possible to find a relatively consistent relationship within an individual watershed (Rasmussen, 2003). Within the Goose Creek watershed, the R^2 value of this comparison was 0.88, which SCCD determined was sufficient for evaluating long-term trends (Figure 6.6). SCCD converted fecal coliform results from 2001 and 2002 to *E. coli* so comparisons among years could be made. These converted data were not used in any listing determination or other regulatory action. Ten sites that did not exceed the fecal coliform bacteria standard in 2001 and/or 2002 did exceed the *E. coli* standard when fecal coliform values were converted to *E. coli* values.

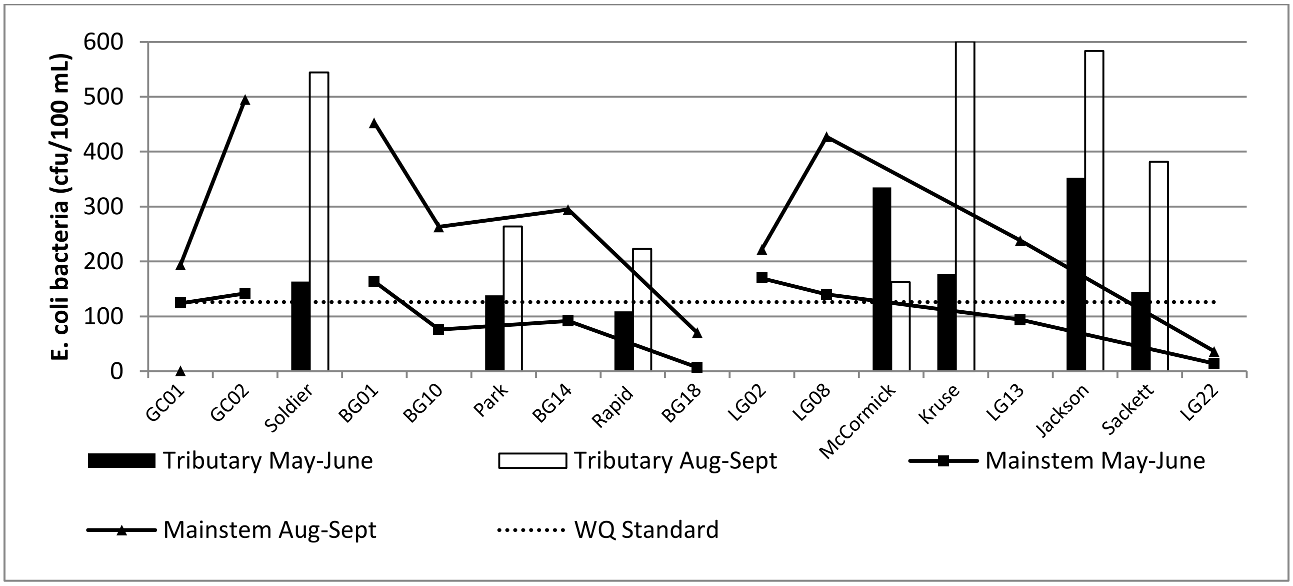
Figure 6.6—Fecal Coliform and *E. coli* Bacteria Comparison from Samples Collected By SCCD in 2002 and 2005 in the Goose Creek Watershed



In 2015, ten *E. coli* bacteria samples were obtained from each of the 24 stations on two separate 60 day periods, May-June and August-September. Most stations had at least one geometric mean that exceeded Wyoming Water Quality Standards with the exception of BG18 and LG22. In 2015, six out of 10 mainstem stations exceeded the *E. coli* standard in May-June, and eight in August-September; six out of seven tributary stations exceeded the *E. coli* standard in May-June, and seven out of seven in August-September.

Geometric mean bacteria concentrations were typically lower in May-June than in August-September; with the exception of McCormick Creek (Figure 6.7). Mainstem sites typically had lower bacteria concentrations than tributary sites. Bacteria concentrations in Little Goose subwatershed tributaries may have contributed somewhat to increases in bacteria concentrations at adjacent downstream stations; tributary bacteria concentrations did not appear to contribute significantly to mainstem sites on lower Big Goose Creek or on Goose Creek stations.

Figure 6.7—2015 Goose Creek Watershed *E. coli* Bacteria Geometric Means



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, 2014). 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 2015 in both May and August (Table 6.11). The number of tributary stations that exceeded the *E. coli* standard in August has remained consistent since 2002.

Table 6.11—Number of Comparable Sites Exceeding Bacteria Standards from 2001-2015

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

An increase in bacteria concentrations from 2001 to 2015 was observed at every comparable site and sampling period, except for Soldier Creek during the early season and Soldier Creek and McCormick Creek during the late season. For samples collected in May-June, most mainstem stations show an increase from 2001 to 2009 or 2012 that is followed by a decrease in 2015. Tributary stations are more variable; however, most stations appear to have an increase in 2005 or 2012 that are followed by subsequent decreases. Bacteria concentrations in McCormick Creek, Kruse Creek, and Sackett Creek, within the Little Goose Creek subwatershed, have increased since 2009. Generally, bacteria concentrations at mainstem stations appear to be increasing from August-September 2001 to 2015, although some stations had a decrease in 2009 or 2012. Tributary stations appeared to have an increase in August-September bacteria concentrations in 2005 or 2012, which was followed by a decrease.

Bacteria concentrations decreased by 18-351% from 2012-2015 at all but one of the mainstem stations in May-June (Table 6.12 and Figure 6.8). The station in Little Goose Canyon (LG22) had a 38% increase in bacteria concentration for the same period; however values were still within water quality standards at 14 cfu/100 mL. For August-September, bacteria concentrations on mainstem sites increased 40-64% from 2012-2015. Increases of 40% and 45% were observed in the Big Goose (BG18) and Little Goose (LG22) canyon stations; these values represented increases from 42 to 70 cfu/100 mL at BG18 and from 20-36 cfu/100 mL at LG22. Decreases from 2012-2015 of 6%, 77%, and 16% were observed at BG10, BG14, and LG02, respectively.

Five of seven tributary stations had 10-58% increases in bacteria concentrations from 2012-2015 during the early season (Table 6.12 and Figure 6.9). May-June 2015 concentrations in Soldier Creek and Rapid Creek decreased from 2012 by 182% and 482%, respectively. The decrease on Rapid Creek represented a decrease from 637 to 109 cfu/100 mL; 2012 was the only year that Rapid Creek exceeded water quality standards for samples collected in May-June. During the late season, the percent change from 2012-2015 among tributary stations was less consistent, with four tributaries showing increases from 3-61% and three showing decreases of 136-386%.

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—Bacteria Geometric Means and Percent Change Among Years at Comparable Stations in the Goose Creek Watershed.

	Site	May-June *E. Coli* geometric means (cfu/100 mL)						Percent Change				
		2001[A]	2002[A]	2005	2009	2012	2015	2001-2015	2002-2015	2005-2015	2009-2015	2012-2015
Mainstem Stations	GC01	55	127	303	309	335	124	125%	-2%	-144%	-149%	-170%
	GC02	96	135	275	391	329	142	48%	5%	-94%	-176%	-132%
	BG01/02[B]	113	55	107	285	223	163	45%	66%	35%	-74%	-36%
	BG10	38	6	41	102	267	76	99%	92%	46%	-34%	-252%
	BG14	21	3	ND[C]	ND[C]	415	92	338%	97%			-351%
	BG18	2	1	9	6	9	7	243%	85%	-37%	13%	-32%
	LG02	43	102	242	119	215	169	294%	40%	-43%	30%	-27%
	LG08	54	73	56	66	165	140	159%	48%	60%	53%	-18%
	LG13	20	18	40	48	118	94[D]	370%	81%	57%	49%	-26%
	LG22	1	2	4	2	9	14	1325%	86%	74%	87%	38%
Tributary Stations	GC-SC01	246	197	1286	133	461	163	-34%	-21%	-688%	18%	-182%
	BG-PC01	139	468[D]	ND[C]	ND[C]	58	138	0%	-238%			58%
	BG-RC01	67	36	35	66	637	109	63%	67%	68%	40%	-482%
	LG-McC01	143	119	139	108	249	335	134%	64%	59%	68%	25%
	LG-KC01	118	80	261	69	101	177	50%	55%	-48%	61%	43%
	LG-JC01	246	14	177	317	508	352	43%	96%	50%	10%	-44%
	LG-SC01	33	7	238	48	129	144	337%	95%	-65%	67%	10%

	Site	August-September *E. Coli* geometric means (cfu/100 mL)						Percent Change				
		2001[A]	2002	2005	2009	2012	2015	2001-2015	2002-2015	2005-2015	2009-2015	2012-2015
Mainstem Stations	GC01	99	38	174	186	69	194	96%	80%	10%	4%	64%
	GC02	374	156	343	319	299	495	32%	69%	31%	36%	40%
	BG01/02[B]	310	122	386	308	246	453	46%	73%	15%	32%	46%
	BG10	80	53	141	165	278	263	229%	80%	46%	37%	-6%
	BG14	69	111	ND[C]	ND[C]	521	294	327%	62%			-77%
	BG18	20	4	11	37	42	70	251%	94%	84%	47%	40%
	LG02	133	184	278	219	257	222	67%	17%	-25%	1%	-16%
	LG08	220	326	302	235	285	427	94%	24%	29%	45%	33%
	LG13	44	73	122	186	132	238	441%	69%	49%	22%	45%
	LG22	7	7	7	18	20	36	417%	80%	79%	51%	45%
Tributary Stations	GC-SC01	2548	420	655	446	480	545	-79%	23%	-20%	18%	12%
	BG-PC01	ND[E]	ND[E]	ND[C]	ND[C]	147[D]	264					44%
	BG-RC01	65	129	326	216	526	223	243%	42%	-47%	3%	-136%
	LG-McC01	303	219	546	289	789	162	-46%	-35%	-237%	-79%	-386%
	LG-KC01	155	150	776	297	585	601	288%	75%	-29%	51%	3%
	LG-JC01	219	206	568	462	1686	584	166%	65%	3%	21%	-189%
	LG-SC01	237	179	228	161	148	382	61%	53%	40%	58%	61%

[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, and 2015 and values from BG02 in 2005 and 2009
[C] BG14 and Park Creek were not sampled in 2005 and 2009
[D] Geometric mean was calculated on 4 samples; sites were inaccessible or dry for one day or through a lab error
[E] Park Creek was dry in August of 2001 and 2002

Figure 6.8—2001-2015 *E. coli* Bacteria Geometric Mean Trends on Goose Creek Watershed Mainstem Stations

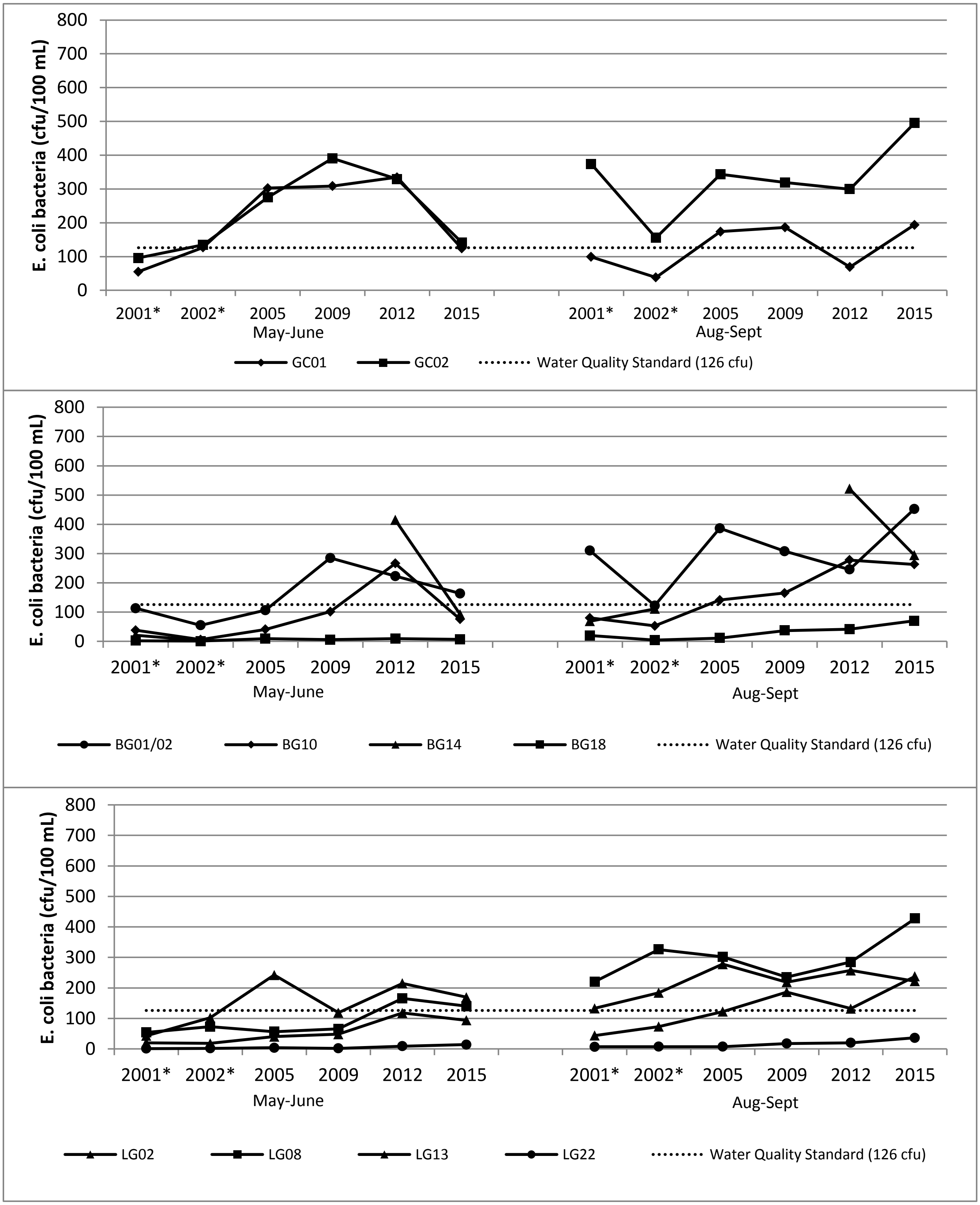
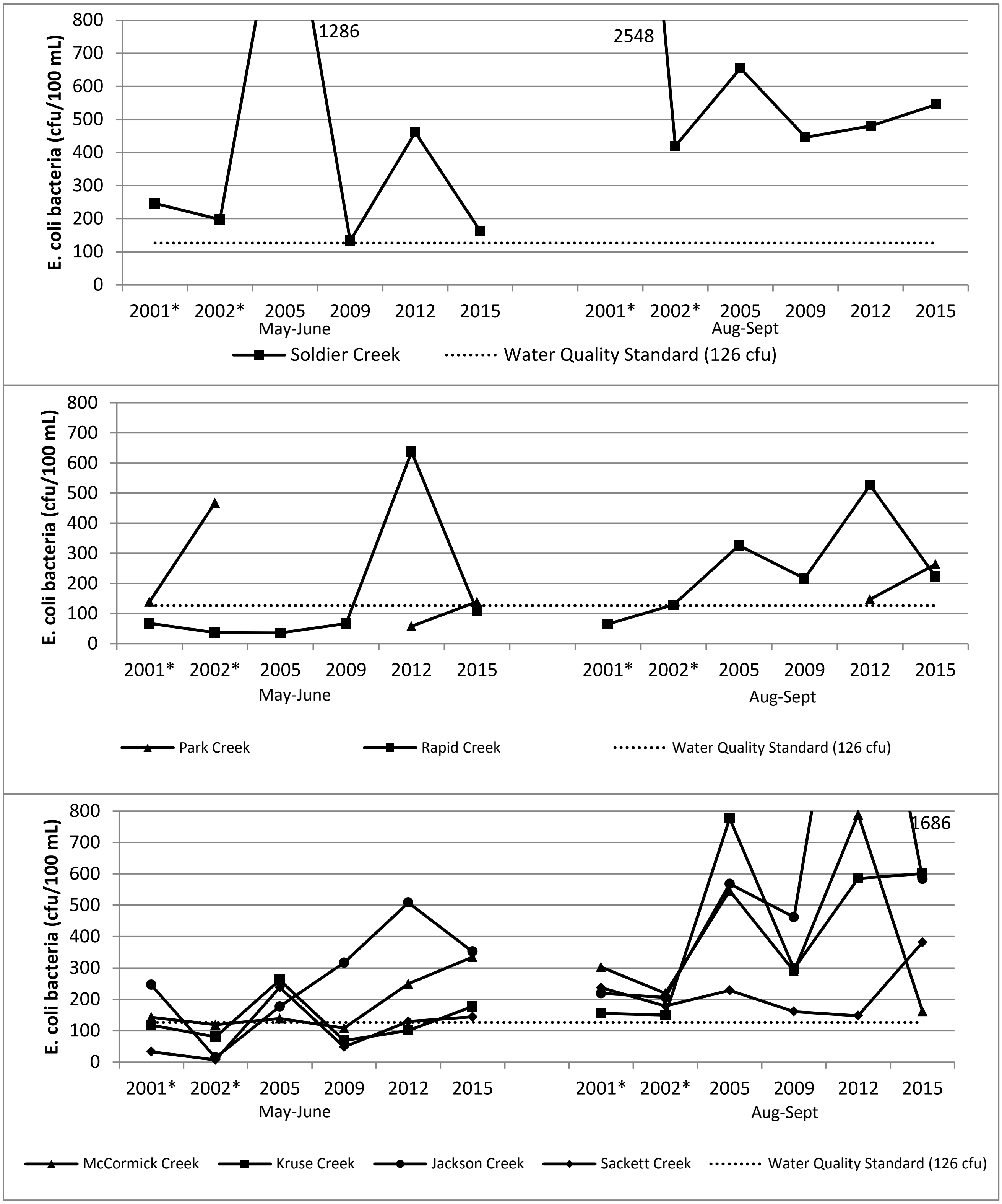


Figure 6.9—2001-2015 *E. coli* Bacteria Geometric Mean Trends on Goose Creek Watershed Tributaries



6.5 METEOROLOGICAL DATA AND SUPPORTING INFORMATION

Cumulative precipitation through October 2015 was 14.96 inches, which was 2.07 inches higher than normal precipitation for the same period (Table 6.13 and Appendix Figure C-11). This increase is primarily attributed to high precipitation in May and June 2015, which were 3.07 and 0.93 inches higher than normal, respectively. Monthly precipitation for other months in 2015 was lower than normal.

Mean daily air temperatures were above average for most of the summer of 2015, with average daily air temperatures being approximately 4-6 °F above normal in June, September, and October (Table 6.13 and Appendix Figure C-12). National Weather Service data at the Sheridan County Airport show normal mean daily air temperatures from April 1st through October average 57.2°F while 2015 mean daily air temperatures averaged of 59.3°F.

Table 6.13—2015 Precipitation and Air Temperature Data Collected by the National Weather Service from the Sheridan County Airport

	Precipitation (inches)				Average Daily Air Temperature (°F)	
	2015	Normal	2015 Cumulative	Normal Cumulative	2015	Normal
January-March			2.13	2.08		
April	1.43	1.60	3.56	3.68	44.4	43.7
May	5.42	2.35	8.98	6.03	50.4	52.5
June	3.05	2.12	12.03	8.15	66.2	61.5
July	0.84	1.18	12.87	9.33	69.1	70.2
August	0.60	0.72	13.47	10.05	69.5	69.0
September	0.27	1.43	13.74	11.48	64.2	58.0
October	1.22	1.41	14.96	12.89	51.4	45.5

6.6 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, 2013) were established to protect aquatic life and human health. Instead of using sampling results from individual chemical and physical water quality parameters, evaluation of benthic macroinvertebrate populations may serve as a direct measure for the attainment of the Aquatic Life beneficial use in addition to validating the effectiveness of individual numeric water quality chemical and physical standards. Benthic macroinvertebrates also serve to integrate water quality and habitat quality interaction, and evaluate potential synergistic effects from multiple chemical and physical water pollutants not measured during routine water quality monitoring.

Wyoming has developed biological criteria for streams statewide, but they have not been adopted as numeric, enforceable standards (Stribling et al., 2000; Jessup and Stribling, 2002; Hargett and ZumBerge, 2006; Hargett, 2011). As such, they may be used as narrative standards to determine beneficial use for aquatic life and the protection and propagation of fish and wildlife. The Biological Criteria in Section 32 of the Wyoming Water Quality Standards provide a narrative standard for protection of indigenous or intentionally introduced aquatic communities (i.e. brown, brook, and rainbow trout species). In addition, Section 4 in the Wyoming Water Quality Standards relates the presence of food sources (e.g. benthic macroinvertebrates) for game and non-game fish as a criterion for Surface Water Classes and (beneficial) uses (WDEQ, 2013).

6.6.1 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). No benthic macroinvertebrate samples were collected in the Goose Creek watershed during 2003, 2006, 2007 and 2008, 2010, 2011, and 2013.

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). With the exception of 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.

6.6.2 Benthic Macroinvertebrate Sampling in 2015

Macroinvertebrate sampling and habitat assessments were performed at six stations in October of 2015 (Appendix A- 1). Two benthic macroinvertebrate samples were collected from two Goose Creek stations (station GC1 and station GC2), three samples were collected from two Big Goose Creek stations (station BG2 and station BG10), and two samples were collected from two Little Goose Creek stations (station LG2A and station LG10). Included in the total number of samples was a duplicate sample collected at Big Goose Creek station BG10. 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 2015 was similar to the number of stations sampled and number of samples collected in 2005, 2009 and 2012. However, the overall reduced number of sample stations and samples collected during 2005, 2009, 2012 and 2015 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 and 2012 were the same as those used for sampling in 2015. In addition, WDEQ benthic macroinvertebrate sampling methods for samples collected in 2004 were identical to those used by SCCD resulting in comparable benthic macroinvertebrate data. Macroinvertebrate samples collected in 2015 were sorted by Aquatic Assessments, Inc. in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. in Corvallis, Oregon. Previous benthic macroinvertebrate samples collected by WDEQ in 2004 were analyzed by Rhithron Associates, Inc. in Missoula, MT.

6.6.3 Benthic Macroinvertebrate Taxa

Taxa lists for benthic macroinvertebrate samples collected in the Goose Creek watershed in 2015 are presented in Appendix Tables D-1 through D-7. The cumulative list of macroinvertebrate taxa identified from samples collected in the Goose Creek watershed from 2001 through 2015 is presented in Appendix Table D-8. The list of benthic macroinvertebrate metrics for samples collected in 1994, 1998, 2001, 2002, 2004, 2005, 2009 and 2012 for those stations sampled only during 2015 is presented in Appendix Tables D-9 through D-14.

A total of 237 benthic macroinvertebrate taxa have been identified since 2001 from a total of 82 samples collected during the project (Appendix Table D-8). Six new taxa were identified during 2015 including the water mite genera *Lebertia* and *Sperchon*, the Chironomidae genus *Limnophyes*, the worm species *Bothrioneurum vejdovskyanum* , the stonefly genus *Haploperla*, and the caddisfly taxon *Oecetis avara* group.

The identification of *Lebertia* and *Sperchon* is likely due to enhanced taxonomic resolution since water mites were previously identified only to subclass. Water mites are common in the Goose Creek watershed streams occurring in 88 percent of samples collected since 2001(Appendix Table D-8). The two water mite genera are common in other streams in Wyoming. *Limnophyes* was identified at Big Goose Creek station BG10 and Little Goose Creek station LG10. This genus is found in rivers, streams, springs, seeps, in moss on rock surfaces, stream margins and other semi-aquatic habitats, as well as in terrestrial habitats (Epler, 2001). *Limnophyes* exhibit a widespread distribution in North America (Ferrington et al. 2008). *Bothrioneurum vejdovskyanum* was identified only at Goose Creek stations GC1 and GC2. *B. vejdovskyanum* is a widespread species that is generally most abundant in large rivers in coarse sand substrates (Stimpson et al. 1985). Kathman and Brinkhurst (1998) reported that *B. vejdovskyanum* was widespread in sand substrates and Brinkhurst (1986) found the species was widespread, especially in sandy situations. The stonefly genus *Haploperla* was identified in the sample collected at Big Goose Creek station BG10 and the duplicate sample collected at BG10. *Haploperla* is distributed in western and eastern North America (Stewart and Stark 1988; Stewart and Stark 2008). Pescador et al. (2000) reported that *Haploperla* nymphs were typically collected in gravel/riffle habitats. The caddisfly *Oecetis avara* group was collected at all stations sampled in 2015. The taxonomic *Oecetis avara* group was recently formed due to the existence of species complexes. Approximately 19 *Oecetis* species are included in the *Oecetis avara* group (Blahnik and Holzenthal, 2014). Oecetis is common in the Goose Creek watershed and occurred in 68 percent of benthic macroinvertebrate samples collected since 2001 (Appendix Table D-8).

No threatened or endangered benthic macroinvertebrate taxa or fish species (incidentally captured during macroinvertebrate sampling) were identified. The widespread occurrence of the freshwater shrimp genera *Gammarus* and *Hyalella*, and the freshwater shrimp species group *Hyalella azteca* (commonly used in laboratory toxicity tests) in the 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. The presence of *Tubifex* in streams may be 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.

Turbellaria flatworms were most common in the Goose Creek watershed and occurred in 93% of the total samples collected (Appendix Table D-8). The riffle beetle genus *Microcylloepus*

(89%), Acari (water mites) (88%), the midge fly genera *Cricotopus* (88%) and *Rheotanytarsus* (80%), the mayfly genus *Tricorythodes* (84%), and the caddisfly genus *Hydropsyche* (83%) were common and occurred in over 80% of the total samples collected. No other taxa occurred in over 80% of the total benthic macroinvertebrate samples.

Chironomidae, Coleoptera and Ephemeroptera were present in 100 percent of samples collected in the Goose Creeks watershed since 2001. Oligochaeta (worms) were present in 78 percent of samples. The Diptera family Chironomidae (midges) had the greatest number of taxa in the project area (N = 57 taxa), followed by the order Ephemeroptera (N = 38 mayfly taxa), the order Trichoptera (N = 36 caddisfly taxa), the class Oligochaeta (N = 18 worm taxa), the order Plecoptera (N = 13 stonefly taxa), the Diptera family Tipulidae (N = 10 cranefly taxa) and the Coleopteran family Elmidae (N = 8 riffle beetle taxa) (Appendix Table D-8).

6.7 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 samples 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	$5^{th}/25^{th}$ or $95^{th}/75^{th}$ %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 during 2015 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 2015; 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 GC1	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 GC2	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 BG2	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	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
	2002	SCCD	41.1	Indeterminate
	2001	SCCD	61.7	Full

Table 6.17 (continued) —Biological condition score and rating for comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations sampled in 2015; based on the Wyoming Stream Integrity Index (WSII) for the High Valleys bioregion (from Hargett, 2011).

Sampling Station	Sampling Year	Sampling Group	Score	Rating
Little Goose Creek LG2A	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	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

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

6.7.1 Goose Creek Biological Condition

Biological condition at Goose Creek station GC1 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 GC1 as evidenced by the slightly negative trend line shown in Figure 6.10. Biological condition at the lower Goose Creek station GC1 was better than biological condition at the upper Goose Creek station GC2 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 GC2 was partial/non-supporting each year with the exception of 1998 and 2005 when biological condition was indeterminate (Table 6.17). The slight improvement in biological condition at GC2 noted from 2001 to 2005 was not observed in 2009, 2012 or 2015. Biological condition has declined since 1998 as evidenced by the negative trend line shown in Figure 6.10. Reduced biological condition at GC2 when compared to GC1 is probably related to the location of GC2 just downstream of the Sheridan Wastewater Treatment Facility (WWTF). Biological communities at GC2 are exposed to effluent discharged from the Sheridan WWTF as well as numerous upstream storm water discharges and urban land use effects. Station GC1 is located several stream miles downstream of GC2 and is not directly affected by Sheridan WWTF effluent, storm water discharges and urban land use effects. The predominant land uses upstream of station GC1 are irrigated pasture/hayland, livestock and wildlife grazing, and some rural residential development.

Figure 6.8 shows that since 2001 mean monthly *E. coli* concentrations were generally reduced from station GC2 to station GC1. The reduction in *E. coli* concentrations was most apparent during the August-September sampling period.

Continued sampling should be conducted at station GC1 and station GC2, and at all original Goose Creek stations, if possible, to determine if the changes observed in biological condition through 2015 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.

6.7.2 Big Goose Creek Biological Condition

Biological condition was partial/non-supporting at Big Goose Creek station BG2 during the most recent sampling event in 2015 (Table 6.17). Biological condition has varied at this station from full support in 1998 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. The trend in biological condition has declined since 1998 at station BG2 as evidenced by the negative trend line shown in Figure 6.10.

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. Biological condition increased in 2009, decreased to partial/non-supporting in 2012, and increased to Indeterminate support in 2015 (Figure 6.10).

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 two stations (BG2 and BG10) 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 BG2 and BG10, and at all original Big Goose Creek stations, if possible, to track changes in biological condition.

6.7.3 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 50 percent of samples collected and partial/non-supporting during 50 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 6.10. This is an important observation since no other station sampled in 2015 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 may be related to a pollution prevention structure installed at the storm drain that reduced the amount of pollutants entering Little Goose Creek. It was encouraging that Table 6-12 showed that *E. coli* concentrations have declined at station LG02 from 2005 to 2015 during both May-June and August-September sampling periods. 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.

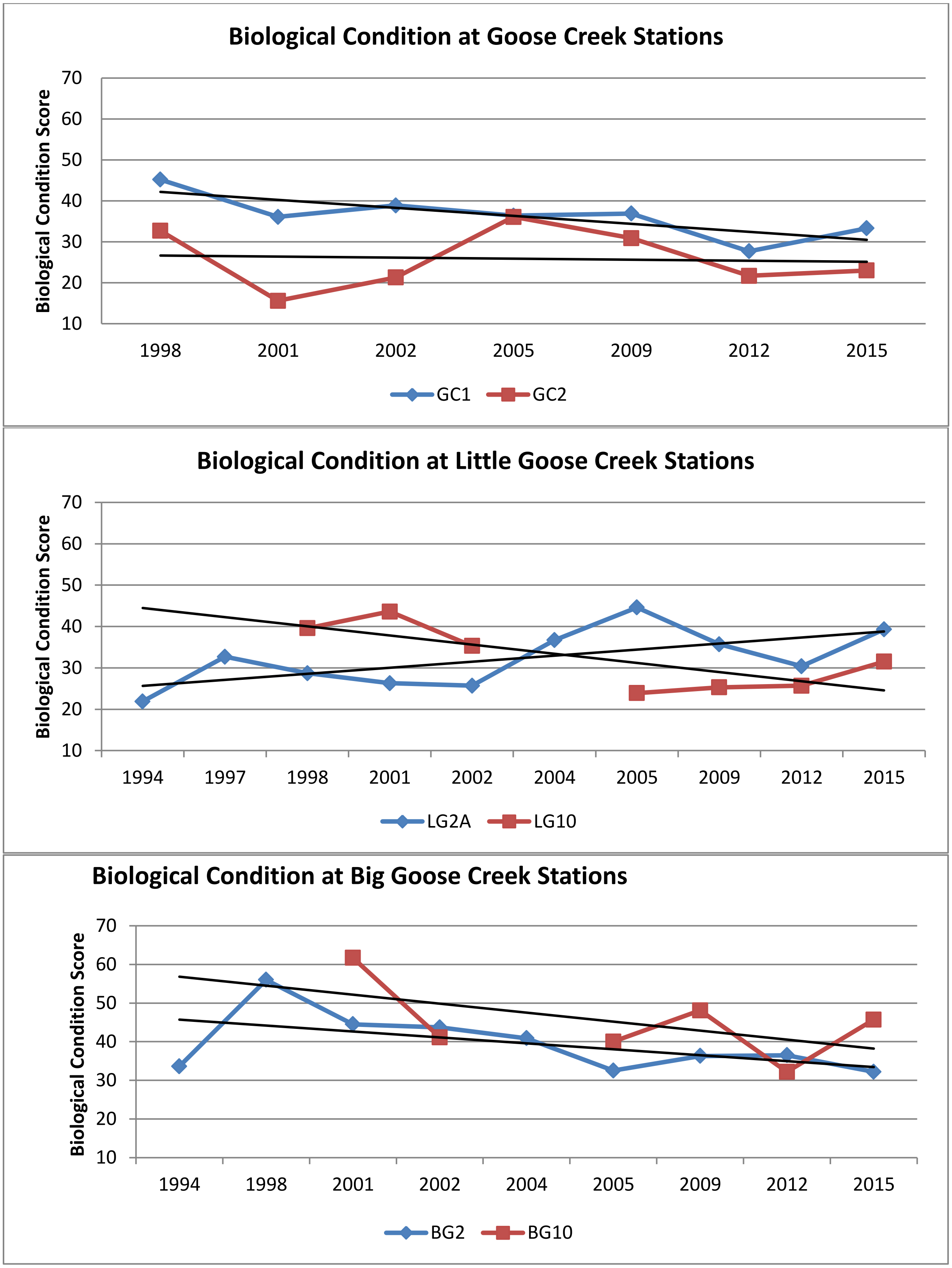
Biological condition at station LG10 was Indeterminate from 1998 to 2002, then decreased to partial/non-supporting from 2005 to 2015 (Table 6.17). Although biological condition decreased from the 1998-2002 period to the 2005-2015 period, biological condition gradually increased during each sampling event from 2005 to 2015 (Figure 6.10).

The reduction in biological condition at station LG10 was primarily due to a reduction in the number of EPT taxa, % EPT (less Arctopsychidae and Hydropsychidae), % Ephemeroptera (mayflies), and % scrapers. The reduction in these four metrics indicated the presence of more pollution tolerant organisms in the benthic macroinvertebrate community**.**

Change in the benthic macroinvertebrate communities through the entire length of Little Goose Creek within the project area could not be determined because only two stations (LG2A and LG10) were consistently 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 LG2A and LG10, and at all original Little Goose Creek stations, if possible, to track changes in biological condition. Planning and implementation of remedial measures to restore full aquatic life use support in Little Goose Creek should continue.

Figure 6.10— Biological condition trends at select stations in the Goose Creek Watershed. Note the solid black trendline shown for each station.



6.8 HABITAT ASSESSMENTS

6.8.1 PREVIOUS HABITAT ASSESSMENTS

The historic habitat 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). Data collected from a total of nine habitat assessments conducted by SCCD in 2012 from nine stations were presented in the *2012 Goose Creek Watershed Interim Monitoring Project* (SCCD, 2014). No habitat assessments were conducted in the Goose Creek watershed during 2003, 2006, 2007 and 2008.

During 2001 and 2002, a total of nineteen habitat assessments were conducted each year by SCCD from nineteen stations (SCCD, 2003). During 2005, SCCD conducted two habitat assessments at two Goose Creek stations (station GC1 and station GC2), two habitat assessments were conducted at two Big Goose Creek stations (station BG2 and station BG10), and two habitat assessments were conducted at two Little Goose Creek stations (station LG2A and station LG10). SCCD collected a total of six habitat assessments from six stations in the Goose Creek watershed in 2009. A total of nine habitat assessments were conducted by SCCD from eight stations in the Goose Creek watershed in 2012.The reduced number of stations assessed during 2005, 2009, 2012 (as well as during 2015) prevented a direct comparison of stream habitat at the ten other stations established on Goose Creek, Big Goose Creek, and Little Goose Creek since these stations were not assessed for habitat quality.

6.8.2 HABITAT ASSESSMENTS IN 2015

A total of six habitat assessments were conducted by SCCD in 2015 from six stations. Two habitat assessments were conducted from two Goose Creek stations (station GC1 and station GC2), two habitat assessments were conducted from two Big Goose Creek stations (station BG2 and station BG10) and two habitat assessments were conducted from two Little Goose Creek stations (station LG2A and station LG10).

The number of stations assessed by SCCD in 2015 was slightly lower than the number of stations assessed in 2005, 2009 and 2012. Big Goose Creek upstream reference station BG18 and Little Goose Creek upstream reference station LG22 were added to the 2012 sampling schedule. However, the reduced number of stations assessed during 2005, 2009, 2012 and 2015 when compared to the sampling regime in 2001 and 2002 precluded a complete evaluation of the habitat assessments between years, and the comparison of habitat assessment at each station in the Goose Creek watershed.

Field habitat assessment methods employed by SCCD in in 2001, 2002, 2005, 2009 and 2012 were the same as those used in 2015.

The habitat assessments 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 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. The change in habitat quality may affect the benthic macroinvertebrate community and biological condition.

6.8.3 Goose Creek Habitat Assessments

The total habitat score at station GC1 varied little between 2001 to 2012 ranging from a total score of 121.5 in 2001 to a total score of 131 in 2012 (Appendix Table E-1). The total habitat score increased to 158 in 2015. The increase in total habitat score during 2015 was primarily due to reduced silt covering and surrounding cobble and gravels (embeddedness), and enhanced instream cover. Stream substrate composition at station GC1 since 2001 was dominated by cobble, coarse gravel and fine gravel. 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. Silt deposits were minimal and accounted for about 2 percent of stream substrate since 2001. Sand accounted for about 11% of stream substrate since 2001 and has generally decreased since 2001 when sand comprised 27 percent of stream substrate. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) was variable at station GC1 since 2001.

There was no large change in habitat at Goose Creek station GC2 since 2001. The total habitat score varied little between 2001 to 2015 ranging from a total score of 99.5 in 2012 to a total score of 136 in 2015 (Appendix Table E-2). Stream substrate composition at station GC2 generally improved since 2001 with an increase in percent cobble 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. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) was variable since 2001.

6.8.4 Big Goose Creek Habitat Assessments

Habitat quality at Big Goose Creek station BG2 improved slightly from 2001 to 2012,then exhibited a decline in 2015 (Appendix Table E-3). The decline in habitat was due to an increase in percent fines, reduced instream cover and pool/riffle ratio, and increased width to depth ratio. The composition of stream substrate was similar at station BG2 from 2001-2002 to 2005 with the exception of a large increase in sand from 2002 (9 percent sand) to 2005 (22 percent sand). The percent sand subsequently dropped approximately 19 percent in 2009 to 3 percent, and then increased to 21.2 and 20.0 percent in 2012 and 2015, respectively. 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. The increase in the percent contribution of sand at station BG2 from 2002 to 2005, and from 2009 to the present indicated an unknown disruption within the watershed upstream of this station that contributed sand to the stream bed. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) has increased since 2009 further indicating an unknown disruption in the watershed.

The habitat quality at station BG10 declined from 2001 to 2005, then improved to 2009 and decreased slightly in 2012 with a further decline in 2015. The habitat quality score in 2015 was the lowest score at BG2 during the project. The low habitat quality score was due to an increase in the amount of fine silt covering cobble and gravel (embeddedness), reduced instream cover and pool/riffle ratio, and low stream flow in the stream channel (channel flow status). Stream substrate composition has been stable at station BG10 from 2001-2002 to 2009 and 2012. Cobble dominated the substrate and comprised from 75 percent of the substrate in 2001, 91 percent in 2002, 80 percent in 2005, 81 percent in 2009, 79 percent of substrate in 2012 and 73 percent in 2015 (Appendix Table E-4). Silt deposits are generally absent. Sand deposition was relatively low and ranged from 4 percent to 9 percent during the period of 2002 to 2012. Sand accounted for 16 percent of stream substrate during 2015 which represented the highest amount of sand observed since 2001.

6.8.5 Little Goose Creek Habitat Assessments

Habitat quality was relatively low at Little Goose Creek station LG2A from 1994 to 2012 (Appendix Table E-5). However, habitat quality greatly improved during the 2015 assessment. The improvement in habitat quality was primarily due a decrease in the amount of fine silt covering cobble and gravel (embeddedness), increased instream cover, velocity/depth and pool/riffle ratio. Since 1994, cobble has dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 18 percent of the stream substrate since 1994, which was considered relatively high.

There were no large changes in habitat at Little Goose Creek station LG10 from 2001 to 2015 (Appendix Table E-6). The mean total habitat assessment score since 2001 for LG10 was 138 compared to a mean total habitat assessment score of 104 at station LG2A. Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand averaged about 21 percent of the stream substrate since 2001, which was considered relatively high. Sand accounted for 46 percent of stream substrate during 2015 which represented an increase of over 64 percent from the previous high percentage of sand observed (28%) during 2005.

6.8.6 Relation Of Habitat Assessments To Biological Condition

Good stream habitat is critical for the establishment and maintenance of good fish, 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 temperature measurements were recorded above the maximum 20°C at the lower mainstem stations and on five tributaries during 2015. Continuous temperature loggers reported temperatures that exceeded 20°C at all but the uppermost canyon stations (BG18 and LG22). For the most part, pH and conductivity were within the expected ranges with two pH values above 9.0 SU in Little Goose Canyon and two tributary stations (Park Creek and McCormick Creek) with conductivity values above 1000 µS. With one exception, all sites met the minimum dissolved oxygen concentration for early and other life stages. Three mainstem stations and four tributary stations returned at least one dissolved oxygen measurement below the water column concentration recommended to achieve the intergravel concentration for early life stages. High discharge in early June corresponds 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. Tributary stations typically had higher turbidity than adjacent mainstem sites, except for Park Creek.

Bacteria concentrations were typically lower in May-June than in August-September; with the exception of McCormick Creek. Mainstem sties typically had lower bacteria concentrations than tributary sites. Most stations had at least one geometric mean that exceeded Wyoming Water Quality Standards in 2015, including six mainstem stations and six tributaries in May-June and eight mainstem stations and seven tributaries in August-September. The only stations that were below the standards for the entire season were BG18 and LG22.

A decrease in bacteria concentrations was observed from 2012-2015 at all but one of the mainstem stations in May-June. At the station in Little Goose Canyon (LG22) bacteria concentrations increased, but were still well within water quality standards. For August-September, however, bacteria concentrations increased at some stations. All but two of the tributary stations had higher bacteria concentrations in May-June 2015 than in 2012. During the late season, the percent change from 2012-2015 among tributary stations was less consistent, with four tributaries showing increases and three showing decreases. From 2001 to 2015, an increase in bacteria concentrations was observed at every comparable site and sampling period, except for Soldier Creek during the early season and Soldier Creek and McCormick Creek during the late season.

Benthic macroinvertebrate sampling was conducted at six stations in October of 2015. Biological condition at Goose Creek station GC1 was indeterminate for all years except for 2012 when it was partial/non-supporting. Biological condition has declined since 1998. However, biological condition at the lower Goose Creek station GC1 was better than biological condition at the upper Goose Creek station GC2. 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 partial/non-supporting at Big Goose Creek station BG2 during 2015. Biological condition varied at this station from full support in 1998 to partial/non-supporting in

2005 and 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.

The biological condition at Little Goose Creek station LG2A has been variable since sampling by WDEQ began in 1994. Since 1994, biological condition was Indeterminate during 50 percent of samples collected and partial/non-supporting during 50 percent of samples collected. The trend in biological condition has improved since 1994 at station LG2. This is an important observation since no other station sampled in 2015 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 2015. Although biological condition decreased from the 1998-2002 period to the 2005-2015 period, biological condition gradually increased during each sampling event from 2005 to 2015.

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, especially when comparing water quality data that has been collected during season 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. Bacteria concentrations, in particular, are known to vary in response to a number of different factors, including changes in water temperatures, water quantity, and suspended sediment loads.

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. The annual release of bacteria "stored" in bed sediments may cause a delay in observing quantifiable changes in bacteria currently entering the system. The data provided in the 2001-2002 assessment and subsequent monitoring years indicate the need for additional improvement projects as well as continued future monitoring to create and measure positive water quality changes.

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

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APPENDICES

APPENDIX A

GOOSE CREEK WATERSHED
2015 MAPS

APPENDIX B

GOOSE CREEK WATERSHED
2015 QUALITY ASSURANCE/QUALITY CONTROL
DOCUMENTATION

APPENDIX C

GOOSE CREEK WATERSHED
2015 WATER QUALITY DATA

APPENDIX D

GOOSE CREEK WATERSHED
2015 BENTHIC MACROINVERTEBRATE DATA

APPENDIX E

GOOSE CREEK WATERSHED
2015 HABITAT ASSESSMENT DATA

APPENDIX F

GOOSE CREEK WATERSHED
2015 PHOTOS