2012 Goose Creek Watershed Interim Monitoring Project

Final Report

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EXECUTIVE SUMMARY

In 2001-2002, SCCD conducted the Goose Creek Watershed Assessment (GCWA), in partnership with Sheridan County and the City of Sheridan. Interim monitoring was also conducted in 2005, 2009, and in 2012 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.

The GCWA was the foundation for the development of the Goose Creek Watershed Plan, which was approved in April 2005. In 2008, the Wyoming Department of Environmental Quality contracted with SWCA to develop a Total Maximum Daily Load (TMDL) for stream segments within the Goose Creek Watershed. Recommendations from the TMDL, which was completed in 2010, were incorporated into the Sampling Analysis Plan for the 2012 monitoring.

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. Interim monitoring evaluates trends in bacteria and sediment, along with benthic macroinvertebrates and habitat assessments at a limited number of stations. The water quality parameters include: water temperature, pH, specific conductivity, dissolved oxygen, discharge, turbidity, and *E. coli.*

In total, SCCD collected water quality samples from 24 stations in the Goose Creek Watershed during 2012. SCCD selected 16 locations used in 2001-2002, 2005, and 2009, six stations sampled only in 2001-2002, and two new sites. These adjustments were made based on recommendations from the Goose Creek Watershed TMDL, to make distances between sampling stations more consistent, and to address difficulties with accessibility. All sampling stations were described in the 2012 SAP; with the exception of GC1A and BG3A, all of the sites chosen for this project were previously used in the 2001 – 2002 assessment. Additionally, SCCD conducted macroinvertebrate sampling and habitat assessments at five of the water quality sample stations and at three other sites.

Of the 24 water sampling stations, there were four sites on Goose Creek, six on Big Goose Creek, six on Little Goose Creek, and one each on Soldier Creek, Beaver Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek. Ten sites were within the Little Goose Creek subwatershed; 9 sites were within the Big Goose Creek subwatershed; and the remaining 5 sites were in the Goose Creek subwatershed (Appendix A, map 1). Sampling sites were within and outside of the impaired segments of Big Goose, Little Goose, and Goose Creeks, and on every impaired tributary within the watershed.

Water quality monitoring during the 2012 monitoring season included the following parameters: water temperature, pH, specific conductivity, dissolved oxygen, discharge, turbidity, and *Escherichia coli* (*E. coli)*. Water quality monitoring included sampling to determine the geometric means of *E. coli* and turbidity, based on 5 samples collected within two 30 day periods in May and July - August. Continuous water temperature data loggers were used to monitor instream temperatures at 15 minute intervals from May 1, 2012 to October 31, 2012 at nine of the 24 stations. Macroinvertebrate sampling and habitat assessments were performed at eight stations in September (Appendix A, map 1).

For the most part, pH, specific conductivity, and dissolved oxygen were within the expected ranges during 2012. Turbidity values were considered normal for the watershed with occasional high values occurring during late-spring, early-summer precipitation and run-off events. In 2012, pH ranged from 7.43 SU to 9.17 SU and appears to be increasing since 2001. There were six samples collected from five stations that exceeded that standard of 9.0 SUs for pH. In general, the geometric mean for specific conductivity at mainstem stations in 2012 increased from upstream to downstream in Little Goose, Big Goose, and Goose Creek. Dissolved oxygen (DO) values were fairly consistent among sites throughout the watershed, with most falling within the approximate range of 6.30 to 11.00 mg/L. There were only two sites that fell below the early life stages standard of 5.0 mg/L. There were 10 stations on Goose Creek (all 4), Big Goose (lower 4), and Little Goose Creek (2) that had values below the 8.0 mg/L water column standard. All tributary stations, except Beaver Creek, had one or more samples below 8.0 mg/L. Goose Creek stations decrease from 2001 to 2012 in both May and August on Goose Creek stations; but either increased or remained consistent on Big Goose, Little Goose stations, and tributary stations. Turbidity geometric means for mainstem stations in 2012 were typically higher than in 2001. For tributary stations, turbidity geometric means do not show a direct increasing trend between 2001 geometric mean values.

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard on several occasions in July and August. Similarly, continuous temperature loggers reported water temperatures above the maximum instream temperature standard of 20°C, often for multiple days, except for station BG18. Maximum water temperatures were higher in 2012 than in 2009 and 2005 at all stations; some stations were lower than in 2001 and 2002.

In 2012, geometric mean bacteria concentrations at mainstem sites were typically lower than tributary sites, with no exceedances of the geometric mean standard in the canyons. For mainstem sites, the geometric means of *E. coli* bacteria ranged from 9 to 415 cfu/100mL in May and 20 to 521 cfu/100mL in August. For tributary stations, the geometric means of *E. coli* bacteria ranged from 58 to 999 cfu/100mL in May and 148 to 1686 cfu/100mL in August. An increase in bacteria concentrations from May 2001 to May 2012 was observed at every comparable site and sampling period, except for BG13 (Park Creek), and LG11 (Kruse Creek).

Although several local improvement projects have been completed to benefit water quality, many factors can affect bacteria concentrations, which make trend comparisons difficult. Changes in water temperature, water quantity, and suspended sediment loads can have an impact on bacteria concentrations. Air temperature was significantly higher than normal in 2012, and precipitation was significantly lower, which may have contributed to the increase in bacteria concentrations. Higher increased percentage of *E. coli* bacteria concentration in May could be associated to precipitation events in the spring, including run-off from snowmelt, that contribute many surface contaminants - not only bacteria - into the local waterways.

Biological condition at Goose Creek stations GC1 and GC2, Big Goose Creek stations BG2 and BG 10 and Little Goose Creek stations LG2A and LG10 sampled in 2012 were partial/non-supporting based on the evaluation of the stream benthic macroinvertebrate communities. Biological condition at the Big Goose Creek most upstream reference station (BG18) was fully supporting while biological condition at the Little Goose Creek most upstream reference station (LG22) was indeterminate supporting. The partial/non-support and indeterminate support classifications 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.

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

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CHAPTER 1 PROJECT BACKGROUND AND WATERSHED IMPLEMENTATION PLAN

1.1 BRIEF PROJECT BACKGROUND

In 2001-2002, the Sheridan County Conservation District (SCCD) conducted the Goose Creek Watershed Assessment (GCWA), in partnership with Sheridan County and the City of Sheridan. Interim monitoring was also conducted in 2005, 2009, and in 2012 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.

The GCWA was the foundation for the development of the Goose Creek Watershed Management Plan, which was approved in April 2005. In 2008, the Wyoming Department of Environmental Quality (WDEQ) contracted with SWCA to develop a Total Maximum Daily Load (TMDL) for stream segments within the Goose Creek Watershed. Recommendations from the TMDL, which was completed in 2010, were incorporated into the Sampling Analysis Plan (SAP) for the 2012 monitoring.

The 2012 interim monitoring consisted of 24 water quality sampling stations. Six stations from the 2001-2002 Assessment were incorporated back into the monitoring schedule, and two 2005 and 2009 interim monitoring sites were eliminated. Two new sites were added to make distances between stations more consistent. Except for the two new sites, all of the 2012 sites and monitoring parameters chosen for this project were previously used in the 2001 – 2002 Assessment and described in the 2012 SAP (Appendix A, map 1). All monitoring methods, standard operating procedures, and data validation protocols used for this project were described in the 2012 Goose Creek SAP, and the 2010 Quality Assurance Project Plan (QAPP), previously approved by WDEQ.

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. Interim monitoring evaluates trends in bacteria and sediment, along with benthic macroinvertebrates and habitat assessments at a limited number of stations. The water quality parameters include: water temperature, pH, specific conductivity, dissolved oxygen, discharge, turbidity, and *E. coli*.

1.2 DESCRIPTION OF PROJECT AREA

The Goose Creek Watershed is identified by hydrologic unit code (HUC) 10090100-010 and is located in north-central Wyoming and originates in the Big Horn Mountains west of Sheridan, Wyoming. It encompasses 267,520 acres (418 square miles) within Sheridan County including the communities of Sheridan and Big Horn, several rural subdivisions, numerous ranches, and a portion of the Bighorn National Forest (BNF). Ownership within this watershed consists of: 115,000 acres (43%) of BNF lands which is managed for recreation, seasonal cattle grazing, logging, and wildlife; 136,700 acres (50%) of privately owned lands where a majority are small and large ranch operations; and the remaining 15,820 acres (7%) of State, City, County or other

Federal lands (Appendix A, Map 3) (SWCA, 2010). Ranching operations within the Goose Creek Watershed contain irrigated hay and crop lands, as well as pastureland for cattle grazing and corrals for feeding (Appendix A, Map 4)(SWCA, 2010). Big game, waterfowl, and other wildlife habitats 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. In previous years, although not at present, the northern area of the watershed was also subject to coal-bed methane production. Subdivisions, converted from rural areas that are occasionally prime farmlands, are becoming more common along Big and Little Goose Creek, especially in areas closer to the City of Sheridan.

After leaving the Big Horn Mountains, the predominant geology along the stream channels is alluvium and colluvium comprised of clay, silt, sand, and gravel (USGS, 1985). Soils along these drainages 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 (NRCS, 1986).

The two largest tributaries within the Goose Creek Watershed are Big and Little Goose Creeks that originate in the Big Horn Mountains west of Sheridan, Wyoming and pass through the BNF, several ranches, rural subdivisions, and through the community of Big Horn and the City of Sheridan. Near the center of Sheridan, Big and Little Goose Creek join to form Goose Creek. North and immediately downstream of the Sheridan city limit, Soldier Creek converges with Goose Creek and becomes the third largest tributary in the Goose Creek Watershed. Near Acme, Wyoming, Goose Creek flows into the Tongue River. Major tributaries to Little Goose Creek include Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek. Major tributaries to Big Goose Creek include Rapid Creek, Park Creek, and Beaver Creek. All of these streams are classified Class 2AB – Coldwater Fisheries and are closely tied to local agriculture, recreational uses, and drinking water supplies (Appendix A, Map 2) (WDEQ, 2001).

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 Emerson, South, and Washington Parks, and Goose Creek passes through Mill, Thorne-Rider and North Park. Since early 2000, an extensive cement bike path follows these waterways within the city limits and adjacent areas. 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 (Appendix A, Map 6). 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 historical coal mine reclamation.

1.3 PREVIOUS SAMPLING ASSESSMENTS

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 evaluate water quality concerns in the Goose Creek Watershed. During 2000, the Goose Creek Drainage Advisory Group (GCDAG) – including representatives from SCCD, Sheridan County, and the City of Sheridan, in consultation with WDEQ – laid plans for conducting the 2001-2002 GCWA. The design included collecting credible chemical, physical, biological, bacteriological, and habitat information on Goose Creek, Big Goose Creek, Little Goose Creek, and on eight tributaries within the watershed. By collecting credible data, GCDAG hoped to evaluate attainment of designated uses applicable to each waterbody and define temporal (seasonal) and spatial (among sample stations) changes in water quality to identify impaired segments. Completion of the GCWA provided the technical basis for the watershed planning and mitigation efforts.

In April 2001, SCCD initiated the monitoring program, which 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 samples were collected and habitat assessments were conducted at 19 sites on Goose Creek, Big Goose Creek, and Little Goose Creek during September. Monitoring year 2001 concluded in October. Monitoring in 2002 was similar to the previous year's monitoring with a few exceptions. 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*. 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.

The second round of interim monitoring for SCCD was scheduled for 2008. Difficulties with funding and staffing resources delayed the 2008 monitoring until 2009. Water quality monitoring during 2009 included the same parameters at the same 18 stations used in 2005, except for fecal coliform. Fecal coliform was replaced with *E. coli* bacteria sampling due to a WDEQ change in 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 during 2009. Macroinvertebrate sampling and habitat assessments were also performed at six stations.

The general trend in bacteria concentrations on Goose Creek appeared to increase upward from 2001 to 2009. Drought conditions in 2001-2002 may have contributed to the lower concentrations in those years. Wetter conditions in 2005 and 2009 may have contributed to increased bacteria concentrations due to additional run-off with overland flow and resuspension of instream sediments. The extremes of short and long-term weather conditions have produced bacteria data that are not directly comparable due to differing hydrologic effects. Nonetheless, values that exceed bacteria standards were observed on essentially the same stream reaches and indicate water quality impairments continue to exist, regardless of hydrologic conditions.

Biological condition at Goose Creek, Big Goose Creek and Little Goose Creek stations sampled in 2009 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.

1.4 WATERSHED PLAN 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 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 accomplished 31 improvement projects including twelve livestock facilities, thirteen septic systems, three stream channel stabilization segments, and one irrigation diversion within the watershed (Appendix A, Map 10). A 27-acre riparian buffer project has also been implemented on Jackson Creek. During the summer of 2004, the City of Sheridan implemented a storm drain stenciling program to educate local residents about dumping materials into City storm drains. 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. While the watershed plan addresses a broad set of water resource issues/needs, the TMDL was needed to provide a more quantitative, focused approach to address bacteria and sediment in the Goose Creek Watershed, which exceeded regulatory water quality standards. WDEQ contracted with SWCA to complete the Goose Creek TMDLs; SCCD provided some local information and assistance in SWCA's efforts. In September of 2010, the Goose Creek TMDL was completed. Under contract with WDEQ, SWCA analyzed existing data from eleven impaired waters within the Goose Creek Watershed and confirmed that all eleven exceeded the Wyoming water quality standards for fecal coliform bacteria, and more recently for *Escherichia coli (E. coli*). Goose Creek and Little Goose Creek are also impaired due to excessive sediment loads and poor habitat, which affect aquatic life and the cold-water fishery (SWCA, 2010). SWCA recommended *E. coli* load reductions that ranged from a low of 17% for Rapid Creek to a high of 84% for Jackson Creek (SWCA, 2010). The recommendations from the 2010 Goose Creek TMDL were used to modify Goose Creek sampling sites for the 2012 interim monitoring project.

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

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CHAPTER 2 STREAM CLASSIFICATIONS AND BENEFICIAL USES

2.1 BENEFICIAL USES AND STREAM CLASSIFICATIONS

As provided in the June 21, 2001 Wyoming Surface Water Classification List (WDEQ, 2001), the stream classifications for the Goose Creek Watershed are provided in Table 2.1 and included in Appendix A, Map 2. Not all streams in Wyoming are classified in the 2001 Wyoming Surface Water Classification List; however, all streams that were impaired and placed on the 2010 Wyoming Watershed Assessment and Impaired Waters List were assigned a classification (WDEQ, 2010). This 2010 classification was used for the purpose of the 2012 monitoring season. Beaver Creek was classified in the 2001 Wyoming Surface Water Classification List as a 3B but listed as a 2AB in the 2010 Wyoming Watershed Assessment and Impaired Waters List; a Class 2AB Surface Water classification was used for interpretation of 2012 data.

Table 2.1 Goose Creek Watershed Stream Classifications and Beneficial Uses

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

Class 2AB waters are

> those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. . .Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses (WDEQ, 2007).

In 2001, Class 2AB waters were protected for "primary contact recreation," although primary contact recreation was not specifically defined. In 2007, a definition was added for primary contact recreation. The difference between primary and secondary contact recreation is related to the potential of the activity to result in "ingestion of the water or immersion" (WDEQ, 2007). In neither case does the protection address the quantity of water; rather it ensures that the quality of the water is "safe for human contact" (WDEQ, 2007).

WDEQ is charged with implementing the policies of the Clean Water Act while also providing for the "highest possible water quality" (WDEQ, 2007). Depending upon its classification, a waterbody is expected to be suitable for certain uses (Table 2.2).

Table 2.2 Surface Water Classes and Use Designations (WDEQ, 2007)

Class	Drinking Water[2]	Game Fish[3]	Non-Game Fish[3]	Fish Consumption[4]	Other Aquatic Life[5]	Recreation[6]	Wildlife[7]	Agriculture[8]	Industry[9]	Scenic Value[10]
1[1]	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2D	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

[1] Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the National Parks and Wilderness areas are Class 1, however, all do not support fisheries or other aquatic life uses (e.g. hot springs, ephemeral waters, wet meadows, etc.).

[2]The drinking water use involves maintaining a level of water quality that is suitable for potable water or intended to be suitable after receiving conventional drinking water treatment.

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

[4]The fish consumption use involves maintaining a level of water quality that will prevent any unpalatable flavor and/or accumulation of harmful substances in fish tissue.

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

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

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

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

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

[10]Scenic value involves the aesthetics of the aquatic systems themselves (odor, color, taste, settleable solids, floating solids, suspended solids, and solid waste) and is not necessarily related to general landscape appearance.

2.2 STREAM LISTINGS

States are required to summarize water quality conditions in the state through section 305(b) of the CWA; this report is commonly known as the 305(b) report. Section 303(d) of the CWA requires states to identify waters that are not supporting their designated uses, and/or need to have a TMDL established to support their uses. A TMDL describes the amount of a given pollutant a waterbody can receive and still meet water quality standards. WDEQ is required to develop TMDLs on waterbodies that do not meet water quality standards. While WDEQ supports and encourages local watershed planning and improvement efforts, they must also meet federal requirements for the development of TMDLs.

Wyoming's 305(b) report and 303(d) list is published every two years. The documents undergo a public comment period prior to being finalized. Chapter 1 of the Wyoming Water Quality Rules and Regulations (WDEQ, 2007) describes the surface water classes and uses that each class is expected to support. In addition, Chapter 1 outlines the water quality standards that must be achieved for a Wyoming waterbody to support its designated uses (WDEQ, 2007). 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 Creek were first placed on the list of impaired waters in 1996 for various parameters, including pathogens (Little Goose) and silt among other things. 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.

In the Wyoming 2012 Integrated Report, (WDEQ, 2012), the WDEQ assigns assessed surface waters into one of five designated use categories:

- Category 1, which support all of their designated uses with no water quality threats or impairments (currently no known category 1 streams in Wyoming);
- Category 2, which support some designated uses, but the status of other uses is unknown;
- Category 3, which have insufficient data to determine use support;
- Category 4, which are impaired or threatened but have a TMDL, other pollution control measures, or something other than a pollutant (such as flow alterations) are determined to be the cause of impairment; and
- Category 5 (the 303(d) list), which are waters where one or more uses are impaired or threatened and require a TMDL.

Impaired waterbodies are first included on the Wyoming 303(d) list of Waters Requiring TMDLs (WDEQ, 2012) under Category 5. 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 2012 Integrated Report (WDEQ, 2012) (Table 2.3 and Appendix A, Map 5).

Table 2.3 Impaired stream segments in the Goose Creek Watershed (Category 4) from WDEQ, 2012

Name	Class	Location	Miles	Uses	Use Support	Causes	Sources	Listing Date of Impairment	De-listing Date
Goose Creek (tributary to Tongue River)	2AB	From the confluence with Little Goose Creek downstream to the confluence with the Tongue River	12.7	Recreation	Not Supporting	Fecal Coliform	Unknown	2000	2012
Goose Creek (tributary to Tongue River)	2AB	From the confluence with Little Goose Creek downstream to the confluence with the Tongue River	12.7	Aquatic life, cold-water fish	Not supporting	Habitat Alterations, Sediment	Stormwater	2006	2012
Soldier Creek (tributary to Goose Creek)	2AB	From the confluence with Goose Creek to a point 3.1 miles upstream	3.1	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Soldier Creek (tributary to Goose Creek)	2AB	From 3.1 miles upstream from the confluence with Goose Creek to a point 17.1 miles upstream	17.0	Aquatic life, cold-water fish	Not supporting	Flow Alterations	Unknown	2012	2012
Big Goose Creek (tributary to Goose Creek)	2AB	From the confluence with Little Goose Creek upstream to the confluence with Rapid Creek	19.2	Recreation	Not supporting	Fecal Coliform	Grazing	1996	2012
Beaver Creek (tributary to Big Goose Creek)	2AB	From the confluence with Big Goose Creek to the confluence with Apple Run	6.5	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Park Creek (tributary to Big Goose Creek)	2AB	From the confluence of Big Goose Creek to a point 2.8 miles upstream	2.8	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Rapid Creek (tributary to Big Goose Creek)	2AB	From the confluence with Big Goose Creek to a point 3.2 miles upstream	3.2	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Little Goose Creek (tributary to Goose Creek)	2AB	From the confluence of Big Goose upstream to Brundage Lane in the City of Sheridan	3.5	Recreation	Not supporting	Fecal Coliform	Unknown	1996	2012
Little Goose Creek (tributary to Goose Creek)	2AB	From the confluence of Big Goose upstream to Brundage Lane in the City of Sheridan	3.5	Aquatic life, cold-water fish	Not supporting	Habitat Alterations, Sediment	Stormwater	2006	2012
McCormick Creek (tributary to Little Goose Creek)	2AB	From the confluence with Little Goose Creek to a point 2.2 miles upstream	2.2	Recreation	Not supporting	Fecal Coliform	Unknown	2004	2012
Kruse Creek (tributary to Little Goose Creek)	2AB	From the confluence with Little Goose Creek upstream to the confluence with East Fork Kruse Creek	2.5	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Jackson Creek (tributary to Little Goose Creek)	2AB	From the confluence with Little Goose Creek to a point 6.4 miles upstream	6.4	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012
Sackett Creek (tributary to Little Goose Creek)	2AB	From the confluence with Little Goose Creek to the confluence with East Fork Sackett Creek	3.1	Recreation	Not supporting	Fecal Coliform	Unknown	2000	2012

CHAPTER 3 HISTORICAL AND CURRENT GOVERNMENT 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.

Table 3.1 highlights the historic hydrologic and water quality sites in the Goose Creek Watershed, type of data collected, and when it was discontinued. WDEQ has not conducted any field/lab water quality samples, habitat assessments, or flow measurements in the Goose Creek Watershed since the last Interim Monitoring Report of 2009. All 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), which only collects field/lab water-quality samples. A summary of water quality data was provided in the 2001-2002 Final Report, 2005 Interim Report, and the 2009 Interim Report for Goose Creek, when available.

For a summary of water quality data collected from USGS Station 06305500 from October 22, 2009 to October 25, 2012, refer to Appendix B, Table B.27.

Table 3.1 Status of USGS Hydrologic Stations Located in the Goose Creek Watershed

Site Number	Site Name/Location	Daily Data/Statistics Start - End Date	Instantaneous Data Archive Start - End Date	Field Measurements Start - End Date	Field/Lab Water-Quality Samples Start - End Date
06301850	Big Goose Creek Above PK Ditch, in canyon, near Sheridan, WY	04/01/2001-09/30/2002	04/01/2001-09/30/2002	04/26/1996-10/04/2002	N/A
06302000	Big Goose Creek near Sheridan, WY	04/01/1930-09/30/2000	06/16/1963-09/30/2000	10/05/1993-10/04/2000	05/21/1987-02/18/1999
06302200	Big Goose Creek above Park Creek, near Sheridan, WY	06/19/1999-06/18/2001	06/20/1999-06/18/2001	05/17/1999-03/28/2001	05/17/1999-08/03/2000
06302500	Goose Creek at Sheridan, WY	06/01/1911-09/30/1916	N/A	N/A	N/A
06303500	Little Goose Creek in canyon near Big Horn, WY	04/01/1941-09/30/2008	06/15/1963-09/29/2007	10/07/1996-10/01/2008	N/A
06303700	Little Goose Creek above Davis Creek, Big Horn, WY	06/20/1999-06/26/2001	06/21/1999-06/26/2001	06/17/1999-03/28/2001	06/27/2000-06/27/2000
06304000	Little Goose Creek near Big Horn, WY	05/01/1919-11/30/1921	N/A	N/A	N/A
06305500	Goose Creek below Sheridan, WY	10/01/1941-09/30/1984	N/A	09/19/1983-08/03/2000	08/05/1959-10/25/2012
06305700	Goose Creek near Acme, WY	05/01/1984-10/05/2007	10/01/1990-09/30/2007	05/02/1984-10/05/2007	10/26/1983-08/04/2008

CHAPTER 4 MONITORING DESIGN

4.1 MONITORING PARAMETERS

Water quality monitoring during 2012 included the following parameters: water temperature, pH, specific conductivity, dissolved oxygen, discharge, turbidity, and *E. coli*. Water quality monitoring was performed at 24 stations. Continuous water temperature data loggers were used to monitor temperature at 15 minute intervals from May 1, 2012 to October 31, 2012 at nine of the 24 stations. Macroinvertebrate sampling and habitat assessments were also performed at eight stations (Appendix A, Map 1).

4.2 SITE DESCRIPTIONS

Sites were selected based on a review of the historical data, previous SCCD and/or WDEQ sampling sites, availability, access, and the recommended adjustments from the Goose Creek TMDL. 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.

In 2012, SCCD selected 16 of the 18 locations used in 2009 and 2005. The TMDL recommendations were applied to add six 2001-2002 Goose Creek sampling sites back into the 2012 interim monitoring project. Two new sites (GC1A and BG3A) were added to make distances between stations more consistent. All sampling stations were described in the 2012 SAP; with the exception of GC1A and BG3A, all of the sites chosen for this project were previously used in the 2001 – 2002 assessment. Of the 24 water sampling stations, there were four sites on Goose Creek, six on Big Goose Creek, six on Little Goose Creek, and one each on Soldier Creek, Beaver Creek, Park Creek, Rapid Creek, McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek. Ten sites were within the Little Goose Creek subwatershed; 9 sites were within the Big Goose Creek subwatershed; and the remaining 5 sites were in the Goose Creek subwatershed (Appendix A, map 1). Sampling sites were within and outside of the impaired segments of Big Goose, Little Goose, and Goose Creeks, and on every impaired tributary within the watershed.

During the initial site reconnaissance and site set-up SCCD identified land uses and other site characteristics (Table 4.1). Latitude and longitude for each site were recorded by Global Positioning System (GPS). Site elevations were predetermined based on 7.5 minute topography maps. Each sampling site was equipped with a staff gauge for flow measurements. During site reconnaissance, these gauges were inspected, surveyed, and replaced if needed; gauges were installed at new sites in 2012. Upon installation and/or inspection, gauges were surveyed and compared with a permanent bench mark; this confirmed the stability of the gauge to ensure consistent measurement. Staff gauge measurements could then be used to develop stage-discharge relationships. A few staff gauges were re-installed due to initial May low-water levels, and re-calibrated using the corresponding benchmark as a reference.

Table 4.1 Site Information and Land Use

Site	UTM Zone 13	Latitude Longitude	Elevation (feet)	Land Use(s)
GC1	0343021E, 4971863N	44°52.974'N 106°59.262'W	3,660	Mainly cattle grazing and irrigated haylands downstream to Sheridan. A few residences along Goose Creek. Railroad and HWY 338 parallel east side of Goose Creek; HWY 339 Bridge is approximately 75 yards upstream.
GC1M	0343043E, 4971598N	44°52.974'N 106°59.244'W	3,660	Only a macroinvertebrate location. Same use as GC1.
GC1A	0344920E, 4968021N	44°50.924'N 106°57.749'W	3,685	Off of a recently divided subdivision. Mainly cattle grazing and irrigated haylands downstream to Sheridan.
GC2	0344758E, 4965129N	44°49.368'N 106°57.819'W	3,700	A concrete plant is located south of creek with settling ponds north of creek. Sheridan WWTP is upstream.
GC2M	0344849E, 4965141N	44°49.369'N 106°57.750'W	3,700	Only a macroinvertebrate location. Same use as GC2.
GC4	0344842E, 4964802N	44°49.186'N 106°57.749'W	3,705	Rural/urban subdivision (Downer Addition) is the main land use in lower Soldier Creek watershed.
GC5	0344984E, 4964299N	44°48.916'N 106°57.632'W	3,708	Predominantly urban / residential.
BG1	0344886E, 4962931N	44°48.176'N 106°57.681'W	3,735	Predominantly urban / residential.
BG2M	0344138E, 4962221N	44°47.783'N 106°58.235'W	3,745	Predominantly urban / residential.
BG3A	0342290E, 4961261N	44°47.241'N 106°59.619'W	3,800	Predominantly urban / residential.
BG6	0338147E, 4959776N	44°46.384'N 107°02.731'W	3,890	Recreational (youth camp), wildlife habitat, cattle grazing, and irrigated hayland.
BG9	0335841E, 4958351N	44°45.583'N 107°04.451'W	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated hayland.
BG10	0335790E, 4958405N	44°45.611'N 107°04.490'W	3,955	Rural residential, wildlife habitat, cattle grazing, and irrigated hayland.
BG13	0331392E, 4957019N	44°44.802'N 107°07.795'W	4060	Rural residential, wildlife habitat, cattle grazing, and irrigated hayland.
BG14	0331315E, 4956620N	44°44.585'N 107°07.845'W	4060	Rural residential, wildlife habitat, cattle grazing, and irrigated hayland.
BG16	0330489E, 4954616N	44°43.492'N 107°08.431'W	4,160	Cattle grazing, irrigated hayland, and wildlife habitat.
BG18	0327127E, 4952184N	44°42.131'N 107°10.927'W	4,505	Primarily wildlife habitat. Infrequent cattle grazing. The BNF boundary is about 1 mile upstream from site.
LG2	0345586E, 4962760N	44°48.093'N 106°57.147'W	3,725	Urban – mostly business with some light industrial and residential areas. Railroad tracks adjacent to east bank.
LG2A M	0346413E, 4961063N	44°47.188'N 106°56.490'W	3,750	Only a macroinvertebrate location. Predominantly urban / residential.

Table 4.1 (continued) Site Information and Land Use

Site	UTM Zone 13	Latitude Longitude	Elevation (feet)	Land Use(s)
LG6	0345192E, 4956823N	44°44.883'N 106°57.338'W	3,820	Small acreage properties in a rural subdivision.
LG8	0345480E, 4953664N	44°43.181'N 106°57.062'W	3,895	Small acreage properties with livestock grazing, wildlife habitat, and irrigated hayland.
LG9	0345218E, 4953494N	44°43.086'N 106°57.258'W	3,905	Small acreage properties with cattle grazing, wildlife habitat, and irrigated hayland.
LG10M	0344898E, 4952854N	44°42.737'N 106°57.488'W	3,915	Only a macroinvertebrate location. Small acreage properties with livestock grazing, wildlife habitat, and irrigated hayland.
LG11	0344955E, 4952623N	44°42.613'N 106°57.441'W	3,915	Small acreage properties with cattle grazing and irrigated hayland.
LG13	0344059E, 4951792N	44°42.152'N 106°58.104'W	3,940	Large subdivisions with small acreage lots, wildlife habitat, and irrigated hayland.
LG17	0342645E, 4950336N	44°41.348'N 106°59.147'W	4,020	Small acreage properties with cattle grazing and irrigated hayland.
LG19	0342526E, 4949684N	44°40.994'N 106°59.225'W	4,040	Small acreage properties with cattle grazing and irrigated hayland. Big Horn community residences are within the lowermost reaches of Sackett Creek.
LG20	0342046E, 4948277N	44°40.229'N 106°59.563'W	4,100	Residential and ranch buildings, cattle grazing, and wildlife habitat.
LG22	0338336E, 4942856N	44°37.253'N 107°02.267'W	4,533	Ranch buildings, cattle grazing, and wildlife habitat. The BNF boundary is approximately 3 miles upstream.
LG22M	0338287E, 4942703N	44°37.169'N 107°02.301'W	4,540	Only a macroinvertebrate location. Same use as LG22.

E. coli and turbidity samples were collected during two 30 day periods in May and July -August. Gauge height, pH, specific conductivity, dissolved oxygen, and instantaneous water temperature were measured during these sampling events. Continuous water temperature data loggers were deployed at nine stations to measure water temperature at 15 minute intervals from May 1st to October 31st, 2012. Benthic macroinvertebrates were collected and habitat assessments were performed at eight stations in September. Detailed site and watershed descriptions were provided in the 2001-2002 Assessment Final Report (SCCD, 2003) and in the 2012 SAP (SCCD, 2012).

All monitoring methods, standard operating procedures, and data validation protocols used for this project were described in the 2012 SAP previously approved by WDEQ. Table 4.2 provides the types of monitoring that were performed at each site and site descriptions.

Table 4.2 Additional Station Descriptions and Type of Monitoring Completed

Site	Creek Being Sampled	Type(s) of Monitoring Completed	Water Quality Sample Site Description	Benthic Macroinvertebrate Sample Site Description
GC1, GC1M	Goose Creek	Continuous Temperature, Water Quality, MACRO-HAB	Located approximately 75 yards downstream of HWY 339 bridge crossing at USGS Station No. 06305700 (approximately 2 miles south of Acme)	Base of riffle located approximately 300 yards upstream from the HWY 339 bridge crossing
GC1A	Goose Creek	Water Quality	Behind Wild Hollow Subdivision	N/A
GC2, GC2M	Goose Creek	Water Quality, MACRO-HAB	Located approximately 200 yards downstream of Sheridan WWTP	Riffle is located about 100 yards downstream of Sheridan WWTP discharge
GC4	Soldier Creek	Water Quality	Located approximately 10 yards downstream from Dana Avenue bridge.	N/A
GC5	Goose Creek	Water Quality	Located approximately 10 yards upstream of Thorne Rider Park footbridge	N/A
BG1	Big Goose Creek	Continuous Temperature, Water Quality	Located off of the bike path, downstream of Senior Apartments building	N/A
BG2M	Big Goose Creek	MACRO-HAB	N/A	Located at first long riffle upstream from the footbridge at Works and Elk Street
BG3A	Big Goose Creek	Water Quality	Approximately 300 yards upstream of Nettie B Heald Ditch	N/A
BG6	Big Goose Creek	Continuous Temperature, Water Quality	Located at the west end of the Poulson Youth Camp on river right of stream	N/A
BG9	Beaver Creek	Water Quality	10 yards upstream from the Big Goose Creek confluence	N/A
BG10	Big Goose Creek	Water Quality, MACRO-HAB	Approximately 40 yards upstream from the County Road 87 bridge crossing	Located at first riffle upstream from County Road 87 bridge crossing
BG13	Park Creek	Water Quality	Approximately 15 yards downstream of Wyoming State Highway 331	N/A
BG14	Big Goose Creek	Continuous Temperature, Water Quality	Approximately 35 yards upstream of Wyoming State Highway 331	N/A
BG16	Rapid Creek	Water Quality	Approximately 15 yards downstream of the County Road 53 bridge	N/A
BG18	Big Goose Creek	Continuous Temperature, Water Quality, MACRO-HAB	Located near the mouth of Big Goose Canyon at USGS Station No. 06302000. The Alliance Ditch intake is about 50 yards downstream.	Located above USGS Station No. 06302000.
LG2	Little Goose Creek	Continuous Temperature, Water Quality	Approximately 30 yards upstream from the concrete flood channel in downtown Sheridan	N/A

Table 4.2 (continued) Additional Station Descriptions and Type of Monitoring Completed

Site	Creek Being Sampled	Type(s) of Monitoring Completed	Water Quality Sample Site Description	Benthic Macroinvertebrate Sample Site Description
LG2AM	Little Goose Creek	MACRO-HAB	N/A	LG2A - Riffle is located in between Coffeen Bridge and first bend downstream (100-150 yards) from Coffeen Avenue bridge
LG6	Little Goose Creek	Water Quality	Approximately 10 yards downstream Country Road 66 Bridge	N/A
LG8	Little Goose Creek	Continuous Temperature, Water Quality	Approximately ¼ mile downstream from McCormick Creek near the Cox Valley Road	N/A
LG9	McCormick Creek	Water Quality	Approximately 20 yards upstream from the Little Goose Creek confluence	N/A
LG10	Little Goose Creek	MACRO-HAB	N/A	Located at first riffle upstream of Hwy 87 Bridge
LG11	Kruse Creek	Water Quality	About 100 yards upstream from the Little Goose Creek confluence	N/A
LG13	Little Goose Creek	Water Quality	Approximately 10 yards upstream of CR 60 bridge in the Knode Ranch subdivision.	N/A
LG17	Jackson Creek	Water Quality	Approximately 35 yards upstream from the Little Goose Creek confluence.	N/A
LG19	Sackett Creek	Water Quality	10 yards upstream from the Little Goose Creek confluence.	N/A
LG20	Little Goose Creek	Continuous Temperature, Water Quality	10 yards downstream of Brinton CR 103 Bridge	N/A
LG22	Little Goose Creek	Continuous Temperature, Water Quality MACRO-HAB	Above the County Road 77 bridge crossing. Same location as USGS Station No. 06303700.	Right above first water gap above bridge. Approximately 300 yards above Road 77 Bridge

4.3 Monitoring Schedule

The 2012 monitoring schedule included sampling to determine the geometric means of *E. coli*, based on 5 samples collected in both May and July-August. A total of ten water quality samples were collected from each site from May through August 2012. Sample dates were determined using random numbers generated for the Tuesdays, Wednesdays, or Thursdays due to lab availability and sample holding times. Continuous temperature data loggers were deployed to measure instream temperatures from May 1st through October 31, 2012. Macroinvertebrate collections and habitat assessments were completed in September. The 2012 monitoring schedule followed the SAP schedule (Table 4.3).

Table 4.3 Accomplished Schedule for 2012 Goose Creek Watershed Monitoring

Date(s)	Sites	Parameters
May 1 – October 31, 2012	GC1, BG1, BG6, BG14, BG18, LG2, LG8, LG20, LG22	Continuous Temperature
May 10	GC1, GC1A, GC2, GC4, GC5, BG1, BG3A, BG6, BG9, BG10, BG13, BG14, BG16, BG18, LG2, LG6, LG8, LG9, LG11, LG13, LG17, LG19, LG20, LG22	Temp, pH, COND, DO, Q, T, and *E. coli*
May 16		
May 22		
May 24		
May 30		
July 31	GC1, GC1A, GC2, GC4, GC5, BG1, BG3A, BG6, BG9, BG10, BG13, BG14, BG16, BG18, LG2, LG6, LG8, LG9, LG11, LG13, LG17, LG19, LG20, LG22	Temp, pH, COND, DO, Q, T, and *E. coli*
August 8		
August 15		
August 23		
August 28		
September - October	GC1, GC2, BG2, BG10, LG2A, LG10	MACRO, HAB, Photo

Abbreviations include: Temp = Instantaneous water temperature, pH = pH, COND = specific conductivity, DO = Dissolved oxygen, Q = Discharge, T = Turbidity, *E. Coli* = *Escherichia coli*, Photo = Panoramic photographs, HAB = Habitat assessments, Macro= Benthic macroinvertebrates

4.4 Sampling and Analysis Methods

The monitoring project was designed to meet WDEQ and USEPA requirements for samples collected under Section 319 of the Clean Water Act as well as the Credible Data Law (Wyoming Statutes 35-11-103(b) and (c) and 35-11-302 and State of Wyoming Enrolled Act 47). Sample protocols were based on methods/procedures in the NRCS National Handbook of Water Quality Monitoring (NRCS, 2003) and the WDEQ Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ, 2004)

Water quality samples, discharge measurements, macroinvertebrate collections, and habitat assessments monitoring were collected by the methods described in the project SAP (SCCD, 2012) and the SCCD Water Quality Monitoring Program Quality Assurance Project Plan (SCCD, 2010) according to accepted analytical methods (Table 4.4). Water quality and macro-invertebrate samples were obtained from representative sample riffles. Discharge was estimated using staff gauge observations that were calibrated using the mid-section method (WDEQ, 2004).

Continuous temperature data were collected by anchoring the data loggers near the bottom of pools to simulate the water temperatures of trout habitat. Discharge measurements at all sites were obtained using calibrated staff gauges. Staff gauge calibrations were performed by measuring instantaneous discharge with a Marsh-McBirney 2000 current meter. Turbidity and *E. coli* samples were hand delivered to Inter-Mountain Laboratories (IML) in Sheridan, Wyoming for analysis. Macroinvertebrate samples were sorted by Aquatic Assessments, Inc. (AA) in Sheridan, Wyoming and analyzed by Aquatic Biology Associates, Inc. (ABA) in Corvallis, Oregon.

Table 4.4 Standard Field and Laboratory Methods

Parameter	Units	Method / Reference[1]	Location of Analyses	Preservative	Holding Time
Temperature	°C	grab/USEPA 1983 170.1	On-site	n/a	n/a
Temperature	°C	continuous recorder	On-site	n/a	n/a
pH	SU	grab/USEPA 1983 150.1	On-site	n/a	n/a
Specific Conductivity	µmhos/cm	grab/USEPA 1983 120.1	On-site	n/a	n/a
Dissolved Oxygen	mg/l	grab/USEPA 1983 360.1	On-site	n/a	n/a
Turbidity	NTU	grab/USEPA 1983 180.1	IML[2]	Ice; at or below 4ºC	48 hours
E. coli	col/100 ml	grab/SM 9222G[5]	IML[2]	Ice; at or below 4ºC	6 hours
Flow	cfs	Calibrated staff gauge	On-site	n/a	n/a
Flow	cfs	Mid-Section Method	On-site	n/a	n/a
Macroinvertebrates	Metrics	King 1993	AA[3] ABA[4]	formalin	n/a
Habitat (Reach level)	n/a	King 1993	On-site	n/a	n/a

[1]Method references for laboratory analyses were provided by the contract laboratories and defined in their SOPs.
[2]IML refers to Inter-Mountain Laboratories in Sheridan, Wyoming
[3]AA refers to Aquatic Assessments, Inc. in Sheridan, Wyoming.
[4]ABA refers to Aquatic Biology Associates, Inc. in Corvallis, Oregon.
[5] SM refers to Eaton et. al., 1995. Standard Methods for the examination of water and wastewater.

CHAPTER 5 QUALITY ASSURANCE/QUALITY CONTROL

5.1 FUNCTION OF QUALITY ASSURANCE AND QUALITY CONTROL

Quality Assurance (QA) may be defined as an integrated system of management procedures designed to evaluate the quality of data and to verify that the quality control system is operating within acceptable limits (Friedman and Erdmann, 1982; USEPA, 1995). Quality control (QC) may be defined as the system of technical procedures designed to ensure the integrity of data by adhering to proper field sample collection methods and operation and maintenance of equipment and instruments. Together, QA/QC functions to ensure that all data generated are consistent, valid and of known quality (USEPA, 1980; USEPA 1990). QA/QC should not be viewed as an obscure notion to be tolerated by monitoring and assessment personnel, but as a critical, deeply ingrained concept followed through each step of the monitoring process. Data quality must be assured before the results can be accepted with any scientific study. Project QA/QC is fully described in the SCCD QAPP (SCCD, 2010) and the Goose Creek SAP (SCCD, 2012).

5.2 TRAINING

Personnel involved in the collection and analysis of samples should receive adequate training for proper implementation of project field and laboratory methods. SCCD personnel responsible for this project had the proper training through a combination of college studies, previous employment experiences, and on the job training. The SCCD District Manager has an M.S. from the University of Wyoming in Rangeland Ecology and Watershed Management (Water Resources Option). The Natural Resource Specialist has a B.S. from the University of Vermont in Environmental Science with a concentration in Ecological Design and 6-month on-the-job training as the water quality intern with WDEQ in Sheridan. Both employees have water quality assessment skills obtained through prior employment experiences. The District Manager has taken a Water Quality Assessment course provided by the Wyoming Association of Conservation Districts. Kurt King, former WDEQ QA/QC Officer, has provided thorough training for the District Manager in conducting benthic macroinvertebrate sampling and reach level habitat assessments. The Natural Resource Specialist was trained by and had on-the-job experience with the WDEQ Water Quality Division on benthic macroinvertebrate sampling, reach level habitat assessments, water quality sampling, stream cross-sections, and flow measurements. On a few occasions, other SCCD staff assisted with the macroinvertebrate sampling and habitat assessments. These personnel were trained by the District Manager prior to sampling and were under direct supervision of the Natural Resource Specialist and/or District Manager during sampling.

5.3 SAMPLE COLLECTION, PRESERVATION, ANALYSIS, AND CUSTODY

5.3.1 COLLECTION, PRESERVATION, AND ANALYSIS

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.

5.3.2 Sample Custody

Project field measurements were recorded on field data sheets. Water samples requiring laboratory analysis were immediately preserved (if required), placed on ice, and hand delivered to the laboratory. A Chain of Custody (COC) form was prepared and signed by the sampler before samples entered laboratory custody. An IML 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 according to their Quality Assurance Plan.

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

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 DO 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 DO meter, used throughout the project, did not require a calibration solution. The DO 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. Before the 2012 field season, the Marsh-McBirney was sent for factory calibration. Onset HOBO data loggers, used for continuous temperature monitoring, were factory calibrated and completely encapsulated. These loggers are considered disposable; when the enclosed battery is depleted, it cannot be replaced. Factory calibration of the loggers was checked by launching them in the office before the start of the season to check temperature unity. The manufacturer's crushed-ice test was performed at the end of the season to validate the logger's 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 QA/QC Results

Data Quality Objectives (DQO's) are qualitative and quantitative specifications used by water quality monitoring programs to limit data uncertainty to an acceptable level. DQO's were established for each monitoring parameter for precision, accuracy, and completeness at levels sufficient to allow SCCD to realize project goals and objectives.

5.5.1 Comparability

Comparability refers to the degree to which data collected during this Project were comparable to data collected during other past or present studies. This was an important factor because future water quality monitoring will occur within the watershed and current project data must be comparable to future data in order to detect water quality change with confidence.

Recognizing that periodic adjustments to locations, parameters, and/or sampling methods are needed, several steps were taken to assure data comparability including:

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

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

5.5.2 Trip Blanks

Trip blanks were prepared to determine whether samples might be contaminated by the sample container, preservative, or during transport and storage conditions. *E. coli* and turbidity trip blanks were utilized during every sampling event. These trip blanks were prepared in advance by the analytical laboratory. Trip blanks were prepared by filling preserved bottles with laboratory de-ionized water. No trip blanks used during the project contained detectable levels of *E. coli*. Only two blanks detected turbidity levels of 0.1 NTU and 0.2 NTU on 8/9/2012. The turbidity data were considered acceptable because they were low turbidity values and both values were at, or approached, the minimum detection limit value of 0.1 NTU.

5.5.3 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 6-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.

5.5.4 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 5.1).

Table 5.1 Summary of 2012 Goose Creek Watershed Duplicates

Parameter	No. of Samples	No. of Duplicates	% Duplicated	DQO (%)
Water Quality Samples (24 sites x 10 samples)	240	30	12.5	10
Macroinvertebrate Samples	8	1	12.5	10
Habitat Assessments	8	1	12.5	10

5.5.5 PRECISION

Precision is 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 chemical, physical, biological, and habitat measurements by conducting duplicate samples at 10 percent of the collected samples. Duplicate intra-crew habitat assessments were conducted simultaneously by each observer conducting the assessment without communication. All parameters met the DQO's for precision (Tables 5.2 and 5.3).

Table 5.2 Precision of 2012 Water Quality Monitoring Data

Parameter	GCD1 Precision (% - RPD)	GCD2 Precision (% - RPD)	GCD3 Precision (% - RPD)	Average	DQO (%)
Water Temperature-Hanna	0.44	0.24	0.43	0.37	10
Water Temperature-YSI	0.37	0.28	0.43	0.36	10
pH	1.96	1.23	0.88	1.36	5
Specific Conductivity	0.70	1.10	1.29	1.03	10
Dissolved Oxygen (%)	5.40	3.08	2.51	3.66	20
Dissolved Oxygen (mg/L)	4.70	3.36	2.71	3.59	20
E. coli	16.62	22.05	25.19	21.29	50
Turbidity	10.71	10.48	8.36	9.85	10

Table 5.3 Precision of 2012 Macroinvertebrate and Habitat Assessment Data

Parameter	Dup 1 (BG2)	Dup 2 (BG2)	Precision (%-RPD)	DQO (%)
Total Abundance	5802	5480	5.71	50
Total Taxa	35	34	2.90	15
Intra-Crew Habitat Assessments	119.5	121.0	1.2	15

5.5.6 ACCURACY

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

5.5.7 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 discharge measurements (Table 5.4). This was the result of staff gauge readings being outside of the calibrated range during high flows or water levels below the staff gauge at low flows.

There were six staff gauges that were emerged on one or multiple sample days. These gauges included LG8, LG13, and LG20 on 5/10/2012, along with GC1A from 8/8/2012 to 8/28/1012, GC5 from 7/31/2012 to 8/28/2012, and BG14 from 7/31/2012 to 8/23/2012. Discharge could not be estimated in those circumstances. Two discharge measurements on BG3A, from 5/10 and 5/30, were questionable and could not be verified. These were discarded and were not used in the calculation of summary statistics.

Table 5.4 Completeness of 2012 Monitoring Data

Parameter	% 2012 Completeness*	DQO (%)
Water Temperature	100.0	95
pH	100.0	95
Specific Conductivity	100.0	95
Dissolved Oxygen	99.6	95
Discharge	**92.5**	95
Turbidity	100.0	95
E. coli	99.6	95
Total Abundance of Marcroinvertebrates	100	95
Total Taxa	100	95
Intra-Crew Habitat Assessments	100	10

*Bold values are below the DQO.

5.5.8 STAGE DISCHARGE RELATIONSHIPS

The relationship between stage height and discharge for a given location yields an equation that allows the calculation of discharge at various stage heights recorded on a staff gauge. A correlation coefficient (R^2 value) of at least 0.95 (95%) is desirable for proper calibration of the gauge. Stage-discharge relationships were established for all staff gauges installed by SCCD

(Table 5.5). These relationships were developed by recording the stage height and measuring discharge using the mid-section method (WDEQ, 2004) on at least three occasions with varying flow conditions.

The R^2 values for BG6, BG9, BG13, LG6, and LG8 were below the DQO value of 0.95 with values of 0.9030, 0.8676, 0.9022, 0.9002, and 0.9402, respectively. Because these presented the best, and in some cases the only, flow information available, the values were used in the calculation of summary statistics and in the development of load estimates, where appropriate.

Table 5.5 Summary of R^2 Values for 2012 Stage-Discharge Relationships

Site	R^2 Value*	DQO Minimum R^2 Value
GC1	0.9998	0.95
GC1A	0.9645	0.95
GC2	0.9999	0.95
GC4	0.9534	0.95
GC5	0.9936	0.95
BG1	0.9989	0.95
BG3A	0.9898	0.95
BG6	**0.9030**	0.95
BG9	**0.8676**	0.95
BG10	0.9994	0.95
BG13	**0.9022**	0.95
BG14	0.9981	0.95
BG16	1.0000	0.95
BG18	0.9659	0.95
LG2	0.9951	0.95
LG6	**0.9002**	0.95
LG8	**0.9402**	0.95
LG9	0.9994	0.95
LG11	0.9794	0.95
LG13	0.9971	0.95
LG17	0.9869	0.95
LG19	0.9824	0.95
LG20	0.9745	0.95
LG22	0.9973	0.95

*Bold values are below the DQO.

5.5.9 Continuous Temperature Data Loggers

Onset's HOBO Pendent Temperature 64 Data Loggers were used at GC1, BG1, BG6, BG14, BG18, LG2, LG8, LG20, LG22 stations to record water temperature during the 2012 monitoring project. These loggers are factory calibrated, encapsulated devices that cannot be re-calibrated. These loggers are considered disposable; when the enclosed battery is depleted, it cannot be replaced.

To verify the accuracy of the factory calibration, the loggers were checked by launching them in the office before the start of the season to check temperature unity. The pre-season check, which was performed on 5/1/2012 between 7:51 AM and 8:05 AM, reported temperatures between 20.996°C to 21.473°C, a range of ± 0.477°C.

The manufacturer's crushed-ice test was performed at the end of the season to verify accuracy. 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 ±0.23°C. The ice bath temperature was reported to be between 0.12°C to 0.23°C on 11/16/2012 between 15:49 PM and 16:02 PM, which was within the manufacturer's predicted range.

One temperature logger malfunctioned during 2012. The logger at station LG2, logger 9775398, would not transfer data into the Onset HOBO Waterproof Shuttle and was replaced on May 30. The manufacturing company was able to retrieve the data from May 1st to May 30th.

Onset suggests the loggers should maintain their accuracy unless they have been used outside the range of intended use (-20°C to 50°C). The loggers were not subject to temperatures outside of the normal operating range and there were no indications that the loggers were functioning improperly. Therefore, the temperature loggers are considered to have maintained their accuracy and to have provided valid water temperature data for 2012.

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, 2010). No lab results were reported below the detection limits in 2012.

Six staff gauges were emerged on multiple days. These gauges included LG8, LG13, and LG20 on 5/10/2012, along with GC1A from 8/8/2012 through 8/28/1012, GC5 from 7/31/2012 through 8/28/2012, and BG14 from 7/31/2012 through 8/23/2012. Discharge estimates could not be calculated. Two staff gauge measurements from BG3A, on 5/10/2012 and 5/30/2012, were questionable and could not be verified. These data were discarded and not used in the 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 simplicity. 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, and have been attached in Appendix G.

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 along with hard copies. All electronic laboratory data are maintained in SCCD database on the SCCD server in Sheridan, Wyoming. Copies of all laboratory reports, field data sheets, calibration logs, field notes, data validation logs, and other project information will be provided separately to WDEQ.

5.8 DATABASE CONSTRUCTION AND DATA REDUCTION

The project database consists of a series of electronic computer files. Each database file was constructed with reportable data (accepted after QA/QC checks) by entering into Microsoft Excel® spreadsheets and Access® Database. 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 discovered, the original field or laboratory data sheet was re-examined and the data entry corrected.

After data validation and database construction, data were statistically summarized for the following calculations, which are provided in Appendix B, Table B.3 – B.26:

- 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. Three separate geometric means were calculated for all of the water quality parameters, one including all ten sampling dates, one for the five samples collected in May, and one for the 5 samples collected in July-August. Discharge estimates outside of the calibrated range and instances where the staff gauge was emerged were not used in the calculation of summary statistics.

5.9 DATA RECONCILIATION

Data collected by SCCD were evaluated before being accepted and entered into the 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.

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CHAPTER 6 WATER QUALITY STANDARDS AND DISCUSSION OF RESULTS

6.1 WATER QUALITY STANDARDS

Wyoming's surface waters are protected through application of narrative (descriptive) and numeric water quality standards described in Chapter 1 of the Wyoming Water Quality Rules and Regulations (WDEQ, 2007). For Class 2AB waters, the Human Health values for "Fish and Drinking Water" listed in Appendix B of Chapter 1 apply. The "acute" and "chronic" values for Aquatic Life apply to all Class 1, 2, and 3 waters. SCCD used the description of the narrative or numeric water quality standards applicable to the Goose Creek Watershed to determine attainment of beneficial uses of waterbodies within the project area (Table 6.1).

Table 6.1 Numeric and Narrative Water Quality Standards for Wyoming Surface Waters Applicable for Waters in the Goose Creek Watershed (WDEQ, 2007)

NUMERIC STANDARDS				
Priority Pollutants[1]				
Parameter	Reference	Standard / Description		
		Human Health[2]	Acute Aquatic Life[3]	Chronic Aquatic Life[3]
Antimony	Section 18; Appendix B	5.6 ug/l		
Arsenic	Section 18 and 21; Appendix B	10 ug/l	340 ug/l	150 ug/l
Asbestos	Section 18; Appendix B	7000000 fibers/L		
Beryllium	Section 18; Appendix B	4 ug/l		
Cadmium	Section 18; Appendix B	5 ug/l	2.0 ug/l (calculated)	0.25 ug/l (calculated)
Chromium (III)	Section 18; Appendix B	100 ug/l	569.8 ug/l	74.1 ug/l
Chromium (VI)	Section 18; Appendix B	100 ug/l	16 ug/l	11 ug/l
Copper	Section 18; Appendix B	1000 ug/l	13.4 ug/l	9 ug/l
Cyanide (free)	Section 18; Appendix B	200 ug/l	22 ug/l	5.2 ug/l
Lead	Section 18; Appendix B	15 ug/l	64.6 ug/l	2.5 ug/l
Mercury	Section 18; Appendix B	0.050 ug/l	1.4 ug/l	0.77 ug/l
Nickel	Section 18; Appendix B	100 ug/l	468.2 ug/l	52.0 ug/l
Selenium	Section 18; Appendix B	50 ug/l	20 ug/l	5 ug/l
Silver	Section 18; Appendix B		3.4 ug/l	
Thallium	Section 18; Appendix B	2.4 ug/l		
Zinc	Section 18; Appendix B	5000 ug/l	117.2 ug/l	118.1 ug/l
Organics, priority	Section 18; Appendix B	Standards for organic priority pollutants are listed		

[1] Priority pollutants are those pollutants listed by USEPA under section 307(a) of the Clean Water Act (WDEQ, 2007); Non-priority pollutants are substances other than those listed by USEPA.
[2] The values that Class 1, 2AB, and 2A waters must meet; these are the "fish and drinking water" values (WDEQ, 2007). Because none of the waterbodies are designated as Class 2B, 2C, or 2D, (suitable for fish consumption but not drinking water), values for consumption of fish (or "fish only") values are not reported here.
[3] Aquatic Life protection values apply to Class 1, 2A, 2B, 2AB, 2C, 3A, 3B, and 3C. Chronic values are 4-day averages while acute values are 1-day averages (WDEQ, 2007). Neither shall be exceeded more than once every 3 years.

Table 6.1 (continued). Numeric and Narrative Quality Standards for Wyoming Surface Waters Applicable for Waters in the Goose Creek Watershed (WDEQ, 2007**)**

Non-Priority Pollutants[1]				
Parameter	**Reference**	**Standard / Description**		
		Human Health[2]	**Acute Aquatic Life[3]**	**Chronic Aquatic Life[3]**
Aluminum (pH 6.5-9.0)	Section 21; Appendix B		750 ug/l	87 ug/l
Barium	Section 18; Appendix B	2000 ug/l		
Carbofuran	Section 18; Appendix B	40 ug/l		
Chloride	Section 21; Appendix B		860000 ug/l	230000 ug/l
Chlorine (total residual)	Section 18; Appendix B		19 ug/l	11 ug/l
Chloropenoxy Herbicide 2,4-D	Section 18: Appendix B	70 ug/l		
Dissolved Gases	Sections 21 and 30; Appendix B			100% saturation 110% saturation below man-made dams
Iron	Section 18 and 21; Appendix B	300 ug/l	1000 ug/l	
Manganese	Section 18 and 21; Appendix B	50 ug/l	3110 ug/l	1462 ug/l
Nitrite (as N)	Section 18; Appendix B	1000 ug/l		
Nitrates (as N)	Section 18; Appendix B	10000 ug/l		
Nitrite + Nitrate (as N)	Section 18; Appendix B	10000 ug/l		
pH	Sections 21 and 26; Appendix B			6.5-9.0 standard units
Picloram	Section 18; Appendix B	500 ug/l		
Sulfide-Hydrogen Sulfide (S2-, HS-)	Section 21; Appendix B			2 ug/l
Ammonia	Section 21; Appendix C	In all Class 3 waters, concentrations shall not affect aquatic life or designated uses. In Class 1, 2A, 2B, 2AB, and 2C waters, Appendix C provides pH and temperature dependent numeric criteria		
Dissolved Oxygen	Sections 21 and 30 Appendix D	For Class 1, 2AB, 2B, and 2C waters 1 day minima Early life: 5.0 mg/L intergravel concentration (8.0 mg/L water column) Other life stages: 4.0 mg/L		

[1] Priority pollutants are those pollutants listed by USEPA under section 307(a) of the Clean Water Act (WDEQ, 2007); Non-priority pollutants are substances other than those listed by USEPA.
[2] The values that Class 1, 2AB, and 2A waters must meet; these are the "fish and drinking water" values (WDEQ, 2007). Because none of the waterbodies are designated as Class 2B, 2C, or 2D, (suitable for fish consumption but not drinking water), values for consumption of fish (or "fish only") values are not reported here.
[3] Aquatic Life protection values apply to Class 1, 2A, 2B, 2AB, 2C, 3A, 3B, and 3C. Chronic values are 4-day averages while acute values are 1-day averages (WDEQ, 2007). Neither shall be exceeded more than once every 3 years.

Table 6.1 (continued). Numeric and Narrative Quality Standards for Wyoming Surface Waters Applicable for Waters in the Goose Creek Watershed (WDEQ, 2007**)**

Parameter	Reference	Standard / Description		
		Human Health[2]	Acute Aquatic Life[3]	Chronic Aquatic Life[3]
E. coli	Section 27	Primary Contact Recreation: Geometric mean of 5 samples obtained during separate 24 hour periods within a 30 day period shall not exceed 126 organisms per 100 ml (May 1-Sept 30). Secondary Contact Recreation: Geometric mean of 5 samples obtained during separate 24 hour periods within a 30 day period shall not exceed 630 organisms per 100 ml.		
Oil and Grease	Section 29	Shall not exceed 10 mg/L or cause visible deposits or sheen, or impair human, animal, plant, or aquatic life		
Radium 226	Section 22	Shall not exceed limits in Federal Primary Drinking water Standards published by USEPA (Class 1, 2AB, and 2A). Shall not exceed 60 pCi/l (Class 2b, 2C, 2D, 3, and 4)		
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.		
Organics, non-priority	Section 18; Appendix B	Standards for organic non-priority pollutants are listed		
NARRATIVE STANDARDS				
Parameter	**Reference**	**Standard / Description**		
Settleable Solids	Section 15	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or affect plant and wildlife.		
Floating and Suspended Solids	Section 16	Shall not be present in quantities that could degrade aquatic life habitat, affect public water supplies, agricultural or industrial use, or affect plant and wildlife.		
Taste, Odor, Color	Section 17	Substances shall not be present in quantities that would produce taste, odor, or color in: fish flesh, skin, clothing, vessels, structures, or public water supplies.		
Macroinvertebrates	Section 32	Class 1, 2 and 3 waters of the state must be free from substances, whether attributable to human-induced point source discharges or nonpoint source activities, in concentrations or combinations which will adversely alter the structure and function of indigenous or intentionally introduced aquatic communities		

[1] Priority pollutants are those pollutants listed by USEPA under section 307(a) of the Clean Water Act (WDEQ, 2007); Non-priority pollutants are substances other than those listed by USEPA

[2] The values that Class 1, 2AB, and 2A waters must meet; these are the "fish and drinking water" values (WDEQ, 2007). Because none of the waterbodies are designated as Class 2B, 2C, or 2D, (suitable for fish consumption but not drinking water), values for consumption of fish (or "fish only") values are not reported here.

[3] Aquatic Life protection values apply to Class 1, 2A, 2B, 2AB, 2C, 3A, 3B, and 3C. Chronic values are 4-day averages while acute values are 1-day averages (WDEQ, 2007). Neither shall be exceeded more than once every 3 years.

Table 6.1 (continued). Numeric and Narrative Quality Standards for Wyoming Surface Waters Applicable for Waters in the Goose Creek Watershed (From WDEQ, 2007)

Parameter	Reference	Standard / Description
ADDITIONAL PARAMETERS, STANDARDS, AND RECOMMENDED LIMITS		
Total Phosphorus	USEPA (1977); USGS (1999)	USEPA: Should not exceed 0.05 mg/L for a stream entering a lake or reservoir (i.e. Tongue River Reservoir); USGS: National background level in undisturbed watersheds is 0.10 mg/L
Total Sulfate	Winget and Magnum (1979) WDEQ (2005) USEPA (1986)	Recommended 150 mg/L for benthic macroinvertebrates Groundwater: 200 mg/L agriculture; 250 mg/L domestic use; 3000 mg/L livestock; 250 mg/L USEPA secondary drinking water
Alkalinity	USEPA (1986)	Minimum 20 mg/L; up to 400 mg/L as $CaCO_3$ for human health
Total Suspended Solids (TSS)	Refer to Sections 15 and 16	No recommended standard for use attainability. Narrative standards prohibit quantities of settleable, floating, or suspended solids that could cause significant degradation in aesthetics and/or habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife.
Total Dissolved Solids	WDEQ (2005)	Groundwater: 500 mg/L domestic use; 2000 mg/L agriculture; 5000 mg/L livestock Groundwater Fish and Aquatic Life: 500 mg/L egg hatching; 1000 mg/L fish rearing; and 2000 mg/L fish and aquatic life
Hardness	Sawyer (1960) *in* USEPA (1986)	Concentrations greater than 300 mg/L may be considered very hard and possibly unsuitable for industrial use
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.
Chloride-Groundwater	WDEQ (2005)	Groundwater: 250 mg/L domestic use; 100 mg/L agriculture; 2000 mg/L livestock
Nitrite-Nitrate-N Groundwater	WDEQ (2005)	Groundwater: 100 mg/L livestock
Manganese-Groundwater	WDEQ (2005)	Groundwater: 0.05 mg/L domestic use; 0.2 mg/L agriculture; 1.0 mg/L aquatic life
SAR	WDEQ (2005)	Groundwater: 8 agriculture use

[1] Priority pollutants are those pollutants listed by USEPA under section 307(a) of the Clean Water Act (WDEQ, 2007); Non-priority pollutants are substances other than those listed by USEPA
[2] The values that Class 1, 2AB, and 2A waters must meet; these are the "fish and drinking water" values (WDEQ, 2007). Because none of the waterbodies are designated as Class 2B, 2C, or 2D, (suitable for fish consumption but not drinking water), values for consumption of fish (or "fish only") values are not reported here.
[3] Aquatic Life protection values apply to Class 1, 2A, 2B, 2AB, 2C, 3A, 3B, and 3C. Chronic values are 4-day averages while acute values are 1-day averages (WDEQ, 2007). Neither shall be exceeded more than once every 3 years.

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6.2 2012 Field Water Chemistry and Physical Parameters

Water quality data were collected in May and July-August, 2012 at all 24 stations (Appendix B, Table B.3 – B.26). Summary statistics and geometric mean values for May and August were calculated for all sites on accepted data (Appendix B, Table B.3 – B.26). For the most part, specific conductivity, pH, and dissolved oxygen were within the expected ranges. Turbidity values were considered normal for the watershed with occasional high values occurring during late-spring, early-summer precipitation and run-off events.

6.2.1 Instantaneous Water Temperature

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard on the days and sites presented in Table 6.2. There were 19 out of 24 stations above the cold water temperature standard on July 31, 2012 (Appendix A, Map 7); 16 out of 24 stations on August 8th, 2012; 1 out of 24 stations on August 23rd, 2012; and 2 out of 24 stations on August 28th, 2012. Every mainstem site of Goose Creek, Big Goose, and Little Goose Creek exceeded the temperature standard on July 31st, 2012 except for the 2 uppermost stations (BG18 and LG22), which are located in the canyons.

Table 6.2 Instantaneous Samples Exceeding the Cold Water Temperature Standard (20°C)

Site	Temperature (°C)			
	7/31/2012	8/8/2012	8/23/2012	8/28/2012
Goose Creek (GC1)	22.2	20.0		
Goose Creek (GC1A)	22.0	20.0		
Goose Creek (GC2)	22.0	20.2		
Solider Creek (GC4)	20.0			
Goose Creek (GC5)	22.8	20.7		
Big Goose Creek (BG1)	22.7	20.6		
Big Goose Creek (BG3A)	23.0	21.0		
Big Goose Creek (BG6)	22.5	20.5		
Big Goose Creek (BG10)	22.2			
Big Goose Creek (BG14)	21.6	20.6		
Little Goose Creek (LG2)	26.8	26.0	23.1	23.2
Little Goose Creek (LG6)	23.4	22.2		
Little Goose Creek (LG8)	23.8	22.6		20.4
McCormick Creek (LG9)	20.1			
Kruse Creek (LG11)	22.3	21.4		
Little Goose Creek (LG13)	22.4	20.8		
Jackson Creek (LG17)	24.6	22.0		
Sackett Creek(LG19)	21.6	20.8		
Little Goose Creek (LG20)	21.5	21.0		

Note: All temperature measurements were taken from the Hanna Instruments meter Model No. 9025.

May and August geometric means were calculated for instantaneous temperature collected from all sites sampled in 2001-2012 and for two stations used in 2001-2009 but not in 2012 (BG2 and LG5). Every station shows higher temperatures in August than in May. Comparisons among years are difficult because of variations in water quantity and air temperatures.

Geometric mean instantaneous temperatures for Goose Creek are relatively consistent among sites. Instantaneous temperatures in May and in August 2012 from GC5 (13.38°C and 19.64°C, respectively) downstream to GC1 (13.72°C and 19.68°C, respectively) are similar (Appendix C, Figure C.1). For mainstem sites on Big Goose Creek and Little Goose Creek, instantaneous temperatures generally decrease from downstream to upstream (Appendix C, Figure C.7 and Figure C.13). All 2012 samples at Big Goose stations are higher in 2012 than in 2009, but similar to instantaneous temperatures collected in 2001. On the Little Goose Creek mainstem sites sampled in 2012, instantaneous temperatures are higher in 2012 than in all other sampling years. This could be attributed to higher than normal air temperatures and lower than normal precipitation (Appendix B, Figure B.18 – B.19).

The tributary sites in the Goose Creek and Big Goose Creek subwatersheds have higher instantaneous temperature geometric means than in 2009, 2005, and 2002. Depending on the specific station, instantaneous temperature comparisons between 2001 and 2012 varied (Appendix C, Figure C.19). The tributary stations in the Little Goose Creek subwatershed seem to have had higher temperatures in 2012 than in 2005 or 2002. Comparisons among 2001, 2009, and 2012 instantaneous temperatures are more variable depending on what sites are being referenced (Appendix C, Figure C.25).

Instantaneous water temperature measurements collected during 2012 did not necessarily represent daily minimum, maximum, or average water temperature. Refer to Section 6.6 for the continuous water temperature data at select stations.

6.2.2 pH

Table 6.3 displays the pH measurements that were recorded above the maximum Wyoming Water Quality standard of 9.00 SU during the 2012 sampling season. The pH measurements ranged from 7.43 SU at GC4 (Soldier Creek) to 9.17 SU at GC1A (Appendix B, Table B.3-B26).

Table 6.3 Samples Exceeding the pH Standard (9 SU)

May 22, 2012		May 30, 2012		August 23, 2012	
Site	pH	Site	pH	Site	pH
LG22	9.06	GC1	9.07	BG18	9.05
		GC1A	9.17		
		LG13	9.07		
		LG22	9.04		

Average pH was 8.35 SU for the mainstem sites on Goose Creek; 8.56 SU for Big Goose Creek mainstem sites; and 8.55 SU for Little Goose Creek mainstem sites. Average pH for the tributary stations was 8.18 for tributaries in the Goose Creek subwatershed; 8.35 SU for tributaries in the Big Goose Creek subwatershed; and 8.47 SU for tributaries within the Little Goose subwatershed. Generally, pH geometric mean calculations during both May and August appear to be increasing since 2001 at several stations with an average increase of 0.48 SU in May and 0.31 SU in August (Table 6.4). The largest increase in pH geometric means was at LG22 for both May and August at 1.18and 1.07, respectively.

Table 6.4 Change in pH Geometric Mean Values from 2001 to 2012

		2001 to 2012 Change in Geometric Mean (SUs)	
		May	**August**
Mainstem Goose Creek Sites	GC1	0.43	- 0.29
	GC2	0.24	0.20
	GC5	0.18	0.02
	AVERAGE	**0.28**	**- 0.02**
Mainstem Big Goose Sites	BG1	0.47	0.19
	BG6	0.54	- 0.35
	BG10	0.81	- 0.27
	BG14	0.57	0.10
	BG18	1.14	0.93
	AVERAGE	**0.71**	**0.37**
Mainstem Little Goose Sites	LG2	0.40	- 0.30
	LG6	0.60	0.32
	LG8	0.44	- 0.36
	LG13	0.58	- 0.25
	LG20	0.43	0.47
	LG22	1.18	1.07
	AVERAGE	**0.61**	**0.46**
Tributary Sites	GC4	0.27	0.02
	BG9	0.15	0.12
	BG13	0.27	N/A
	BG16	0.51	0.03
	LG9	0.40	0.20
	LG11	0.18	0.17
	LG17	0.49	0.91
	LG19	0.38	0.60
	AVERAGE	**0.33**	**0.29**
TOTAL AVERAGE		**0.48**	**0.31**

Large increases in pH have occurred at both canyon sites since 2001, although both sites are below the WDEQ standard for surface water. If increases in pH continue, these canyon sites may exceed the water quality standard for the State of Wyoming in 2015; pH may need to be examined in greater detail in future sampling years.

6.2.3 Specific Conductivity

In general, the geometric mean for specific conductivity at mainstem stations in 2012 increased from upstream to downstream in Little Goose, Big Goose, and Goose Creek (Appendix C). Maximum, minimum, and average values for 2012 are presented in Table 6.5.

Table 6.5 2012 Maximum, Minimum, and Average Specific Conductivity

	Goose Creek Sites	Big Goose Creek Sites	Little Goose Creek Sites	Tributary Sites
Average	565.10	415.07	416.13	630.34
Maximum	834.0 (GC1)	871.0 (BG14)	745.0 (LG2)	1108.0 (BG13)
Minimum	302.0 (GC5)	45.0 (BG18)	52.0 (LG22)	242.0 (BG16)

On Goose Creek and Little Goose Creek, the most downstream sites produced the highest specific conductivity values and the highest upstream sites produced the lowest values. However, on Big Goose Creek, BG18 had the lowest value of specific conductivity, but only 4.3 miles downstream, BG14 produced the highest value. These values, though, were not procured on the same sampling day. Specific conductivity averages for 2012 remain the same for Little Goose and Big Goose Creek, and due to downstream flow, increase for Goose Creek. There is no standard for specific conductivity in the state of Wyoming; however, because specific 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.

6.2.4 Dissolved Oxygen

Dissolved oxygen (DO) values were fairly consistent among sites throughout the watershed, with most falling within the approximate range of 6.30 to 11.00 mg/L. There were only four occurrences on two sites that fell below the early life stages standard of 5.0 mg/L. These include one measurement from Goose Creek (GC1A) on July 31, 2012 (4.94 mg/L), and three measurements from Park Creek (BG13) on July 31st (3.18 mg/L), August 8th (4.92 mg/L), and August 15th, 2012 (4.39 mg/L). WDEQ recommends a water column concentration standard of 8.0 mg/L to achieve the 5.0 mg/L intergravel concentrations (WDEQ, 2007). Several stations returned at least one DO measurement below the water column concentration standard of 8.0 mg/L (Table 6.6). The most upstream mainstem sites (BG14, BG18, LG13, LG20, and LG22) produced no values below the 8.0 mg/L DO standard. Beaver Creek (BG9) was the only tributary site that never had a DO value below the 8.0 mg/L standard (Table 6.6).

Table 6.6 Dissolved Oxygen Values Below the Water Column Standard (8.0 mg/L)

Creek Name	Site ID	Dissolved Oxygen Concentration (mg/L)									
		May 2012					July-August 2012				
		5/10	5/16	5/22	5/24	5/30	7/31	8/8	8/15	8/23	8/28
Goose	GC1		7.34	7.16		7.80	6.53	6.49	6.35	6.66	6.75
	GC1A		7.42	7.25			4.94	6.77	5.46	5.84	6.21
	GC2						7.45		7.34	7.52	
	GC5								7.33	NS	
Big Goose	BG1								7.21		
	BG3A						6.63	6.48	7.77		6.67
	BG6								7.88		
	BG10						7.52				
	BG14										
	BG18										
Little Goose	LG2							7.61			
	LG6										
	LG8						7.92				
	LG13										
	LG20										
	LG22										
Soldier	GC4		7.80	7.88			6.30	6.72	6.76	6.82	7.88
Beaver	BG9										
Park	BG13		7.87	6.83	7.57		3.18	4.92	4.39	5.53	5.32
Rapid	BG16						7.94	6.88			
McCormick	LG9						7.69		7.76		
Kruse	LG11						7.26		7.45		
Jackson	LG17			6.50							
Sackett	LG19	7.89	7.77	7.08			6.12	6.67	7.60		7.53

NS: Concentration amount not recorded because of instrument malfunction.

Geometric mean values were calculated for all of the years sampled for each site. For the 2012 sampling year, every station had lower geometric mean values for DO in August than in May, except for BG14 (mainstem of Big Goose Creek), and LG17 (Jackson Creek) (Appendix C). The fluctuation between geometric mean values in May and August for all of the 24 stations ranged from 0.10 mg/L (LG8) to 3.14 mg/L (Park Creek). The largest decrease in a mainstem station was 2.35 mg/L (GC1A), and the smallest decrease in tributary stations was 0.52 mg/L (Beaver Creek). The average fluctuation of DO geometric mean values for stations that decreased from May to August was 1.25 mg/L, and the average fluctuation for stations that increased from May to August was 1.18 mg/L.

6.3 TURBIDITY

There is no turbidity standard for surface waters in the State of Wyoming except when it relates to point source discharges. Geometric means for samples collected in May were higher than in August at all stations, except for BG13 (Park Creek), LG11 (Kruse Creek), and LG22. Turbidity values ranged widely throughout the watershed, though values generally increased from upstream to downstream on the mainstem sites (Appendix B, Figures B.1 – B.5), except in August on Goose Creek. The highest turbidity value reported from a mainstem site was 32.8 NTUs at LG2 on May 24th, 2012; the lowest mainstem value was 0.8 NTU at BG18 on August 8th and 15th, 2012. The highest turbidity value reported from a tributary station was 67.1 NTUs at

GC4 (Soldier Creek) on May 30th, 2012; the lowest tributary value was 0.8 NTU at BG16 (Rapid Creek) on August 15th, 2012. Turbidity samples on tributary stations were typically higher than the values on nearby mainstem sites, with the exception of BG13 (Park Creek) with values ranging from 1.2 to 12.7 NTUs, and BG16 (Rapid Creek) with values ranging from 0.8 to 13.1 NTUs.

In 2012, geometric mean values for turbidity at the mainstem stations on Big Goose, Little Goose, and Goose Creek averaged 9.36 NTUs in May and 4.08 NTUs in August, a decrease of 5.28 NTUs. For tributary sites, geometric mean values for turbidity in 2012 averaged 15.07 NTUs in May and 9.81 NTUs in August, a decrease of 5.26 NTUs.

Turbidity geometric means for mainstem stations in 2012 were higher than in 2001, with the exception of BG18 and LG22 in May, and LG8 and LG22 in August (Appendix C). Turbidity geometric mean comparisons between 2001 and 2012 were more variable (Appendix C).

6.4 DISCHARGE

SCCD used calibrated staff gauges to estimate discharge during water sampling events (Appendix B, Table B.3 – B.26). Mainstem stations on Goose Creek and Big Goose Creek had high discharge from 5/22/2012 to 5/30/2012 with peak discharge occurring on 5/30/2012. The exceptions are BG14 and BG18, which had high discharge from 5/16/2012 to 5/30/2012. Little Goose Creek stations did not have high discharge and consequently peak discharge until 5/30/2012, with the exception of LG22 which had high discharge from 5/22/2012 to 5/30/2012.

High discharge timeframes differ on tributary stations depending on the subwatershed. In the Big Goose Creek and Goose Creek subwatersheds, high discharge was observed from 5/22/2012 to 5/30/2012 with peak discharge occurring on 5/30/2012. The exception was on BG13 (Park Creek), which had high discharge on 5/30/2012 and peak discharge on 7/31/2012. Discharge measurements on tributaries in the Little Goose Creek subwatershed varied slightly. LG9 (McCormick Creek) and LG11 (Kruse Creek) had high and subsequently peak discharge only on 5/30/2012, whereas LG17 (Jackson Creek) had high discharge from 5/24/2012 to 5/30/2012 with peak discharge on 5/30/2012. LG19 (Sackett Creek) did not have peak flow until 7/31/2012 and continued to show high discharge until 8/8/2012.

High discharge corresponds to an increase in precipitation or snowmelt, which were both lower than normal for this period during 2012 (Appendix B, Figure B.21). Discharge geometric means on Little Goose, Big Goose, and Goose Creeks were typically higher than in 2001, but lower than in 2009 (Appendix C). The same pattern was observed on most tributary stations, with the exception of Jackson Creek (LG17), Sackett Creek (LG19), and McCormick Creek (LG9).

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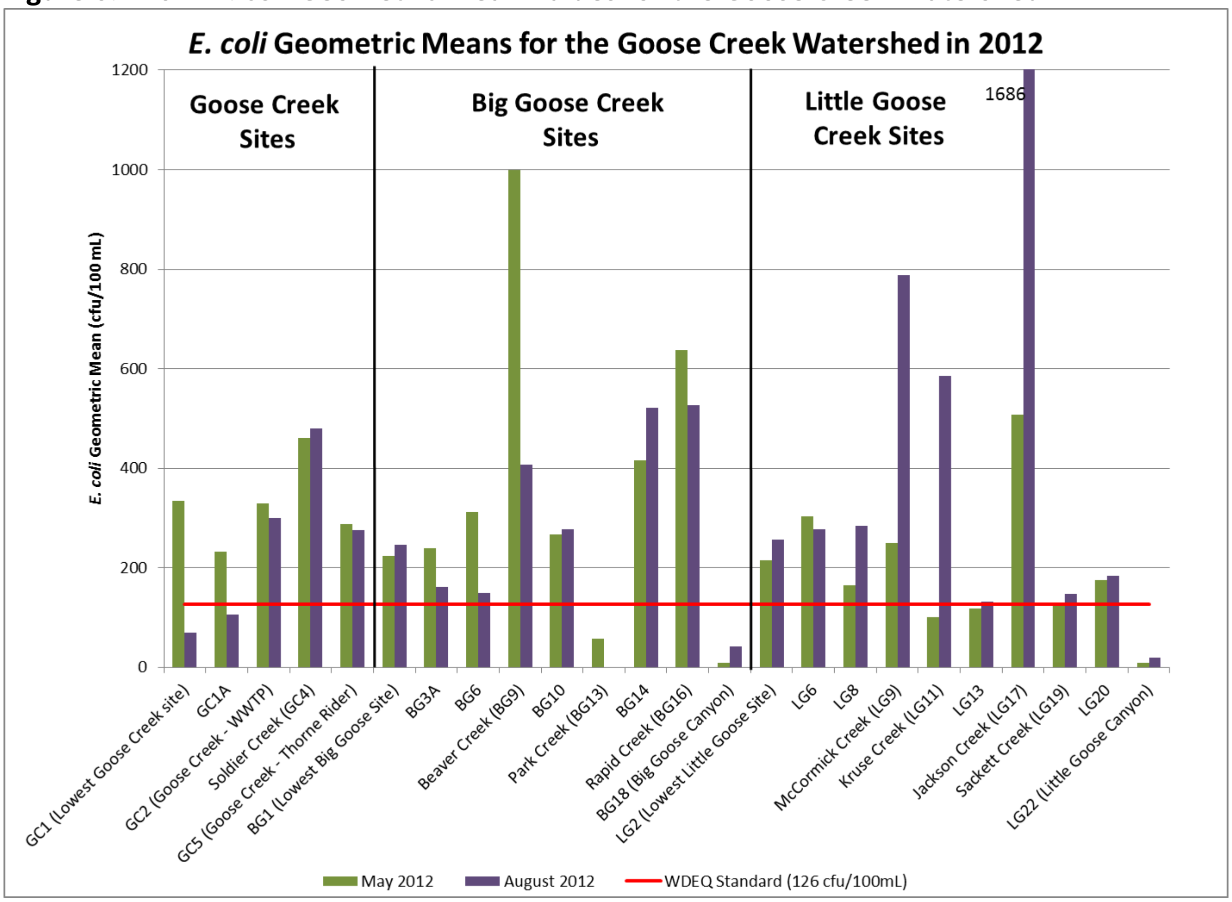
6.5 *E. coli* Bacteria

In the 2012 sampling season, ten *E. coli* bacteria samples (five in May, and five in July/August) were obtained from each of the 24 stations (Appendix B, Tables B.3 – B.26). Geometric means were then calculated for each of the sampling periods. Geometric mean bacteria concentrations at mainstem sites of Goose, Big Goose, and Little Goose Creeks were typically lower than tributary sites. Most stations had at least one geometric mean that exceeded Wyoming State Standards with the exception of BG18 and LG22 (Figure 6.1). In 2012, 13 out of 16 mainstem stations exceeded the *E. coli* standard in May, and 12 in August; six out of eight tributary stations exceeded the *E. coli* standard in May, and seven out of seven in August (Figure 6.1 and Appendix A, Maps 8 and 9). The August geometric mean for Park Creek (BG13) could not be calculated because of a lab error with one of the five samples.

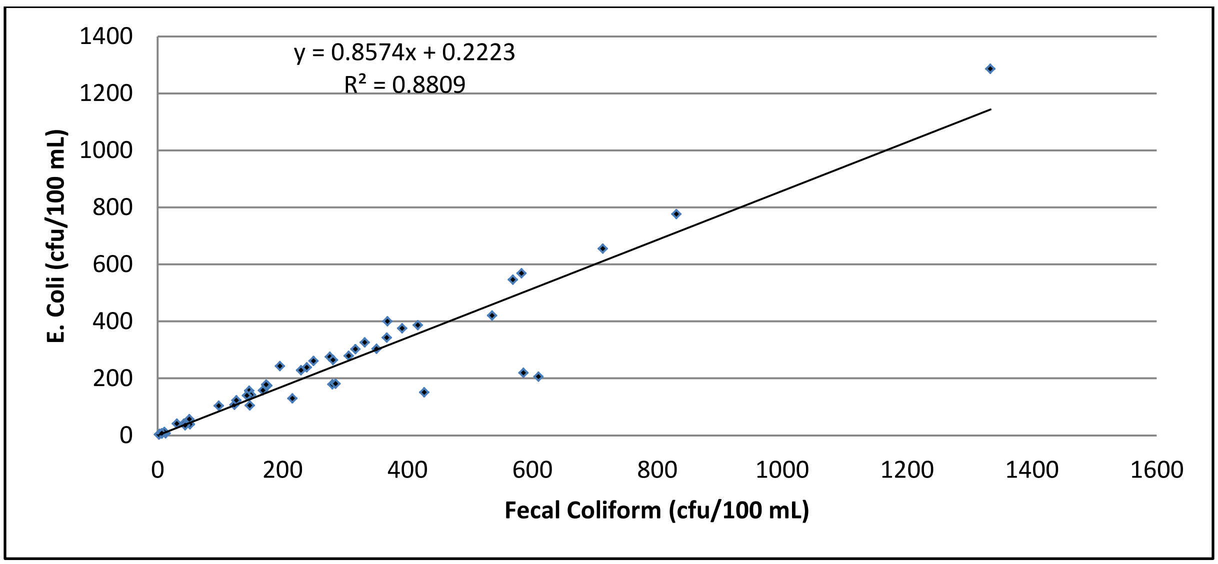
Figure 6.1 2012 *E. coli* Geometric Mean Values for the Goose Creek Watershed



For mainstem sites, the geometric means of *E. coli* bacteria ranged from 9 to 415 cfu/100mL in May, with an average geometric mean of 227 cfu/100mL, and a median of 236. For mainstem sites in August, the geometric mean values of *E. coli* bacteria ranged from 20 to 521 cfu/100mL, with an average and median geometric mean of 207 and 215 cfu/100mL, respectively. For tributary stations, the geometric means of *E. coli* bacteria ranged from 58 to 999 cfu/100mL in May, with an average geometric mean of 393 cfu/100mL, and a median of 355. For tributary sites in August, the geometric mean values of *E. coli* bacteria ranged from 148 to 1686 cfu/100mL, with an average of 660 cfu/100mL and median of 526 cfu/100mL.

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. 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 6.2). SCCD converted fecal coliform results from 2001 and 2002 to *E. coli* so comparisons among years could be made (Appendix C, Table C.1). 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 6.2 Fecal Coliform and *E. coli* bacteria comparison from samples collected by SCCD in 2002 and 2005



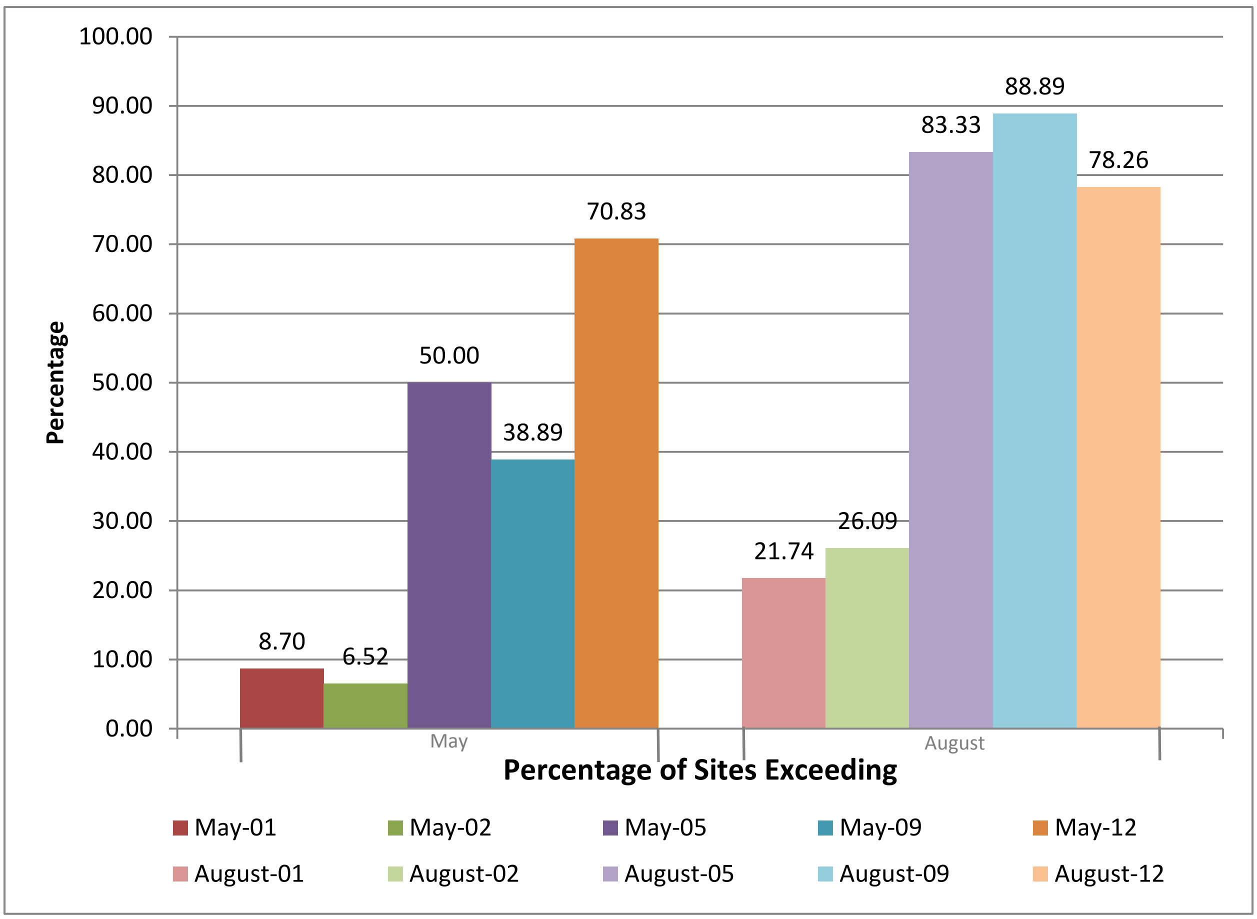
Of the 24 sites sampled in 2012, 22 were sampled in 2001-2002 and 16 were sampled in 2005 and 2009. Interim monitoring in 2005 and 2009 was conducted at 18 of the monitoring stations from the 2001-2002 assessment. The number of comparable mainstem sites with geometric means that exceeded the standard increased from 2001 to 2012 in both May and August (Table 6.7). The number of tributary stations that exceeded the *E. coli* standard in August has remained consistent since 2002. The percentage of total sites that exceeded the standard also increased from 2001-2012 (Figure 6.3).

Table 6.7 Number of comparable sites exceeding *E. coli* bacteria standard from 2001-2012

Sample Period	Number of Sites Exceeding			Comparable Sites Sampled		Total Sites Sampled
	Mainstem	Tributaries	Total	Mainstem	Tributaries	
May 2001	1	5	4	14	8	46
May 2002	2	2	3	14	8	46
May 2005	3	6	9	9	7	18
May 2009	2	3	7	9	7	18
May 2012	10	6	17	14	8	24
August 2001	6	6	10	14	7	45*
August 2002	6	7	12	14	7	45*
August 2005	6	7	15	9	7	18
August 2009	7	7	16	9	7	18
August 2012	11	7	18	14	7	23*

* Park Creek (BG13) was not sampled in August 2001 and 2002 because it was dry; it was not sampled again until 2012. The geometric mean for Park Creek was not calculated in August 2012 due to a spill at the lab.

Figure 6.3 Percentage of Monitored Sites Exceeding *E. coli* Standard From 2001 – 2012



An increase in bacteria concentrations from 2001 to 2012 was observed at every comparable site and sampling period, except for BG13 (Park Creek), and LG11 (Kruse Creek) during the month of May (Appendix C, Table C.1 and Figures C.31-C.34). When comparing 2012 bacteria concentrations to the sixteen comparable 2009 stations, all sites showed increases in May, with the exception of GC2. For mainstem sites, the largest percent increase from May 2009 to May 2012 was observed on BG18 (194%); however, this represents an increase from only 3 to 9 cfu/100mL. The next largest percent increase was at BG6 (174%), which increased from 114 to 312 cfu/100mL. On tributary stations, May bacteria concentrations increased 865% from 2009 to 2012 on Rapid Creek (BG16). The geometric means on Rapid Creek (BG16) for May 2009 and 2012 were 66 cfu/100mL and 637 cfu/100mL, respectively.

In August of 2012, bacteria concentrations increased at fourteen of the 21 comparable stations from 2001 (Appendix C, Table C.1 and Figures C.31-C.34). Two sites on Goose Creek (GC1, GC2), one site each on Big Goose and Little Goose Creek (BG1 and LG6), Soldier Creek (GC4), and Sackett Creek (LG19) produced geometric mean levels below levels observed in 2001. Bacteria concentrations increased from August 2009 to 2012 at 10 of the sixteen comparable stations, five of which were tributary sites. A decrease in bacteria concentrations from August 2009 to 2012 was observed at both of the comparable sites on Goose Creek (GC1, GC2), one site each on Big Goose Creek and Little Goose Creek (BG6, LG13), Beaver Creek (BG9), and Sackett Creek (LG19). The largest percent increase on the mainstem sites was observed at BG10 (68%). This represents an increase from 165 cfu/100mL to 278 cfu/100mL in August of 2009 to 2012, respectively. The largest increase observed on a tributary from August 2009 to 2012 was on Jackson Creek (LG17). Bacteria concentrations on Jackson Creek increased 265% from August 2009 (462 cfu/100mL) to August 2012 (1686 cfu/100mL).

Higher bacteria concentrations in May sampling periods can be associated with precipitation events in the spring, including run-off from snowmelt, that contribute many surface contaminants, not only bacteria, into the local waterways. In addition, deeper, faster moving water within the stream channels can scour and suspend sediment that has been previously deposited on the channel bottom. These bed sediments have been found to contain elevated levels of bacteria. Rangeland studies in Idaho have shown that *E. coli* concentrations can be 2 to 760 times greater in bottom sediment than in the water column (Stephenson and Rychert, 1982). A similar study on the Goose Creek watershed showed up to 3-fold increases of fecal coliform bacteria when disturbing the bed sediment (SCCD, 2003). The approximate duration for which sediment dwelling bacteria populations can remain viable is unknown.

Although several local improvement projects have been completed to benefit water quality (Appendix A, Map 10), many factors can affect bacteria concentrations, which make trend comparisons difficult. Changes in water temperature, water quantity, and suspended sediment loads can have an impact on bacteria concentrations. In 2012, air temperature was higher than normal and precipitation was lower.

6.6 CONTINUOUS WATER TEMPERATURE DATA

Onset's HOBO Pendent Temperature 64 Data Loggers were used at nine stations from May 1st through November 7th, 2012. There was one station on Goose Creek (GC1) and four each on Big Goose Creek (BG1, BG6, BG14, and BG18) and Little Goose Creek (LG2, LG8, LG20, and LG22). The temperature logger at LG2, 9775398, malfunctioned early in the season and would not transfer data into the Onset HOBO Watershed Shuttle. The manufacturing company was able to retrieve the data from May 1st to May 30th, but the logger was deemed unusable and was replaced.

Maximum water temperatures for GC1, BG1 (in comparison to BG2), and BG6 were higher in 2012 than in 2009 and 2005, but lower than in 2001 and 2002. Maximum water temperatures observed at BG18, LG2, and LG8 were highest in 2012 (Table 6.8). The first year that continuous temperature was recorded at BG14 and LG20 was 2012; therefore, comparisons among years could not be made. Water temperatures at BG14 were 4% lower than BG1, which is 13 miles downstream. Temperatures at LG 20 were 22% lower than LG2, 18 miles downstream, but 16% higher than LG22, which is 2 miles upstream.

Table 6.8 Number of days that exceeded the Temperature Standard (20°C) and maximum temperatures from the Continuous Temperature Loggers from 2001 to 2012

Site	Number of days when water temperatures exceeded 20°C					Maximum water temperature recorded(°C)				
	2001	2002	2005	2009	2012	2001	2002	2005	2009	2012
GC1	103	93	59	59	82	30.17	30.36	27.96	25.42	29.15
BG1/2	92	76	47	34	77	29.88	29.14	26.86	24.01	28.66
BG6	100	90	46*	31	77	30.52	31.67	28.73	24.42	30.46
BG14					65					27.47
BG18	0	0	0	0	0	19.74	18.93	19.11	16.37	19.95
LG2	110	88	55*	55	93	29.93	29.21	29.88	26.16	30.66
LG8	90	63	25*	20	69	27.29	27.65	25.44	22.81	30.15
LG20					48					23.87
LG22	2	0	0	0	1	20.62	18.51	18.88	16.75	20.52

Note: BG1 replaced BG2 in 2012; both sites are located within the City of Sheridan approximately 0.7 miles apart.
*Site had period during 2005 when data were not collected (logger lost or beached on streambank).

Maximum daily water temperatures on Goose Creek exceeded the water temperature standard (20°C) from 5/15/2012 to 5/17/2012 and again from 6/23/2012 to 9/9/2012 (Appendix B, Figure B7). The highest water temperature occurred on July 23rd, 2012 (29.15°C). The average maximum daily air temperature at the Sheridan Airport during 6/22/2012 through 9/10/2012 was 32.7°C (90.9°F). Average minimum daily air temperature during 6/22/2012 thru 9/10/2012 was 11.8°C (53.2°F). The maximum mean daily air temperature recorded was 28.33°C (83°F) on July 1, 2012.

All of the stations on Big Goose Creek, with the exception of BG18, reported maximum daily water temperatures above the water temperature standard from 6/26/2012 to 9/3/2012 (Appendix B, Figures B.8-B.12). Maximum water temperatures on Big Goose

Creek occurred on 7/23/12 and 8/8/12 at BG 1 (28.66°C), on 7/31/12 at BG6 (30.46°C), on 7/29/2012 at BG14 (27.47°C); and on 7/23/2012 at BG18 (19.95°C).

Maximum water temperatures above the water temperature standard occurred from 6/23/2012 to 9/2/2012 on all Little Goose Creek stations, with the exception of LG22 (Appendix B, Figures B.13-B.17). In addition, lower watershed stations had additional periods where daily temperatures exceeded the water temperature standard. Maximum water temperatures on Little Goose Creek occurred on 7/3/12 at LG2 (30.66°C), on 5/15/12 at LG8 (30.15°C), on 7/19/12 at LG20 (23.87°C), and 7/23/12 at LG22 (20.52°C). The maximum water temperature on LG2 is the only date that coincides with very high air temperature (38.9°C or 102°F). The maximum water temperature at LG8 occurred much earlier (5/15/12) than all other stations and is much higher than adjacent days.

Periods where maximum water temperatures exceeded the water temperature standard in 2012 seem to be longer than 2005 and 2009, but are shorter than 2001 and 2002 (Appendix B, Figures B.18-B.19). Water temperatures that exceed the water quality standard appear to consistently occur at lower stations from July 11th to August 7th of each sampling year. The two upper stations (BG18 and LG22) had a combined total of three days where maximum daily temperatures were above the water temperature standard. All of these occurred at LG 22, two in 2001 and one in 2012.

6.7 Hydrological and Meteorological Data

Mean daily air temperatures were below average during the beginning and end of May and October, and parts of June and August. Overall mean daily air temperatures were above normal mean daily temperatures for the Sheridan County Airport (Appendix B, Figure B.20). National Weather Service data at the Sheridan County Airport reported normal mean daily air temperatures from May 1st through October 31st that had an average of 16.52°C (59.45°F) while 2012 mean daily air temperatures had an average of 15.25°C (61.73°F). The average daily air temperatures for the months of July and August, 2012 were 24.48°C (76.06°F) and 21.22°C (70.19°F), respectively. Average normal air temperatures for the months of July and August were 21.20°C (70.16°F) and 20.56°C (69.00°F), respectively.

Precipitation in 2012 was lower than normal from May 1st thru October 31st, 2012 (Appendix B, Figure B.21). Precipitation from May 1st, 2012 through October 31st, 2012 was 7.94 inches. Normal precipitation for this same time period averages 12.91 inches.

There were no stream flow measurements or hydrological information collected at any of the USGS Stations for 2012.

6.8 Current USGS Water Quality Data

A summary of water quality data collected from USGS Station 06305500 from October 22, 2009 to October 25, 2012 is reported in Appendix B, Table B.27 Overall, the USGS parameter results that correspond to SCCD's water quality monitoring are similar to samples collected by SCCD. USGS collects a variety of other parameters including several heavy metals, nutrients, organic compounds, and trace elements; it was not within the scope of this project to evaluate these parameters.

6.9 Benthic Macroinvertebrates

Macroinvertebrate sampling and habitat assessments were performed at eight stations in September of 2012 (Appendix A, map 1).

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

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.

6.9.2 Benthic Macroinvertebrate Sampling In 2012

A total of nine benthic macroinvertebrate samples were collected by SCCD in 2012 from eight stations. Two benthic macroinvertebrate samples were collected from two Goose Creek stations (station GC1 and station GC2), four samples were collected from three Big Goose Creek stations (station BG2, station BG10 and station BG18) and three samples were collected from three Little Goose Creek stations (station LG2A, station LG10 and station LG22). Included in the total number of samples was a duplicate sample collected at Big Goose Creek station BG2. The duplicate sample was used only for QA/QC purposes, construction of taxa lists and for general discussion of macroinvertebrate results. The duplicate sample was not used for the determination of biological condition.

The number of sampling stations and the number of samples collected by SCCD in 2012 were slightly higher than the number of stations sampled and number of samples collected in both 2005 and 2009. 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 sample stations and samples collected during 2005, 2009 and 2012 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 and 2009 were the same as those used for sampling in 2012. 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 2012 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.

6.9.3 Benthic Invertebrate Taxa

Taxa lists for Goose Creek watershed benthic macroinvertebrate samples collected in 2012 are presented in Appendix D, Tables D.1-D.9. The cumulative list of macroinvertebrate taxa identified from samples collected in the Goose Creek watershed from 2001 through 2012 is presented in Appendix D, Table D.10. The list of benthic macroinvertebrate metrics for samples collected in 2001, 2002, 2004, 2005 and 2009 for those stations sampled only during 2012 is presented in Appendix D, Tables D.11-D.14.

A total of 232 benthic macroinvertebrate taxa have been identified since 2001 from a total of 75 samples collected during the project (Appendix D, Table D.10). All taxa have been previously identified from north-central Wyoming streams and rivers with the exception of the mayfly genera *Tricorythodes explicates* and *Stenonema femoratum* and the cranefly genus *Pseudolimnophila*. The common mayfly genus *Tricorythodes minutus* was synonymized with *Tricorythodes explicates* by Baumgardner (2009). Accordingly, previous taxa lists containing *Tricorythodes minutus* will be replaced with *Tricorythodes explicates.* The presence of *Stenonema femoratum* is likely due to enhanced taxonomic resolution since the genus *Stenonema* has been previously identified at Goose Creek station GC3 and Big Goose Creek stations BG8 and BG10. *Stenonema femoratum* was identified from six sampling stations during 2009 suggesting that it may be common within the lower portion of the watershed.

The cranefly genus *Pseudolimnophila* is widespread throughout the United States (Merritt et al., 2008) and will likely be found in other north-central Wyoming streams with additional sampling. *Pseudolimnophila* was found only at the most upstream Big Goose Creek foothill station BG18.

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 96% of the total samples collected (Appendix D, Table D.10). The riffle beetle genus *Microcylloepus* (88%), Acari (water mites) (88%), the midge fly genera *Cricotopus* (88%) and *Rheotanytarsus* (80%), the mayfly genus *Tricorythodes* (83%), and the caddisfly genus *Hydropsyche* (81%) 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 79 percent of samples. The Diptera family Chironomidae (midges) had the greatest number of taxa in the project area (N = 56 taxa), followed by the order Ephemeroptera (N = 38 mayfly taxa), the order Trichoptera (N = 34 caddisfly taxa), the class Oligochaeta (N = 14 worm taxa), the order Plecoptera (N = 12 stonefly taxa), the Diptera family Tipulidae (N = 10 cranefly taxa) and the Coleopteran family Elmidae (N = 8 riffle beetle taxa) (Appendix D, Table D-10).

6.10 BIOLOGICAL CONDITION

Biological condition scores were determined using the Wyoming Stream Integrity Index (WSII) initially developed by Jessup and Stribling (2002) and revised by Hargett and ZumBerge (2006). The WSII is based on the analysis of benthic macroinvertebrate monitoring data collected by WDEQ from 1993 through 2001 from multiple reference and non-reference quality streams statewide. The WSII identified seven bioregions for Wyoming. Each bioregion used different scoring criteria because the biological communities naturally differ between bioregions.

Biological condition scoring criteria developed for the Bighorn and Wind River Foothills bioregion were used to evaluate biological condition for streams in the Goose Creek watershed within the project area. Table 6.9 lists the WSII metrics and metric formulae used to determine biological condition for benthic macroinvertebrate communities in the Bighorn and Wind River Foothills bioregion.

Table 6.9 Wyoming Stream Integrity Index (WSII) metrics and scoring criteria for benthic macroinvertebrate communities in the Bighorn and Wind River Foothills bioregion (from Hargett and ZumBerge, 2006)

Macroinvertebrate Metric	Metric Scoring Formulae	5^{th} or 95^{th} %ile (as per formula)
No. Ephemeroptera Taxa	100*X / 95^{th}%ile	9
No. Trichoptera Taxa	100*X / 95^{th}%ile	11
No. Plecoptera Taxa	100*X / 95^{th}%ile	7
% Non-insect	100*(74-X) / (74-5^{th}%ile)	0.3
% Plecoptera	100*X / 95^{th}%ile	19
% Trichoptera (w/o Hydropsychidae) (% within the Trichoptera)	100*X / 95^{th}%ile	100
% Collector-gatherer	100*(91.4-X) / (91.4-5^{th}%ile)	16.5
% Scraper	100*X / 95^{th}%ile	50.3
HBI	100*(8-X) / (8-5^{th}%ile)	1.8
No. Semivoltine Taxa (less semivoltine Coleoptera)	100*X / 95^{th}%ile	5

The calculated biological condition value was then used to rate the biological community as Full-support, Indeterminate, or Partial/Non-support (Table 6.10). A biological condition rating of Full-support indicates full support for narrative aquatic life use. The Indeterminate biological classification is not an attainment category in itself, but is a designation indicating the need for additional information or data to determine the proper narrative aquatic life use designation such as Full-support or Partial/Non-support (Hargett and ZumBerge, 2006). The Partial/Non-support classification indicates the aquatic community is stressed and water quality or habitat improvements are required to restore the stream to full support for narrative aquatic life use.

Table 6.10 Assessment rating criteria for benthic macroinvertebrate communities based on the Wyoming Stream Integrity Index (WSII); (from Hargett and ZumBerge, 2006) in the Bighorn and Wind River Foothills bioregion of Wyoming.

Rating of Biological Condition (Aquatic Life Use Support)	Bighorn and Wind River Foothills bioregion
Full Support	>62.1
Indeterminate Support	41.4 – 62.1
Partial/ (Non - Support)	0-41.3

Table 6.11 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 2012 is presented in Table 6.12.

Table 6.11 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 6.12 Biological condition score and rating for comparable historic and current Goose Creek Watershed benthic macroinvertebrate sample stations sampled in 2012; based on the Wyoming Stream Integrity Index (WSII) for the Bighorn and Wind River Foothills bioregion (from Hargett and ZumBerge, 2006).

Sampling Station	Sampling Year	Sampling Group	Score	Rating
Goose Creek GC1	2012	SCCD	33.4	Partial/Non-support
	2009	SCCD	32.8	Partial/Non-support
	2005	SCCD	38.4	Partial/Non-support
	2002	SCCD	34.9	Partial/Non-support
	2002 - Duplicate	SCCD	37.9	Partial/Non-support
	2001	SCCD	33.8	Partial/Non-support
	1998	WDEQ	40.2	Partial/Non-support
Goose Creek GC2	2012	SCCD	26.6	Partial/Non-support
	2009	SCCD	30.1	Partial/Non-support
	2005	SCCD	29.4	Partial/Non-support
	2002	SCCD	25.0	Partial/Non-support
	2002 - Duplicate	SCCD	26.7	Partial/Non-support
	2001	SCCD	21.1	Partial/Non-support
	1998	WDEQ	38.2	Partial/Non-support
Big Goose Creek BG2	2012	SCCD	33.0	Partial/Non-support
	2012 - Duplicate	SCCD	34.9	Partial/Non-support
	2009	SCCD	37.6	Partial/Non-support
	2009 - Duplicate	SCCD	37.6	Partial/Non-support
	2005	SCCD	31.8	Partial/Non-support
	2004	WDEQ	35.4	Partial/Non-support
	2002	SCCD	35.2	Partial/Non-support
	2001	SCCD	40.9	Partial/Non-support
	1998	WDEQ	47.4	Indeterminate Support
	1994	WDEQ	34.1	Partial/Non-support
Big Goose Creek BG10	2012	SCCD	43.7	Indeterminate Support
	2009	SCCD	46.6	Indeterminate Support
	2005	SCCD	37.6	Partial/Non-support
	2002	SCCD	45.8	Indeterminate Support
	2001	SCCD	55.1	Indeterminate Support
Big Goose Creek BG18	2012	SCCD	64.1	Full
	2002	SCCD	63.6	Full
	2001	SCCD	65.6	Full
	1998	WDEQ	82.1	Full
Little Goose Creek LG2A	2012	SCCD	29.3	Partial/Non-support
	2009	SCCD	32.1	Partial/Non-support
	2005	SCCD	33.9	Partial/Non-support
	2004	WDEQ	27.6	Partial/Non-support

Table 6.12 (continued).

Sampling Station	Sampling Year	Sampling Group	Score	Rating
Little Goose Creek LG2A (continued)	2002	SCCD	32.1	Partial/Non-support
	2001	SCCD	24.4	Partial/Non-support
	1998	WDEQ	35.9	Partial/Non-support
	1997	WEST *	30.2	Partial/Non-support
	1994	WDEQ	22.0	Partial/Non-support
Little Goose Creek LG10	2012	WDEQ	40.1	Partial/Non-support
	2009	SCCD	38.7	Partial/Non-support
	2005	SCCD	33.7	Partial/Non-support
	2002	SCCD	37.9	Partial/Non-support
	2001	SCCD	44.6	Indeterminate Support
	2001 - Duplicate	SCCD	42.5	Indeterminate Support
Little Goose Creek LG22	2012	SCCD	62.1	Indeterminate Support
	2002	SCCD	76.4	Full
	2001	SCCD	80.3	Full
	1998	WDEQ	81.5	Full
	1996	WDEQ	70.4	Full

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

6.10.1 Goose Creek Biological Condition

Biological condition was partial/non-supporting at Goose Creek stations GC1 and GC2 during sampling each year (Table 6.12). Biological condition has declined slightly since 1998 at both stations (Figure 6.4). The slight improvement in biological condition at Goose Creek station GC2 noted from 2001 to 2009 was not observed in 2012. Biological condition at Goose Creek station GC1 has been relatively consistent since 2001.

Continued sampling should be conducted at station GC1 and station GC2 and at all original Goose Creek stations to determine if the changes observed in biological condition through 2012 continue. The generally low biological condition scores continue to indicate 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.

6.10.2 Big Goose Creek Biological Condition

Biological condition was partial/non-supporting at Big Goose Creek station BG2 during the most recent sampling event in 2012 (Table 6.12). Biological condition has varied at this station since 1994 (Figure 6.4). 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 2009 with a subsequent slight decrease from 2009 to 2012. A similar pattern was observed at station

BG10 where biological condition decreased from 2001 to 2005 with a subsequent increase in biological condition from 2005 to 2009, then a slight decrease from 2009 to 2012.

Biological condition at the most upstream Big Goose Creek reference station BG18 has been fully supporting since 1998 (Table 6.12 and Figure 6.4). However, biological condition has decreased over time and the station may not fully support aquatic life use in the future should this trend continue.

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 in 2001 have been consistently sampled. Whether biological condition has improved or declined at the other Big Goose Creek stations since 2002 is unknown since they were not sampled.

Continued macroinvertebrate sampling should be conducted at all Big Goose Creek stations to track potential changes in biological condition.

6.10.3 Little Goose Creek Biological Condition

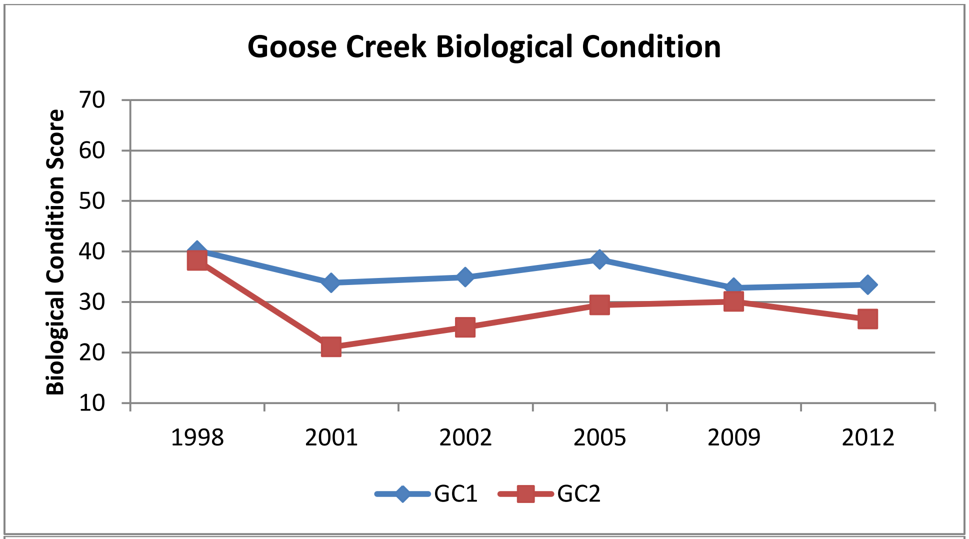
Biological condition at station LG2A has been partial/non-supporting since sampling by WDEQ began in 1994 (Table 6.12; Figure 6.4). Biological condition scores were more variable at station LG2A when compared to any other station in the Goose Creek watershed. This observation may be due to the fact that this station is located downstream of a large storm drain outfall that likely discharges highly variable quantity and quality of storm drain effluent. In contrast, biological condition at station LG10 decreased from 2001 to 2005 with a subsequent increase in biological condition from 2005 to 2012.

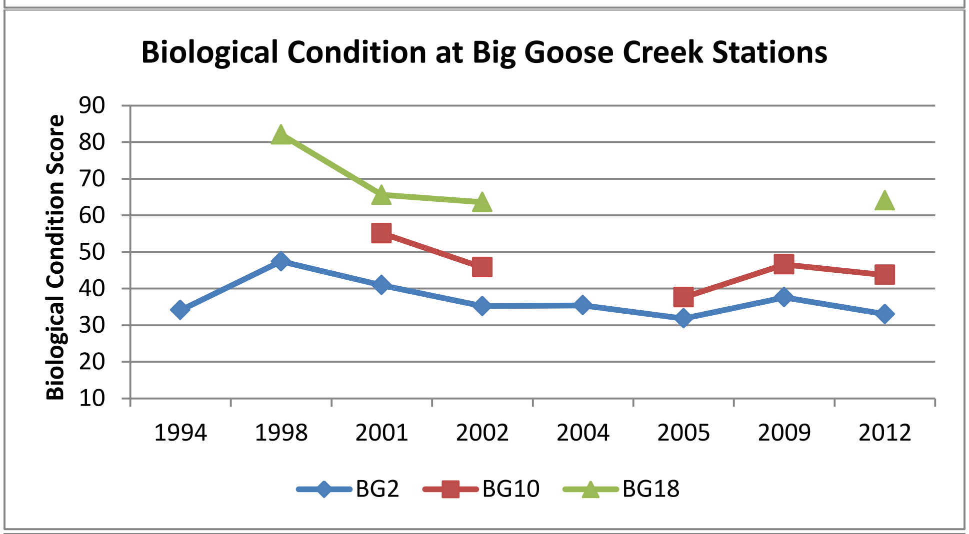
Biological condition at the most upstream Little Goose Creek reference station LG22 has been fully supporting from 1996 to 2002 with a decrease to indeterminate support in 2012 (Table 6.12 and Figure 6.4). The trend in biological condition at station LG22 was similar to the trend in biological condition at the Big Goose Creek reference station BG18 in that both stations have exhibited a decline in biological condition since 1998.

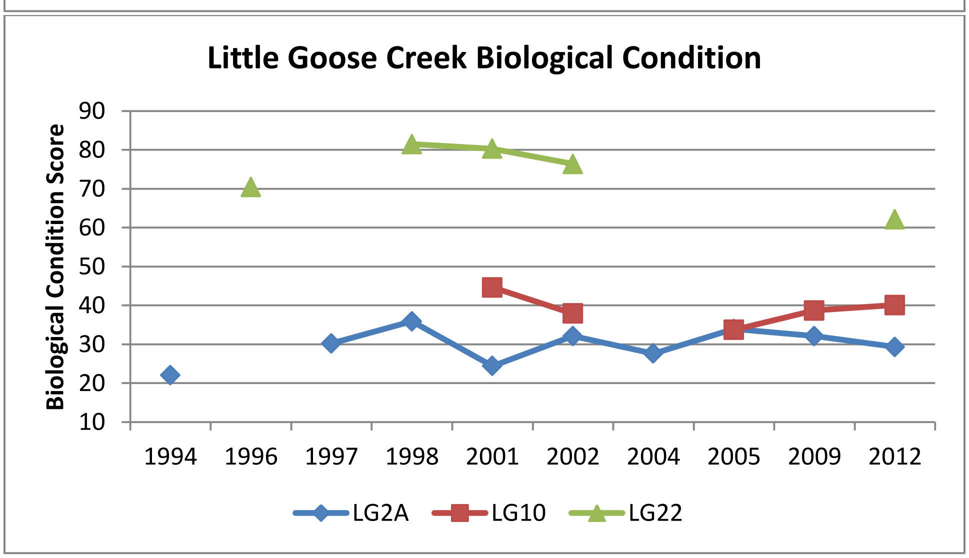
Change in the benthic macroinvertebrate communities through the entire length of Little Goose Creek within the project area could not be determined because only two stations (LG2A and LG10) were consistently sampled out of the total seven benthic macroinvertebrate stations established in 2001. Whether 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 to track potential changes in biological condition with special consideration toward monitoring the apparent upward trend in biological condition noted at station LG10 since 2005. Planning and implementation of remedial measures to restore full aquatic life use support in Little Goose Creek should continue.

Figure 6.4 Biological condition trends at select stations in the Goose Creek Watershed







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6.11 HABITAT ASSESSMENTS

6.11.1 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). 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. The reduced number of stations assessed during 2005 and 2009 (as well as during 2012) prevented a direct comparison of stream habitat at the thirteen other stations established on Goose Creek, Big Goose Creek, and Little Goose Creek since these stations were not assessed for habitat.

6.11.2 HABITAT ASSESSMENTS IN 2012

A total of nine habitat assessments were conducted by SCCD in 2012 from nine stations. Two habitat assessments were conducted from two Goose Creek stations (station GC1 and station GC2), three habitat assessments were conducted from three Big Goose Creek stations (station BG2, station BG10 and station BG18) and three habitat assessments were conducted from three Little Goose Creek stations (station LG2A, station LG10 and station LG22).

The number of stations assessed by SCCD in 2012 was slightly higher than the number of stations assessed in both 2005 and 2009. Big Goose Creek upstream 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 and 2012 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 and 2009 were the same as those used in 2012.

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.

6.11.3 Goose Creek Habitat Assessments

There was no large change in habitat at Goose Creek stations GC1 or GC2 since 2001. The total habitat score at station GC1 varied little between years ranging from a total score of 121.5 in 2001 to a total score of 131 in 2012 (Appendix E, Table E.1). Stream substrate composition at station GC1 and station GC2 generally improved since 2001 with an increase in percent cobble and percent coarse gravel, and a decrease in sand. A mixture of substrate of different sizes was present and provided good microhabitat for the establishment and maintenance of a diverse benthic macroinvertebrate community which serves as a food source for fish. The amount of fine silt covering cobble and gravel (the weighted embeddedness value) was variable at station GC1 and station GC2 since 2001.

6.11.4 Big Goose Creek Habitat Assessments

Habitat quality at Big Goose Creek station BG2 has improved slightly from 2001 to 2012 (Appendix E, Table E.2). The habitat quality at station BG10 declined from 2001 to 2005, then improved to 2009 and decreased slightly in 2012. 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 percent in 2012. 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 indicated an unknown disruption within the watershed upstream of this station that contributed sand to the stream bed. 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, and 79 percent of substrate in 2012 (Appendix E, Table E-2). Stream habitat was the best at the most upstream reference station BG18. Total habitat scores ranged from 146 in 2002 to 167 in 2001. In 2012, the habitat score for BG18 was 165.5. The stream substrate at station BG18 was dominated by cobble ranging from 49 percent in 2001 to 72 percent in 1998; 2012 showed 60 percent dominance by cobble.

6.11.5 Little Goose Creek Habitat Assessments

Habitat quality has remained low at Little Goose Creek station LG2A since 2001-2002 (Appendix E, Table E.3). The lower habitat score (77) at station LG2A during 2012 was due primarily to channelization of Little Goose Creek for flood control in Sheridan that reduced undercut banks, the number of pools, instream cover for fish, and the riparian zone. The channelization for flood control isolated the stream from the normal floodplain affecting the dynamics of stream flow and disrupting stream habitat at and downstream from the immediate channelized reaches. The habitat quality at station LG2A ranked 2nd lowest among all stations assessed in the Goose Creeks watershed during 2001-2002 (SCCD, 2003). Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 18 percent of the stream substrate since 1994, which was considered relatively high.

There were no large changes in habitat at Little Goose Creek station LG10 from 2001 to 2012 (Appendix E, Table E.4). The average total habitat assessment score since 2001 for LG10 was 137 during this period compared to an average total habitat assessment score of 98 at station LG2A. Cobble dominated the stream substrate followed by coarse gravel and then sand. Sand has averaged about 16 percent of the stream substrate since 2001, which was considered relatively high.

Upstream reference station LG22 exhibited the best habitat. Total habitat scores ranged from 150 in 2012 to 172 in 1998 (Appendix E, Table E.4). The stream substrate at station LG22 was dominated by cobble ranging from 50 percent in 2002 to 72 percent in 1998. In 2012, the cobble substrate at station LG22 was 69 percent. Mean coarse gravel, fine gravel and sand comprised 11 percent, 12 percent, and 12 percent of the total stream substrate, respectively. The mean weighted embeddedness value (amount of silt covering and surrounding cobble and gravels) was 93 indicating that about 95 percent of cobble and gravels were free of silt.

6.12 Relation Of Habitat Assessments To Biological Condition

Good stream habitat is critical for the establishment and maintenance of good fishery, benthic macroinvertebrate populations and other aquatic life. Habitat quality is directly related to biological condition at streams in the Goose Creek watershed (see Figure 8-99 in *Goose Creek Watershed Assessment 2001-2002, Final Report* (SCCD, 2003)). The relationship between habitat quality and biological condition was strong and significant (Correlation Coefficient = 0.7235; $p<0.99$). This relationship is important because improvement in habitat quality, in the absence of effects due to water quality, will result in improved biological condition. Those Goose Creek, Big Goose Creek and Little Goose Creek stations exhibiting Indeterminate Support or Partial/ Non - Support of aquatic life use may be improved by enhancing habitat quality.

Chapter 7 Conclusions and Recommendations

2012 sampling season experienced higher than normal air temperatures and lower than normal precipitation, which resulted in drought conditions for Sheridan County. Water quality data collected by SCCD on the Goose Creek watershed were generally obtained during below normal flow conditions during 2001 and 2002, and during higher than normal flow conditions during 2005 and 2009. Although normal flow conditions cannot be anticipated nor expected during monitoring, these varying conditions do make water quality comparisons more difficult.

Instantaneous water temperature measurements were recorded above the maximum 20°C instream temperature standard at least once at all sites except for BG 18 and LG22, which are located in the canyons. Every continuous temperature logger reported water temperatures above the maximum instream temperature standard of 20°C – often for multiple days – except for station BG18.

Generally, pH geometric mean calculations during both May and August appear to be increasing since 2001. Most extreme increases in pH since 2001 occurred in the two most upstream canyon sites, LG22 and BG18. Changes in pH may need to be examined in greater detail in future sampling years.

E. coli bacteria concentrations are known to vary due to a number of different water quality and water quantity factors. During the past several years of monitoring on the Goose Creek, Tongue River, and Prairie Dog Creek watersheds, SCCD has observed the greatest variations in bacteria concentrations during and shortly after heavy precipitation and/or snow melt run-off events. Even with the varying air and water temperatures, and precipitation levels, the general trend in bacteria concentrations on Goose Creek appears to be increasing upward since 2001, and more sampling sites are reaching above the bacteria standard. An increase in bacteria concentrations from 2001 to 2012 was observed at every comparable site and sampling period, except for BG13 (Park Creek), and LG11 (Kruse Creek) during the month of May.

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 resulted in increased bacteria concentrations through additional run-off and overland flow and resuspension of instream sediments. The extremes in short and long-term weather conditions during the years of monitoring on the watershed have produced bacteria data that are not directly comparable between years. Nonetheless, exceedances in bacteria standards have occurred on essentially the same stream reaches year after year and indicate that the water quality impairments continue to exist, regardless of hydrologic conditions.

Biological condition at Goose Creek stations GC1 and GC2, Big Goose Creek stations BG2 and BG10 and Little Goose Creek stations LG2A and LG10 sampled in 2012 were partial/non-supporting based on the evaluation of the stream benthic macroinvertebrate communities.

Biological condition at the Big Goose Creek most upstream reference station (BG18) was fully supporting while biological condition at the Little Goose Creek most upstream reference station (LG22) was indeterminate supporting. The partial/non-support and indeterminate support classifications 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. Continued benthic macroinvertebrate sampling should be conducted at stations in the watershed to track potential changes in habitat quality. Planning and implementation of remedial measures to restore full aquatic life use support in the streams in the Goose Creek watershed should continue. Habitat quality can be improved at minimal cost often by minor changes in management of the riparian zone and stream corridor by landowners. Implementations of Best Management Practices (BMPs) to improve habitat quality also serve to reduce water pollutants from entering streams. BMPs can be effective if implemented and maintained over time.

Attempts to determine if BMPs and improvement projects have improved overall water quality are often difficult, especially when comparing water quality data that has been collected during seasons varying significantly in hydrological and meteorological conditions. The positive effects on water quality improvement projects through the local watershed planning and implementation efforts are not readily measurable at this time. The watershed planning process has improved widespread local awareness about several important resource issues and has led to more public interest in the watershed. The SCCD anticipates that voluntary, incentive based watershed planning and implementation efforts will be successful; however, it may require several years to actually measure these achievements. Continued monitoring can provide information on water quality changes over the long-term.

CHAPTER 8 REFERENCES

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

Baumgardner, D.E. 2009. *Tricorythodes minutus* Traver, A new synonym of *Tricorythodes explicatus* Eaton (Ephemeroptera: Leptohyphicae). Proceedings of the Entomological Society of Washington. 111(1); 57-67.

Eaton, A., L. Clesceri, A. Greenberg. 1995. Standard Methods for the examination of water and wastewater. Washington, D.C.

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

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

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

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

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

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

Merritt, R.W., K.W. Cummins, and M.B. Berg. 2008. An introduction to the aquatic insects of North America. Fourth Edition. Kendall/Hunt Publishing Company. Dubuque, IA.

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

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

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

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

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

Sheridan County Conservation District. 2010. Water Quality Monitoring Program, Quality Assurance Project Plan. Revision Number 3. Sheridan, WY.

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

Sheridan County Conservation District. 2012. 2012 Goose Creek Watershed Monitoring Project: Sampling and Analysis Plan. Sheridan, WY.

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

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

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

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

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

U.S. Environmental Protection Agency. 1977. Basic water monitoring program. EPA-440/9-76-025.

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

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

U.S. Environmental Protection Agency. 1986. Quality criteria for water: 1986. Office of Water Regulation and Standards. Washington, D.C.

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

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

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

United States Geological Survey. 1999. The quality of our nation's waters-nutrients and pesticides. USGS circular 1225. Reston, VA. 82 pp.

Winget, R.N. and F.A. Mangum. 1979. Biotic condition index, integrated biological, physical, and chemical stream parameters for management. United States Department of Agriculture, Forest Service, Intermountain Region.

Wyoming Department of Environmental Quality. 2001. Wyoming Surface Water Classification List. Water Quality Division, Surface Water Standards. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2004. Manual of Standard Operating Procedures for sample collection and analysis. Cheyenne, WY.

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

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

Wyoming Department of Environmental Quality. 2007. Water Quality Rules and Regulations, Chapter 1, Quality standards for Wyoming surface waters. Cheyenne, WY.

Wyoming Department of Environmental Quality. 2010. Wyoming's Water Quality Assessment and Impaired Waters List (2010 Integrated 305(b) and 303(d) Report). Cheyenne, WY.

Wyoming Department of Environmental Quality. 2012. Wyoming's Water Quality Assessment and Impaired Waters List (2012 Integrated 305(b) and 303(d) Report). Cheyenne, WY.

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APPENDICES

APPENDIX A

PROJECT AREA MAPS

APPENDIX B

2012 WATER QUALITY DATA ON THE GOOSE CREEK WATERSHED

APPENDIX C

2001-2012 WATER QUALITY GEOMETRIC MEAN DATA AND CHARTS

APPENDIX D

BENTHIC MACROINVERTEBRATE DATA

APPENDIX E

HABITAT ASSESSMENT DATA

APPENDIX F

2012 QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION

APPENDIX G

2012 PHOTOGRAPHS IN THE GOOSE CREEK WATERSHED