SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM ASSESSMENT/PLANNING PROJECT FINAL REPORT

BEAR BUTTE CREEK WATERSHED ASSESSMENT

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Project Sponsor:
Elk Creek Conservation District

October, 2018

This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

EPA Grant # C999 8185-99

Executive Summary

The primary objectives of this project were to (1) assess the current physical, chemical, and biological integrity of Bear Butte Creek, (2) locate and document non-point source critical areas and sources of impairment, (3) produce feasible restoration alternatives to support a watershed implementation project to reduce water quality impairments within the creek, and (4) develop a Total Maximum Daily Load (TMDL).

Bear Butte Creek, from the headwaters to the Lawrence County line, was included in the 1998 South Dakota 303(d) impaired waterbodies list (SD DENR, 1998) for total suspended solids (TSS), cadmium, copper, and zinc. The 2002 South Dakota impaired waterbodies list (SD DENR, 2002) indicated that Bear Butte Creek was meeting heavy metals criteria during the 1996-2001 reporting period, so the stream was delisted for cadmium, copper, and zinc. Lower Bear Butte Creek met all beneficial uses criteria during this reporting period; however, the stream segment from headwaters to the confluence with Strawberry Creek was listed for TSS. Bear Butte Creek was delisted in 2004, as the 2002 TSS listing was determined to be an error. Currently, Bear Butte Creek is not listed as an impaired waterbody (SD DENR, 2004). However, data collected during this study period indicates a need for a TMDL for TSS impairment, as greater than 10% of TSS samples at two monitoring sites exceeded the state water quality standard.

While sampling periods varied among watershed monitoring sites, a two-year study period or “averaging period” (water years 1999 and 2000; i.e. October 1, 1998 through September 30, 2000) was defined for this assessment report in order to make comparisons among sites. Data was collected by three agencies: the United States Geological Survey (USGS) performed monthly and event water quality sampling at four Bear Butte Creek sites; South Dakota Department of Environment and Natural Resources (SD DENR) Surface Water Quality Program performed monthly water quality sampling at three headwater sites (two on Bear Butte Creek, one on Strawberry Creek); SD DENR Water Resources Assistance Program performed water quality sampling and habitat analysis (the four Bear Butte Creek sites also sampled by USGS, two Spring Creek sites, and one Cottle Creek site).

Landuse and regional geology of the Bear Butte Creek watershed were considered in order to compare habitat and water quality along the length of the creek. The creek flowed across four Level IV ecoregions: the headwaters of the creek flowed from the Black Hills Core Highlands (granitic and metamorphic rock) and then across the Black Hills Plateau (metamorphic and sedimentary rock), where flows of less than 12 cubic feet per second (cfs) were lost for much of the year. Stream flow typically reemerged on the outer edge of the Black Hills Foothills ecoregion, an area of sandstone and shale formations east of Sturgis, SD. From this area, the creek flowed through the Semiarid Pierre Shale Plains before meeting the confluence of the Belle Fourche River.

The habitat and water quality issues within the creek were as variable as its ecoregion characteristics. Water quality parameters above the loss zones showed elevated ammonia, dissolved solids, and conductivity concentrations, primarily due to the effects of abandoned mine drainage and cleanup. The available habitat in this area (core highland and plateau

region) was of higher quality due to a higher density canopy cover and larger average substrate diameter (cobble and coarse gravel). Water quality below the loss zones showed a tendency toward higher total suspended solids and fecal coliform concentrations and lower dissolved oxygen levels. The available habitat in this area (shale plains region) was of generally poorer quality due to a general lack of canopy cover and smaller average substrate diameter (silt).

As previously discussed, elevated TSS concentrations instigated this assessment. Highest TSS concentrations in the study were observed at lower Bear Butte Creek sites and the Spring Creek tributary. Water quality sampling revealed 10 exceedances of the TSS standard among all sites over a two-year period. Approximately 13% of samples collected at site BB-3 exceeded the TSS standard, and 17% of samples collected at site BB-4 exceeded the standard.

Surges in sediment, nutrient, and fecal coliform bacteria transport were detected during periods of rising flow. For the 10 observed TSS exceedances, the measured stream flow at the time of sample collection was 48 cfs or greater. To consider the probability of TSS exceedance, mainstem TSS concentration data were related to stream flow rate data. TSS concentrations were positively correlated to stream flow.

Results from the habitat analysis showed the least habitat impairment at site BB-2, which was rated at 79% comparibility to ideal habitat conditions. The habitat quality of the remaining sites ranged from severe to slight impairment. Overall, the two most important factors in the decline of habitat quality were the lack of available substrate and cover and increased sedimentation. The Spring Creek site (SC-1) was the lowest-scored habitat, based on a lack of stable instream habitat, the prevalence of shallow over deep pools, moderate sedimentation, lack of channel sinuosity, and narrow riparian zones. The substrate at SC-1 contained the highest percentage of silt in the study (96%).

FLUX model results from site BB-4 were used to set the TMDL goal, as this site required the greatest level of TSS load reduction and provides a conservative TMDL goal. At site BB-4, the original modeled load was 5,611,373 kg/yr, and the TMDL load is 2,177,370 kg/yr. An estimated 61% reduction of TSS load is required to meet the TSS water quality standard at site BB-4. This goal was applied to the entire impaired stream reach.

Restricting cattle and other livestock access to Bear Butte Creek and its tributaries and establishing buffer zones in the areas immediately adjacent to the stream should result in an appreciable reduction of sediment and nutrient loadings. Management of livestock should include prescribed grazing, constructing fences or other barriers to control concentrated livestock access to riparian areas, livestock crossing structures, and alternative water supply. Other alternatives include seasonal access or rotational grazing to reduce the intensity and duration of access to riparian zones and uplands.

Proposed BMPs to address riparian area degradation include livestock use exclusion, stream bank stabilization and protection, and reseeding or manual planting of native plant species. Sloughing banks and eroding areas were observed in the Bear Butte Creek watershed. These areas contribute to the overall sediment and nutrient input along the mainstem sites and should be included in an implementation plan. Restoration alternatives could include, but are not limited to, laying back steep banks, replanting barren and susceptible areas with suitable vegetative species, or by stabilizing these areas with non-vegetative structure.

Conservation practices could be implemented on croplands within the Bear Butte Creek watershed to reduce sheet and rill erosion, reduce soil erosion from wind, reduce the transport of sediment and other water-borne contaminants, and improve water use efficiency.

Acknowledgements

The contributions and cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Bear Butte Creek and its watershed could not have been completed without their assistance.

- US Environmental Protection Agency – Non-point Source Program
- US Geological Survey
- Meade County
- Lawrence County
- Meade County Conservation District
- Elk Creek Conservation District
- SD Department of Game, Fish and Parks
- SD Department of Environment and Natural Resources – Surface Water Quality Program
- SD Department of Environment and Natural Resources – Water Resources Assistance Program

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Introduction

Watershed Description

The Bear Butte Creek watershed is located in Lawrence and Meade counties in South Dakota (Figure 1). Bear Butte Creek, which is 97.1 km in length (60.4 mi) drains approximately 57,000 ha (141,000 acres) into the Belle Fourche River (HUC 10120202). Streams in this drainage network are typically 4 m wide or less. Approximately two-thirds of the landuse in the watershed is agricultural and one-third is forested. Major landuse categories found in this watershed include rangeland (54%), forest (30%), and cropland (14%). Other landuse in the watershed includes mining, industrial/commercial services, and urban/residential areas (2%). Crops grown in this area include wheat, oats, alfalfa, sorghum, barley and rye (Figure 2).

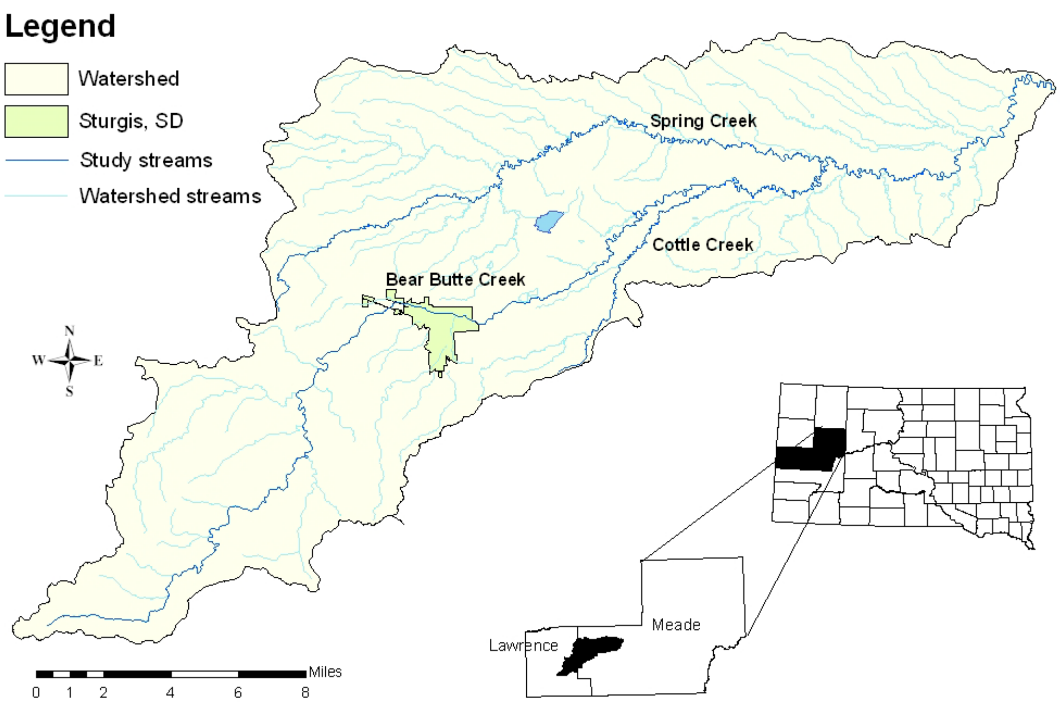


Figure 1. Location of the Bear Butte Creek watershed in Lawrence and Meade Counties, South Dakota.

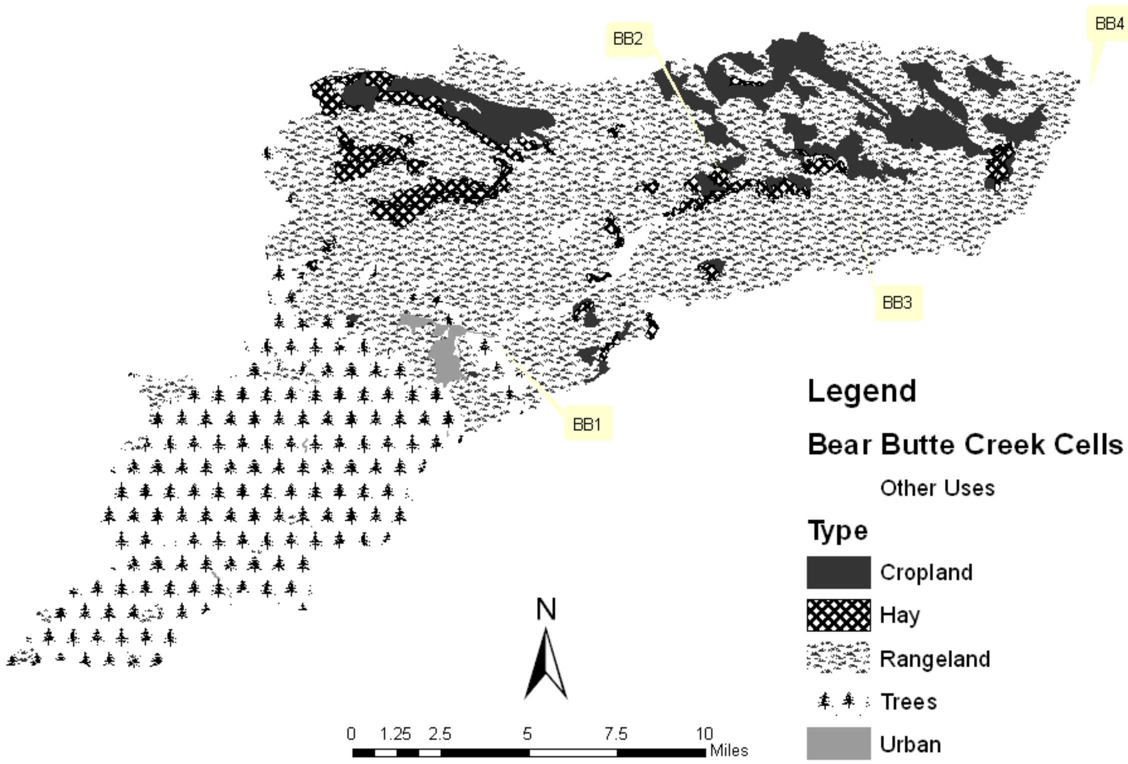


Figure 2. Landuse categories for the Bear Butte Creek watershed.

Major soil associations found in the eastern part of the watershed (Meade County) include Delphill-Assinniboine, Nunn-Satanta-Zigweid, Blackpipe-Savo-Manvel, Blackpipe-Assinniboine-Savo, Canyon-Lakoa-Maitland, Citadel-Vanocker, Tilford-Nevee, St. Onge-Keith, Lohmiller-Glenberg, Kyle-Pierre-Hisle,Winler-Lismas-Swanboy, Samsil-Lismas-Pierre, and Grummit-Pierre.

The mean annual precipitation in the Black Hills is approximately 18.6 inches (Driscoll et al, 2002) with greater amounts occurring in the northern Black Hills. The Bear Butte Creek drainage receives a mean precipitation rate of 20 to 28 inches per year (Driscoll et al, 2002). Studies at the Gilt Edge Mine site (Strawberry Hill) have estimated the mean annual precipitation at the mine site to be between 25 and 30 inches per year (USEPA, 2001). Eighty percent of the annual precipitation in the watershed typically occurs in April through September, with Lawrence County receiving slightly more precipitation during the winter than other counties. The mean seasonal snowfall for the Black Hills National Forest is 38 inches per year (USDA, 2003).

Watershed elevation ranges from about 1,968 feet MSL in the northwestern part of the watershed to about 1,413 feet MSL in the eastern part. Most of the Bear Butte Creek watershed is in the Northwestern Great Plains Level III Ecoregion with the western edge of the watershed in the Middle Rockies Level III Ecoregion. Level III ecoregions can be refined to Level IV to elicit more resolution of landscape conditions. The Bear Butte Creek watershed is located in four Level IV ecoregions (three in the Middle Rockies and one in the Northwestern Great Plains). As shown in Figure 3, Bear Butte Creek originates in the Black Hills Core Highlands, flows through the Black Hills Plateau, and exits the Black Hills through the Black Hills Foothills Ecoregion. After leaving the Middle Rockies Ecoregion, Bear Butte Creek enters the Semiarid Pierre Shale Plains and empties into the Belle Fourche River (Bryce et al., 1998).

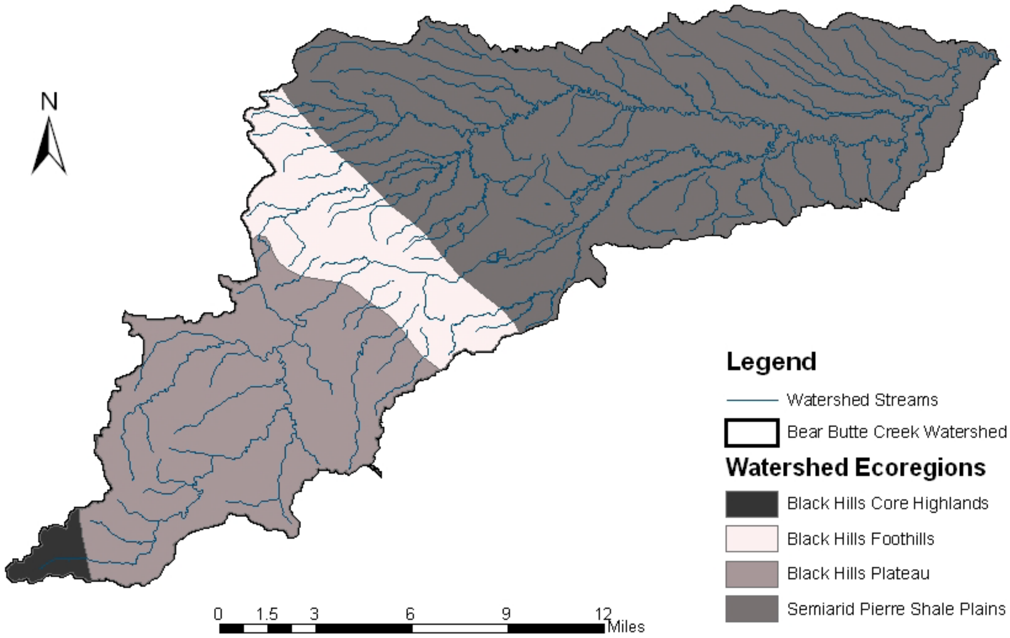


Figure 3. Level IV ecoregions in the Bear Butte Creek watershed.

Water Quality Standards and Beneficial Use Assignment

Water quality standards consist of beneficial use classifications and suites of water quality criteria necessary to protect these uses. All surface waters in the state are classified by one or more of the beneficial uses listed in

Table 1. All lakes and streams in the state are assigned the beneficial uses of fish and wildlife propagation, recreation and stock watering (category 9); all streams are assigned the additional beneficial use of irrigation (category 10). Other beneficial use classifications may be assigned by the state based upon a use analysis of each waterbody (SD DENR, 2002).

Table 1. South Dakota's beneficial use categories for all waters of the state.

Category	Beneficial Use
1	Domestic water supply
2	Coldwater permanent fish life propagation
3	Coldwater marginal fish life propagation
4	Warmwater permanent fish life propagation
5	Warmwater semipermanent fish life propagation
6	Warmwater marginal fish life propagation
7	Immersion recreation
8	Limited-contact recreation
9	Fish and wildlife propagation, recreation, and stock watering
10	Irrigation
11	Commerce and industry

Assigned beneficial use categories for one particular stream may not be continuous for all stream segments. In Bear Butte Creek, for example, two segments have the designated use of coldwater *permanent* fish life propagation (category 2), while the other segments have the designated use of coldwater *marginal* fish life propagation (category 3). From SD State Highway 79 to Dead Man Creek and from the boundary of S2, T4N, R4E to the boundary of S22, T4N, R3E, Bear Butte Creek is designated as a coldwater permanent fish propagation stream. All other portions of Bear Butte Creek are designated as coldwater marginal fisheries (Figure 4).

Additional beneficial uses for Bear Butte Creek include limited-contact recreation (category 8), fish and wildlife propagation, recreation and stock watering (category 9), and irrigation (category 10). Unless specified, the beneficial use classifications (other than categories 9 and 10) do not apply to Bear Butte Creek tributaries.

Table 2 lists the assigned beneficial uses for all segments of Bear Butte Creek and the named tributaries according to the numeric standards assigned to beneficial uses (SD DENR, 2002). An important tributary in the study, Cottle Creek, was not listed in

Table 2 because it was not assigned beneficial uses other than categories 9 and 10.

For each beneficial use classification, a suite of numeric water quality standards have been established for a daily maximum (acute) and average (chronic) water quality conditions. The daily maximum limit is the standard for a single water quality sample. The 30-day mean value is calculated from the arithmetic mean of three consecutive samples taken in separate weeks over a 30-day period (water quality sampling for the Bear Butte Creek study was only performed on a monthly basis; no mean values were established).

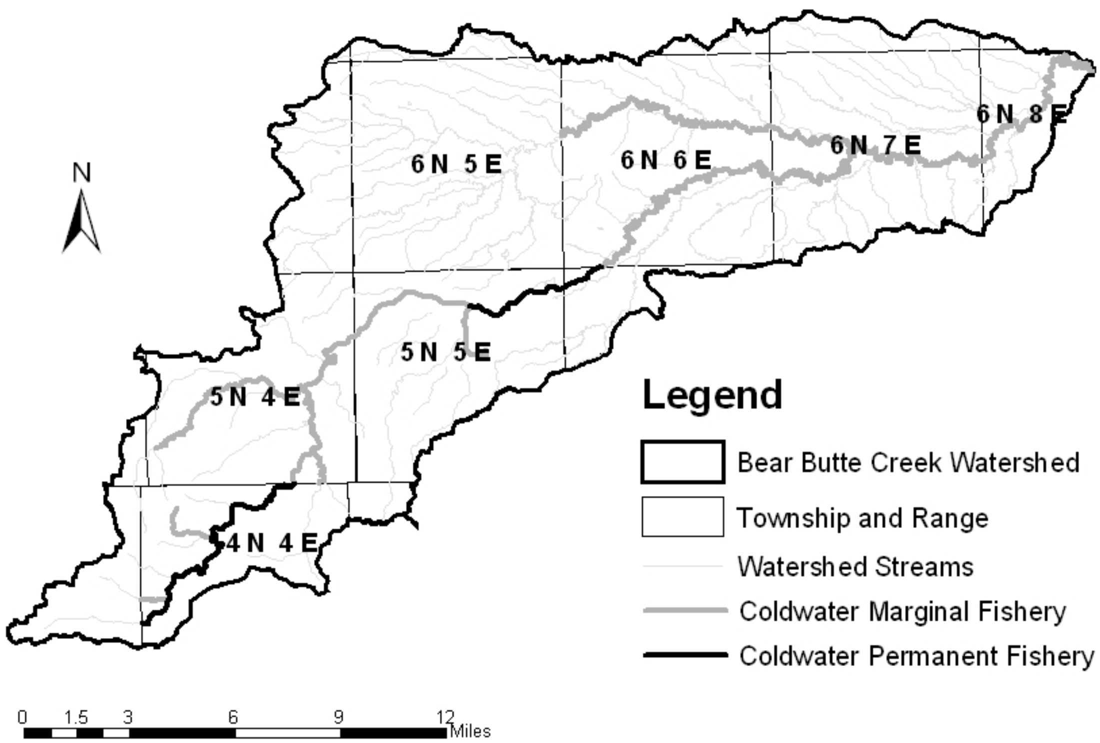


Figure 4. Stream segments with designated beneficial uses of coldwater permanent and marginal fish propagation for the Bear Butte Creek watershed.

Measured water quality values that exceed applicable standards indicate an impairment of beneficial uses. When multiple standards exist for a particular parameter, the most stringent standards are used. Daily maximum water quality standards for segments of Bear Butte Creek with coldwater permanent fish propagation and coldwater marginal fish propagation are listed in Table 3 and Table 4, respectively. The standards listed in Table 5 apply to all other waterbodies in the study area.

In addition to physical and chemical standards intended to preserve beneficial uses, South Dakota has developed narrative criteria for the protection of aquatic life uses, which states that "All waters of the state must be free from substances, whether attributable to human-induced point source discharge or nonpoint source activities, in concentration or combinations which will adversely impact the structure and function of indigenous or intentionally introduced aquatic communities" (ASRD § 74:51:01:12).

Table 2. Assigned beneficial uses for Bear Butte Creek and named tributaries designated as fisheries in the Bear Butte Creek watershed.

Water Body	From	To	Beneficial Uses*	County
Bear Butte Creek	Belle Fourche River	Route 79	3, 8, 9, and 10	Meade
Bear Butte Creek	Route 79	Dead Man Creek	2, 8, 9, and 10	Meade
Spring Creek	Bear Butte Creek	S14, T6N, R5E	3, 8, 9, and 10	Lawrence
Bear Butte Creek	Dead Man Creek	S2, T4N, R4E	3, 8, 9, and 10	Meade
Bear Butte Creek and south fork	S2, T4N, R4E	S22, T4N, R3E	2, 8, 9, and 10	Lawrence
Boulder Creek	Bear Butte Creek	Two Bit Creek	3, 8, 9, and 10	Lawrence
Two Bit Creek	Boulder Creek	S30, T5N, R4E	3, 8, 9, and 10	Lawrence
Bear Butte Creek (north fork)	Bear Butte Creek	S14, T4N, R3E	3, 8, 9, and 10	Lawrence
Park Creek	Bear Butte Creek	S11, T4N, R4E	3, 8, 9, and 10	Lawrence
Strawberry Creek	Bear Butte Creek	S5, T4N, R4E	3, 8, 9, and 10	Lawrence
Vanocker Creek	Bear Butte Creek	S32, T5N, R5E	3, 8, 9, and 10	Lawrence

*** See**

Table 1 for definition of beneficial use categories.

Two tributaries of the Bear Butte Creek system, Spring and Strawberry Creeks, could be mistaken for similarly named streams elsewhere in the Black Hills. The Spring Creek referred to within the Bear Butte Creek study area is located north of Bear Butte and Interstate 90, flows through no cities, and has no impounding structures (the more familiar Spring Creek is south of the interstate, flows through Hill City and Hermosa, and has 2 impoundments, Lake Mitchell and Sheridan Lake). Likewise, the Strawberry Creek in the study flows southwest from Anchor Hill and is an impaired waterbody well known for the Gilt Edge Mine Site (Syracuse Research Corporation, 2001), which was included on the Superfund National Priorities List in December 2000 (the other Strawberry Creek flows northwest along the face of Strawberry Ridge and into Whitewood Creek).

Table 3. Water quality standards (daily maximum) for Bear Butte Creek with beneficial use classifications of coldwater permanent fish propagation and limited-contact recreation.

Parameter	Daily Maximum Conc.
Un-ionized ammonia nitrogen as N [1]	
Dissolved oxygen [2]	$\geq$ 6.0 mg/L
pH	$\geq$ 6.6 - $\leq$ 8.6
Total suspended solids	$\leq$ 53 mg/L
Total dissolved solids	$\leq$ 4,375 mg/L
Temperature (°C)	$\leq$ 18.3° C
Fecal coliform [3]	$\leq$ 2,000 colonies/100mL
Undissociated hydrogen sulfide [4]	$\leq$ 0.002 mg/L
Chloride [4]	$\leq$ 175 mg/L
Chlorine [4]	$\leq$ 0.019 mg/L
Total alkalinity as calcium carbonate	$\leq$ 1313 mg/L
Conductivity at 25° Celsius	$\leq$ 4,375 μmhos/cm
Nitrates as N	$\leq$ 88 mg/L
Sodium Absorption Ratio [4,5]	$\leq$ 10
Total petroleum hydrocarbon [4]	$\leq$ 10 mg/L
Oil and grease [4]	$\leq$ 10 mg/L

[1] Un-ionized ammonia is the fraction of ammonia toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. The daily maximum of un-ionized ammonia standard is 1.75 times the calculated criterion for the single sample (SD DENR, 1997).
[2] Dissolved oxygen concentrations must be $\geq$ 7.0 mg/L in spawning areas during the spawning season.
[3] The fecal coliform standard is in effect from May 1 to September 30.
[4] Parameters not measured during this project.
[5] The SAR is used to evaluate the sodium hazard of irrigation water based on the Gapon equation (Equation 1).

The Sodium Absorption Ratio (SAR)

Irrigation water should meet the criterion for compliance, known as the Sodium Absorption Ratio (SAR), calculated by using the Gapon equation (Equation 1). The SAR is calculated using the concentrations of sodium (Na^+), calcium (Ca^{+2}), and magnesium (Mg^{+2}) expressed in milliequivalents per liter. Use of water that exceeds the SAR compliance standard (10) may cause a salt layer to build up on the surface of the soil and reduce the water infiltration rate (Tchobanoglous et al., 2003).

Equation 1. The Gapon equation is commonly used to determine the ratio of sodium to calcium and magnesium.

$$\text{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

Table 4. Water quality standards (daily maximum) for all portions of Bear Butte Creek with beneficial use classifications of coldwater marginal fish propagation and limited-contact recreation.

Parameter	Daily Maximum Conc.
Un-ionized ammonia nitrogen as N [1]	
Dissolved oxygen [2]	≥ 5.0 mg/L
pH	≥ 6.5 - ≤ 8.8
Total suspended solids	≤ 158 mg/L
Total dissolved solids	≤ 4,375 mg/L
Temperature (°C)	≤ 23.9°C
Fecal coliform [3]	≤ 2,000 colonies/100mL
Undissociated hydrogen sulfide [4]	≤ 0.002 mg/L
Chlorine [4]	≤ 0.019 mg/L
Total alkalinity as calcium carbonate	≤ 1313 mg/L
Conductivity at 25° C	≤ 4,375 μmhos/cm
Nitrates as N	≤ 88 mg/L
Sodium Absorption Ratio [4, 5]	≤ 10
Total petroleum hydrocarbon [4]	≤ 10 mg/L
Oil and grease [4]	≤ 10 mg/L

[1] Un-ionized ammonia is the fraction of ammonia toxic to aquatic life. The concentration of un-ionized ammonia is calculated and dependent on temperature and pH. The daily maximum of un-ionized ammonia standard is 1.75 times the calculated criterion for the single sample (SD DENR, 1997).
[2] Dissolved oxygen concentrations must be ≥ 7.0 mg/L in spawning areas during the spawning season.
[3] The fecal coliform standard is in effect from May 1 to September 30.
[4] Parameters not measured during this project.
[5] The SAR is used to evaluate the sodium hazard of irrigation water based on the Gapon equation (Equation 1).

Table 5. Water quality standards (daily maximum) for all other portions of Bear Butte Creek not otherwise classified.

Parameter	Daily Maximum Conc.
pH	≥ 6.0 - ≤ 9.5
Total dissolved solids	≤ 4,375 mg/L
Total alkalinity as calcium carbonate	≤ 1313 mg/L
Conductivity at 25° C	≤ 4,375 μmhos/cm
Nitrates as N	≤ 88 mg/L
Sodium Absorption Ratio [1, 2]	≤ 10
Total petroleum hydrocarbon [1]	≤ 10 mg/L
Oil and grease [1]	≤ 10 mg/L

[1] Parameters not measured during this project.
[2] The SAR is used to evaluate the sodium hazard of irrigation water based on the Gapon equation (Equation 1).

Water Quality Standards Exceedances

During the project period, seven of the assessed parameters exceeded water quality standards (Table 6). Water quality exceedances in the Bear Butte Creek mainstem were for dissolved oxygen (DO), pH, TSS, temperature, fecal coliform bacteria, and specific conductivity. Low DO at BB-3 was measured during a routine sample at normal flow, high pH values were measured in the headwater area during June 2000, TSS and fecal exceedances occurred during storm events and periods of rising base flow; the temperature exceedances occurred during the summer periods of minimal flow; conductivity exceedance at WQM-125 could be attributed to contributions from Strawberry Creek.

Table 6. **Water quality standards exceedances from October 1998 to September 2000 by percent of site samples. Information is displayed as follows: number of samples exceeding the standard / total number of samples (percent of samples exceeding the standard).**

Stream Name	Station	DO	pH	TSS	TDS	Temp	Fecal	Cond
Bear Butte	WQM-126	--	1/23 (4%)	1/22 (5%)	--	2/23 (9%)	--	--
Strawberry	WQM-116	--	--	--	8/22 (36%)	--	--	2/7 (29%)
Bear Butte	WQM-125	--	1/23 (4%)	1/22 (5%)	--	1/23 (4%)	--	--
Bear Butte	BB-1	--	--	--	--	--	1/24 (4%)	--
Bear Butte	BB-2	--	--	--	--	--	2/24 (8%)	--
Bear Butte	BB-3	1/24 (4%)	--	3/24 (13%)	--	--	1/24 (4%)	--
Bear Butte	BB-4	--	--	4/24 (17%)	--	--	--	--
Spring	SC-1	--	1/9 (11%)	--	--	--	1/8 (13%)	--
Spring	SC-2	--	1/7 (14%)	1/7 (14%)	--	--	--	--
Cottle	CC-3	--	--	--	--	--	--	--

Two tributaries of Bear Butte Creek also exceeded water quality standards. Strawberry Creek exceeded standards for pH, TDS, and conductivity. Although no exceedances for TDS were detected in Strawberry Creek during the early portion of the study period, TDS exceedances occurred routinely from late 1999 until early 2002.

Spring Creek samples exceeded water quality standards for pH, TSS, and fecal coliform bacteria. The cause for a low pH value on Spring Creek (SC-1; 5.12) was unknown. The cause for the low pH value (6.06) observed at SC-2 was also unknown, but could be related to elevated TSS (584 mg/L) and total phosphorus (0.742 mg/L) concentrations measured during the same routine sampling event. The fecal exceedance (SC-1) occurred the morning after a storm event. Since only nine samples total were taken on Spring Creek, the samples exceeding state standards represent a large percentage of the total. As a result, the Spring Creek findings do not meet the 25% exceedance criterion (for a sample set of less than 20 samples) required to initiate a TMDL study (SD DENR, 2002).

Project Goals, Objectives and Activities

Project Goals

The long-term goal of the Bear Butte Creek Watershed Landuse Assessment Project is to locate and document sources impairments in the watershed and produce feasible restoration alternatives in order to provide adequate background information needed to develop a TMDL and to drive a watershed implementation project to improve water quality.

Project Objectives and Activities

Objective 1: Landuse Modeling

The Bear Butte Creek watershed was intended to be modeled using the PSIAC model in order to identify areas requiring management to reduce erosion. PSIAC is a comprehensive land use model which estimates soil loss and delivery and evaluates the impacts of livestock grazing areas. After dividing the watershed into small sub-watersheds, the subwatershed areas could then be analyzed by a multi-disciplinary team consisting of range specialists, soils scientists, district conservationists and others. Random areas of cropland can be selected and analyzed using the Revised Universal Soil Loss Equation (RUSLE). Additional data collection regarding animal feeding operations was also intended. Results were proposed as a tool to identify critical areas of nonpoint source pollution to the surface waters in the watershed.

Unfortunately, the PSIAC modeling effort has not yet been completed. Therefore, other means were used to identify critical areas for implementation of management practices, including subwatershed export coefficients and the Annualized AGNPS Pollution Loading Model.

Objective 2: Estimate Sediment and Nutrient Loadings

Sediment and nutrient loadings were estimated through hydrologic and chemical monitoring. In addition to establishing the TMDL, loading information will be used to develop subwatershed export coefficients (i.e. a measure of the parameter mass per unit time delivered per acre) to locate critical areas in the watershed to be targeted for implementation.

Objective 3: Quality Assurance/Quality Control (QA/QC)

Approved QA/QC procedures were used when sampling and collecting field data in accordance with the SD DENR *Standard Operating Procedures for Field Samplers* (SD DENR, 2000). A minimum of 10 % of all the water quality samples collected were QA/QC samples. QA/QC samples consisted of field blanks and field duplicate samples. The activities involved with QA/QC procedures and the results of QA/QC monitoring are provided in a subsequent section of this report. See Appendix C for QA/QC raw data.

Assessment Methods

Hydrologic Data Collection Methods

Hydrologic data were collected by the South Dakota Department of Environment and Natural Resources (SD DENR) Water Resource Assistance Program (WRAP) at seven locations (Figure 5). Two headwater locations on Bear Butte Creek (WQM-126 and WQM-125) and a tributary site on Strawberry Creek (WQM-116) were also sampled by the SD DENR Surface Water Quality Program (SWQP); however, no hydrologic data were available for these sampling locations. Hydrologic data were collected at four United States Geological Survey (USGS) gaging stations located in Bear Butte Creek (Table 7) and were used to maintain a continuous stage record for Bear Butte Creek.

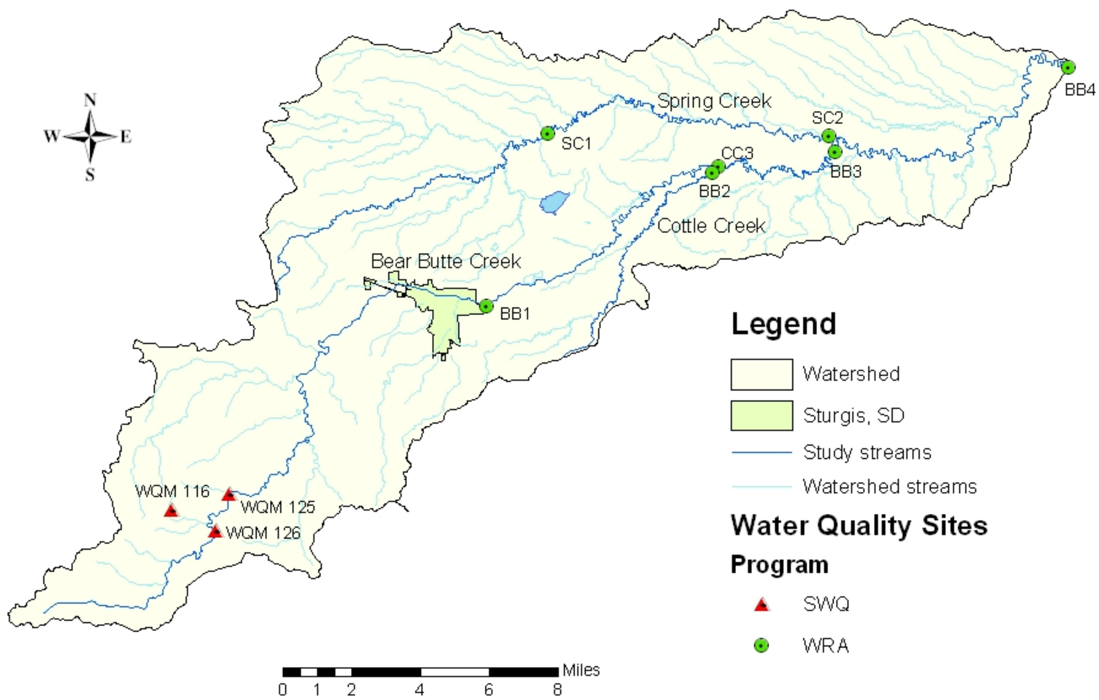


Figure 5. Location of sampling sites for the Bear Butte Creek watershed assessment study.

Table 7. Site identification numbers and locations for USGS gaging stations.

Site Name	Source	Site ID	Site Coordinates	Description
BB-1	USGS	6437400	44 24' 44"; 103 29' 10"	At Sturgis, SD
BB-2	USGS	6437500	44 28' 53"; 103 16' 31"	Near Sturgis, SD
BB-3	USGS	442811103205000	44 28' 11"; 103 20' 50"	Below Sturgis, SD
BB-4	USGS	443048103091400	44 30' 48"; 103 09' 14"	Near Mouth (Vale, SD)

Water level recorders were also installed by the WRAP on three tributary monitoring sites (SC-1, SC-2, and CC-3). Discrete discharge measurements were taken on a regular schedule and during storm events with a hand held current velocity meter (Marsh-McBirney Model 201). Discharge measurements and water level data (Appendix A) for water years 1999 and 2000 (October 1, 1998 to September 30, 2000) were used to calculate a hydrologic budget for the watershed. The results of the hydrologic loading calculations are shown in Table 9.

Tributary Water Quality Sampling

A variety of parameters were assessed to characterize the physical, chemical and biological condition of Bear Butte Creek (Table 8). Physical and chemical water quality samples were collected monthly from June 1998 through October 2000 for all mainstem sites (BB-1, BB-2, BB-3, and BB-4) by the USGS. Water quality monitoring was also performed monthly by SD DENR (SWQP) during the study period at the following sites: WQM-116, WQM-125, and WQM-126. Additional water quality samples were collected by SD DENR (WRAP) from mainstem and tributary sites at various months during WY 2000. The compiled water quality sampling results are included in Appendix B. Physical habitat assessments (Appendix D) were also performed at each site in August 2000.

Table 8. Tributary physical, chemical and biological parameters analyzed in Bear Butte Creek watershed assessment.

Chemical Measurements	Physical Measurements	Biological Measurements
Total Alkalinity	Air Temperature	Fecal Coliform Bacteria
Field pH	Water Temperature	Benthic Macroinvertebrates
Dissolved Oxygen	Water Depth	
Total Solids	Velocity	
Total Suspended Solids	Visual Observations	
Total Volatile Suspended Solids		
Ammonia		
Nitrate-Nitrite		
Total Kjeldahl Nitrogen		
Total Phosphorus		
Total Dissolved Phosphorus		
Conductivity		

Samples were collected using the methods described in the EPA approved SD DENR *Standard Operating Procedures for Field Samplers* (SD DENR, 2000). All water samples were sent to the State Health Laboratory in Pierre, SD for analysis. Quality Assurance/Quality Control (QA/QC) samples were collected for approximately 10% of the total number of samples. These QA/QC sample results were composed of replicate (split), duplicate, or blank samples and are discussed in more detail in a subsequent section of this report.

Modeling Methods

Tributary Loading Calculations

FLUX, a eutrophication model developed by the Army Corps of Engineers (US ACOE, 1999) was used to develop nutrient and sediment loadings for Bear Butte Creek. FLUX calculates loadings using several different models (average flow, flow weighted, etc.). The accuracy of each model was evaluated by reviewing the coefficient of variation (CV), which is the variation of the data relative to the mean. This allows the user to choose a loading model based on the smallest CV. The input data were stratified by the FLUX program, when possible.

After the loadings for all sites were completed, export coefficients were developed for each of the subwatershed hydrologic contribution and water quality parameters. Export coefficients were calculated by taking the total hydrologic contribution (acre-feet), nutrient, or sediment load (kg) and dividing by the total area of the sub-watershed (in acres). These values were used to determine which subwatersheds were more likely to contribute hydrologic runoff and to target areas within the watershed with excessive nutrient and sediment loads. These areas will also be used to identify priority areas for the implementation of Best Management Practices (BMPs).

Landuse Modeling

In addition to water quality monitoring, information was collected to complete a comprehensive watershed land use model. AnnAGNPS Pollutant Loading Model is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The model divides the watershed into cells of varying sizes based on topography. Each cell is assigned a primary land use and soil type. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells and load reductions are calculated at the watershed outlet.

The input data set for AnnAGNPS consists of 33 sections of data, which can be supplied by the user in a number of ways. This model execution utilized digital elevation maps (DEMs) to determine cell and reach geometry, SSURGO soil layers to determine primary soil types and the associated NASIS data tables for each soils properties, and LANSAT imagery to determine landuse. Climate data was generated using a synthetic weather generator based on climate information from nearby weather stations

It is important to note that model results are based on 25 simulated years of data with wide ranging precipitation statistics. The simulated time period does not represent the project period. Instead, model results represent a long-term average. When analyzed as a group, model results provide an efficiency analysis for management practices implemented in the watershed. Results of the AnnAGNPS model are reported on pages 63-66.

Assessment Results

Hydrologic Loadings

The monthly hydrologic contributions from each subwatershed area were calculated as an output of the FLUX modeling program in cubic hectometers. These hydrologic contributions were grouped together by season as follows:

Winter – December, January, February
Spring – March, April, May
Summer – June, July, August
Fall – September, October, November

An analysis of the hydrologic contributions is included in Table 9. The total annualized hydrologic volume resulting from the FLUX-modeling of stage and instantaneous flow data, at site BB-4, was approximately 22,803 acre-feet. Seasonalized hydrologic contributions for each subwatershed were also calculated as well as percentages of the annualized contribution at each site. Further, the seasonal hydrologic load is represented as a percentage of the total hydrologic load for each site.

Three loss zones (surface water downwelling into bedrock) occur between the headwater sites and lower stream segment sites (Nelson, 2000). The first loss zone was located where Bear Butte Creek crosses the Madison formation, or about 4 miles downstream of Galena, SD. The second loss zone was located within the Upper Minnelusa formation and the third in the Lower Minnelusa formation. As reported by Hortness and Driscoll, the loss threshold for each zone was approximately 4 cfs. If the creek was flowing at greater than 12 cfs, then surface flow would continue past the loss zones, given that the streambed substrate was saturated. If there was insufficient flow to exceed the threshold loss, surface flow would cease at the location where the loss rate exceeded flow rate. It has been considered common for stream flow to cease at some point within this loss area, though the nature of the subsurface flow has yet to be clarified.

Alluvial flow or storage is minimal because of limited to minor alluvial extent along the loss area (Hortness and Driscoll, 1998). The underground flow is either through a karst conduit or subterranean flow of an amorphous nature (diffusing through fractured limestone into an underground aquifer), though the residence times and rates of mixing are not well known. Careful assumptions must be made about how the water chemistry of Bear Butte Creek is affected within the contact zone.

Bear Butte Creek reemerges at the edge of an outcrop, in an alluvial area east of Sturgis, SD, near Woodle Field (the exact origin of the water is not known, although Deadman and Vanocker Creeks may provide a minor amount of flow). Historical records (Miller and Driscoll, 1997) indicate that surface flow generally continues from this site to the Belle Fourche River.

The data used to perform the hydrologic and parameter loading is included at Appendix A.

Table 9. Seasonal and annual hydrologic contributions by site for water years 1999-2000.

Site	Season	Flow (ac ft/yr)	Percent of Flow*
WQM-125	Winter	556.1	7.2%
	Spring	3186.5	41.5%
	Summer	1979.0	25.8%
	Fall	1951.0	25.4%
	Total	**7672.6**	
SC-1	Winter	241.6	19.7%
	Spring	280.9	22.9%
	Summer	364.0	29.7%
	Fall	337.7	27.6%
	Total	**1224.2**	
SC-2	Winter	844.8	16.8%
	Spring	1054.7	21.0%
	Summer	1632.8	32.5%
	Fall	1486.8	29.6%
	Total	**5019.1**	
CC-3	Winter	160.5	20.2%
	Spring	184.0	23.1%
	Summer	233.1	29.3%
	Fall	218.1	27.4%
	Total	**795.7**	

Site	Season	Flow (ac ft/yr)	Percent of Flow*
BB-1	Winter	797.7	14.3%
	Spring	1098.1	19.7%
	Summer	1942.9	34.9%
	Fall	1734.5	31.1%
	Total	**5573.2**	
BB-2	Winter	1500.6	16.0%
	Spring	1930.7	20.6%
	Summer	3118.8	33.3%
	Fall	2820.9	30.1%
	Total	**9371.0**	
BB-3	Winter	2983.4	17.4%
	Spring	3753.2	21.9%
	Summer	5441.5	31.8%
	Fall	4929.5	28.8%
	Total	**17107.7**	
BB-4	Winter	3283.0	14.4%
	Spring	4647.0	20.4%
	Summer	7840.8	34.4%
	Fall	7032.1	30.8%
Watershed	**Total**	**22802.9**	

* Represents a seasonal percentage of total annual stream flow

Water Quality Parameters

Acidification Analysis

The primary measurements of acidification are alkalinity and pH. The pH scale ranges from 0 to 14, with 7 being neutral. Water with pH less than 7.0 is considered acidic, while water with pH greater than 7.0 is considered basic. The pH of water is regulated mostly by the interaction of hydrogen ions. Natural waters exhibit wide variations in acidity and alkalinity. The pH of natural waters ranges between the extremes of 2 and 12 (Wetzel, 2001), yet most forms of aquatic life require an environment within the narrow range of 6.5 to 9.0 standard pH units (su).

Figure 6 shows the median, lower and upper quartile, and range of pH values for each sampling site on Bear Butte Creek. The greatest variability occurs in the headwater areas where the median pH was generally higher. The pH was considerably reduced at BB-1, but had risen back to headwater levels at BB-4.

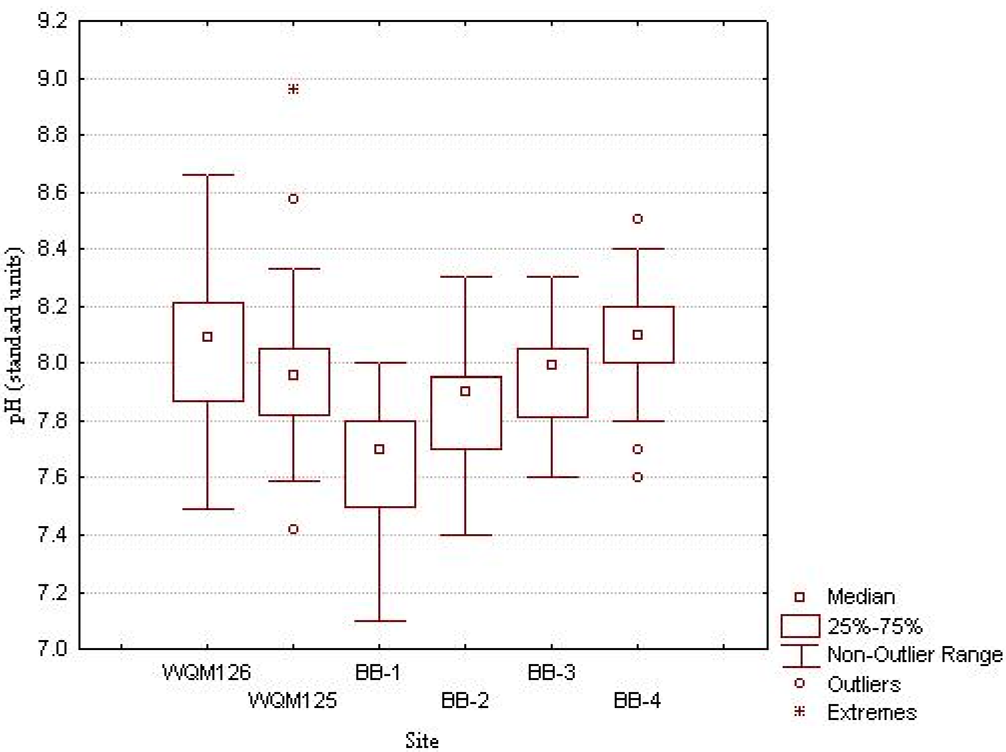


Figure 6. Box plot of field pH values by site for Bear Butte Creek mainstem sites. Six exceedances of the pH standards occurred in the study area: two high pH values were observed at the headwater sites and four low pH values in the tributary sites.

As shown in Table 10, field pH for all sites ranged from 5.05 to 8.96 (mean = 7.74). Spring Creek pH levels were the most variable in the study area. The lowest pH recorded was in Strawberry Creek (WQM-116). Two high pH values in Bear Butte Creek (WQM-125 and

WQM-126) and two low values in Spring Creek (SC1 and SC2) were outside the limits of state water quality standards.

Table 10. Descriptive statistics for pH concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	8.05	23	0.26	7.49	8.66	7.87	8.09	8.21
WQM-116	7.27	23	0.53	6.54	8.74	6.80	7.28	7.64
WQM-125	7.97	23	0.34	7.42	8.96	7.82	7.96	8.05
BB-1	7.65	25	0.24	7.10	8.00	7.50	7.70	7.80
BB-2	7.85	24	0.21	7.40	8.30	7.70	7.90	7.95
BB-3	7.95	24	0.19	7.60	8.30	7.82	8.00	8.05
BB-4	8.07	24	0.22	7.60	8.50	8.00	8.10	8.20
CC-3	7.18	9	0.52	6.45	7.87	6.79	7.02	7.65
SC-1	7.02	9	0.84	5.12	7.82	6.74	7.15	7.63
SC-2	7.37	7	0.73	6.06	7.94	6.86	7.89	7.91
All Sites	7.74	191	0.50	5.12	8.96	7.60	7.87	8.00

Alkalinity Analysis

Alkalinity refers to the buffering ability of the carbonate system in water. The term is also used interchangeably with ‘acid neutralizing capacity,’ which is the capacity to neutralize strong inorganic acids (Wetzel, 2001). Alkalinity is a product of geological setting. Soils rich in carbonate rock, such as limestone, provide a source of high alkalinity (Monson, 2000). In general, increased alkalinity inhibits severe pH changes. Alkalinity typically ranges from 20 to 200 mg/L in natural environments (Lind, 1985).

Figure 7 shows the median, lower and upper quartile, and ranges of total alkalinity values for Bear Butte Creek sites. Similar to the pH values, alkalinity concentrations were distinctly different between the headwater and mainstem sites. The abrupt rise in alkalinity is likely due to carbonate flux as the water flows through the Madison and Minnelusa formations. Alkalinity concentrations further downstream became lower as a result of chemical interaction and/or dilution.

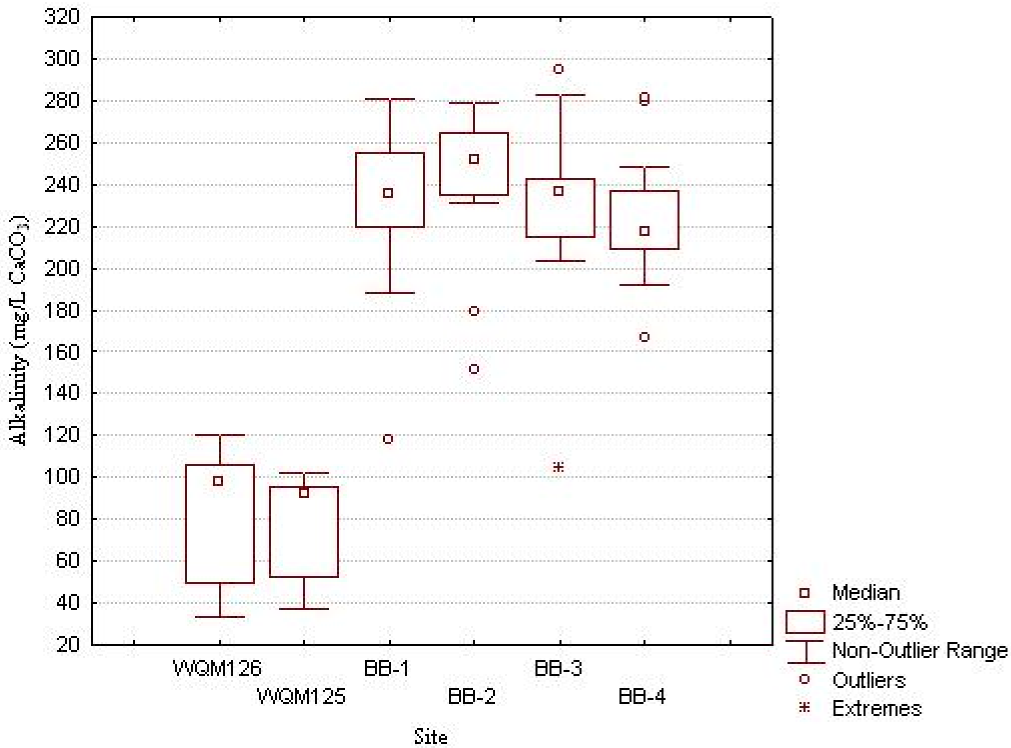


Figure 7. Box plot of total alkalinity concentrations by site for Bear Butte Creek mainstem sites. The highest alkalinity concentrations were observed in Cottle Creek (not shown).

Alkalinity statistics are listed in Table 11. Concentrations among all sites ranged from 10 to 325 mg/L (mean = 210) and were generally lowest in the headwater areas. The lowest mean values were recorded in Strawberry Creek. The highest alkalinity concentrations, with the exception of one extreme value on Bear Butte Creek (BB-1), were observed in Cottle Creek (CC-3). Cottle Creek's high concentrations did not appear to increase alkalinity concentrations at mainstem sites (the Cottle Creek confluence lies between BB-1 and BB-2). Below site BB-2, alkalinity concentrations decreased along the mainstem. All samples were well below the state standard of 1,313 mg/L.

Table 11. Descriptive statistics for alkalinity concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	80	7	34	33	120	50	98	106
WQM-116	46	7	28	10	95	22	54	57
WQM-125	77	7	25	37	102	53	92	96
BB-1	234	24	34	118	281	220	236	256
BB-2	246	24	29	151	279	236	252	265
BB-3	229	24	34	105	295	215	236	243
BB-4	222	24	26	167	281	209	217	237
CC-3	297	7	28	239	325	290	308	310
SC-1	238	8	25	182	261	234	242	256
SC-2	208	7	20	182	232	188	209	226
All Sites	210	139	69	10	325	199	232	251

Conductivity

Conductivity is a measure of how well a water sample conducts electricity and is measured in micromhos per centimeter (μmhos/cm). Conductivity is an indicator of the concentration of dissolved solids. As more minerals (salts) are dissolved in the water, the solution becomes more electrolytic. The metabolism of aquatic organisms is primarily affected by the amount of salts present, but concentration variability can also lead to shocking effects.

Figure 8 shows the median, lower and upper quartile, and ranges of conductivity values at mainstem sites. Specific conductivity measurements within Bear Butte Creek were most variable at WQM-125, located downstream of the Strawberry Creek (WQM-116) confluence, with little variability in the other stream segments.

The creek clearly accumulates conductivity from upstream to downstream. Limited assays of dissolved constituents were performed. However, for the few completed assays, the sodium absorption ratio (SAR) was typically below 5 (to support irrigation uses, the SAR standard is ≤10).

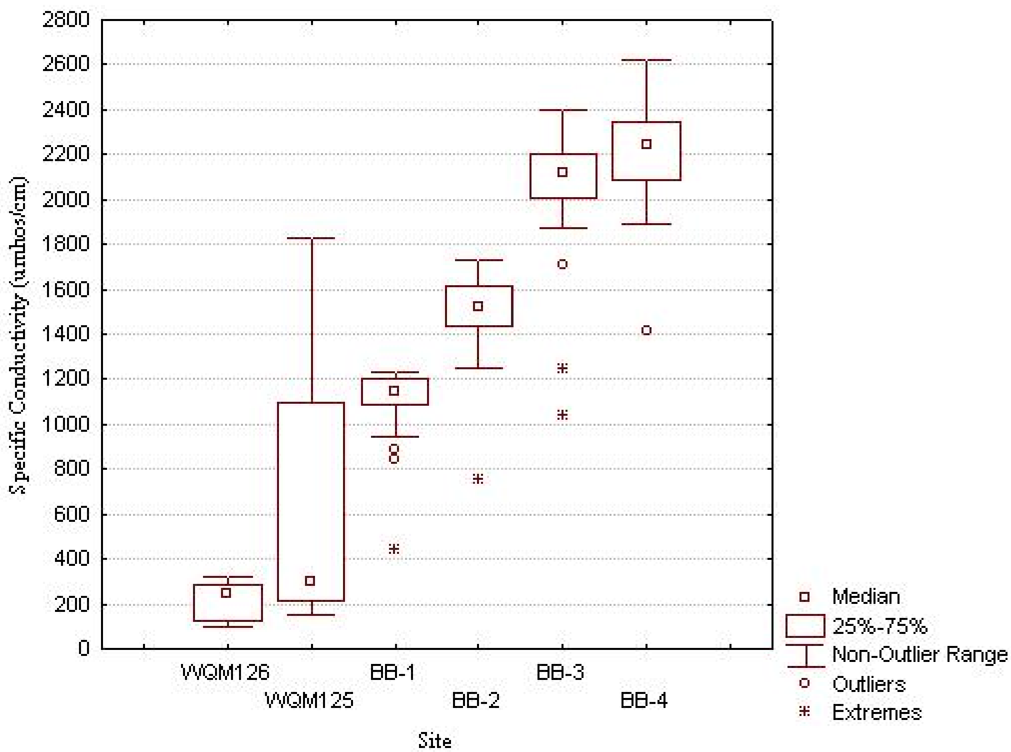


Figure 8. Box plot of specific conductivity concentrations by site for Bear Butte Creek mainstem sites. Concentrations increased from upstream to downstream and were most variable below the Strawberry Creek confluence.

Descriptive statistics are provided in Table 12. The mean value of Strawberry Creek conductivity (2,522 µmhos/cm) was the highest among all sites, and exceeds the value of the upper quartile for all sites. Two exceedances of the state standard (4,375 µmhos/cm) were observed at site WQM-116 during the study period, with a maximum value of 6,810 µmhos/cm. No other sites exceeded the standard.

Too few conductivity measurements were taken at the Spring and Cottle Creek sites to provide a representative mean (only one measurement available for each stream), but seem to be relatively high as the SC-1 and CC-3 values rank near the 75th quartile.

Table 12. Descriptive statistics for specific conductivity concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	216	7	84	101	324	129	248	289
WQM-116	2,522	7	2,932	462	6,810	653	970	6,790
WQM-125	601	7	629	153	1,830	218	300	1,100
BB-1	1,098	25	172	438	1,230	1,090	1,150	1,200
BB-2	1,465	24	248	751	1,730	1,435	1,520	1,615
BB-3	2,028	24	308	1,040	2,400	2,005	2,120	2,200
BB-4	2,203	24	245	1,410	2,620	2,085	2,245	2,346
CC-3	2,059	1	0	2,059	2,059	2,059	2,059	2,059
SC-1	2,171	1	0	2,171	2,171	2,171	2,171	2,171
SC-2		0						
All Sites	1,598	120	946	101	6,810	1,131	1,530	2,135

Dissolved Oxygen Analysis

Dissolved oxygen (DO) greatly affects aquatic life, since the metabolism of all aerobic aquatic organisms requires dissolved oxygen. For this reason, it is important to monitor DO in aquatic systems. Concentrations of DO often vary both spatially and temporally. Seasonal loadings of organic matter greatly influence DO concentrations (Wetzel, 2001). Physical factors, such as temperature and pressure, also influence concentrations of DO. Atmospheric oxygen solubility is most affected by temperature. The capacity for DO increases considerably with colder water temperatures.

Figure 9 shows the median, lower and upper quartile, and ranges of DO values for all Bear Butte Creek sites. DO concentrations in sampled permanent and marginal coldwater fishery stream segments were well above standards. The greatest variability in mainstem concentrations occurred in at sites BB-3 and BB-4.

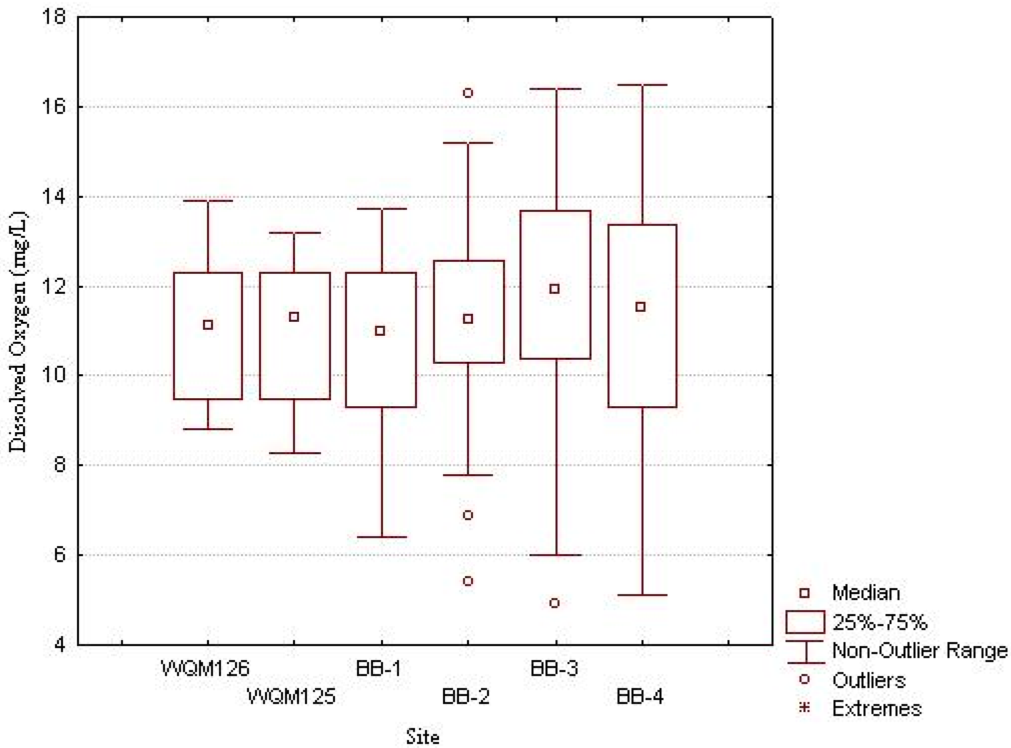


Figure 9. Box plot of dissolved oxygen concentrations by site for Bear Butte Creek mainstem sites. The lowest DO concentrations were observed at site CC-3.

Oxygen criteria of 5.0 mg/L and 6.0 mg/L are required to support cold water marginal and coldwater permanent fish life propagation, respectively. A criterion of 7.0 mg/L is required for spawning areas during the spawning season.

Table 13 shows the highest mean DO levels were at site BB-3 (11.43 mg/L), with the lowest mean in Strawberry Creek (9.68 mg/L). The maximum values occur in the three lowest mainstem segments, with BB-2 (March 1999), BB-3, and BB-4 (both in December 1999) all observed having greater than 16 mg/L.

During the summer of 1999, monthly Bear Butte Creek DO limits at BB-3 reached the lowest levels recorded during the study (4.9 mg/L) and resulted in one exceedance of the standard.

Table 13. Descriptive statistics for dissolved oxygen concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	11.14	23	1.50	8.80	13.90	9.50	11.10	12.30
WQM-116	9.68	23	1.31	7.50	12.10	8.60	10.00	10.50
WQM-125	11.11	23	1.53	8.30	13.20	9.50	11.30	12.30
BB-1	10.81	23	1.87	6.40	13.70	9.30	11.00	12.30
BB-2	11.20	24	2.59	5.40	16.30	10.30	11.25	12.55
BB-3	11.43	24	2.91	4.90	16.40	10.40	11.90	13.70
BB-4	11.14	24	2.94	5.10	16.50	9.30	11.50	13.35
CC-3	9.79	9	1.85	7.40	13.20	8.30	9.90	10.20
SC-1	11.02	9	1.97	8.70	13.80	9.90	10.50	12.80
SC-2	9.93	7	1.77	8.20	12.70	8.30	9.60	11.90
All Sites	10.85	189	2.20	4.90	16.50	9.20	10.90	12.30

Nitrogen Compounds

Three types of nitrogen were assessed in water quality samples: (1) ammonia, (2) nitrate/nitrite, and (3) Total Kjeldahl Nitrogen (TKN). With these three parameters, relative concentrations of organic and inorganic nitrogen can be determined, as well as total nitrogen concentrations.

Ammonia (NH_3) is the nitrogen product of bacterial decomposition of organic matter and is the form of nitrogen most readily available to plants for uptake and growth. Sources of ammonia in the watershed may come from animal feeding areas, decaying organic matter, or bacterial conversion of other nitrogen compounds. In the aquatic environment, ammonia molecules will join, or become associated with, water molecules (H_2O) to form two types of ammonia complexes.

In a reversible organic reaction (Equation 2), the ammonia is joined with the single hydrogen ion (H^+) from water to become the protonated, or ionized, form of ammonia (ammonium). Ammonium (NH_4^+) is ionized because the molecule carries more positively charged particles (protons) than negatively charged particles (electrons). This speciation occurs in medium to low pH ranges due to a surplus of hydrogen ions.

$$\mathbf{NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-}$$

Equation 2. The ionization of the ammonia molecule occurs more readily in aqueous solutions with a higher ratio of surplus hydrogen ions (low pH). The double arrow indicates the reaction is reversible.

In waters with a pH range above approximately 8.75 su, there will not be the same surplus of hydrogen ions as before, so certain amounts of ammonia remain in an uncharged, or un-ionized, state. How much ammonia will become ionized is highly dependent upon the pH and temperature of the water. According to Wetzel (Wetzel, 2001), G.E. Hutchinson (Hutchinson, 1957) calculated the approximate ratios of ionized to un-ionized ammonia at various pH values:

pH 6	3,000:1
pH 7	300:1
pH 8	30:1
pH 9	1:1

For every unit increase of pH, the hydrogen ion availability is reduced by a factor of ten. As the availability of the hydrogen ions are reduced, the amount of NH_3 also increases tenfold (NH_3 may also be written as NH_4OH, because the ammonia is weakly associated with a water molecule).

Un-ionized ammonia (NH_3) is toxic to aquatic organisms but especially in fish, where ammonia is known to cause gill damage, physiological stress, and abnormal development (Francis-Floyd and Watson, 1990). The concentration of un-ionized ammonia can be calculated based upon the known ammonia concentration, temperature and pH (Emerson et al, 1975). As temperature and pH increase, so does the percent of ammonia which is toxic to aquatic organisms. Since pH, temperature and ammonia concentrations are in a state of constant flux, un-ionized ammonia is calculated by sample using the following steps.

1) Determine the pka: 0.09018 + [2729.92 / (Water Temp ^{o}C + 273.15)].

2) Determine the percentage of un-ionized ammonia: 100 / [1 + 10($^{pka-pH}$)].

3) Determine the concentration of un-ionized ammonia: [Percentage of un-ionized NH_3 * Concentration of NH_3]/100.

Nitrate and nitrite (NO_3^- and NO_2^-) are inorganic forms of nitrogen easily assimilated by algae and macrophytes. Sources of nitrate and nitrite include agricultural fertilizers, septic tanks, precipitation, groundwater, and decaying organic matter. Nitrite is an unstable form of nitrogen, resulting from oxidation of ammonia and ammonium, and is extremely toxic to aquatic organisms in small concentrations (Metcalf & Eddy, 2003). Nitrate-nitrite can also be converted from ammonia through de-nitrification by bacteria. This process increases with increasing temperature and decreasing pH.

Total Kjeldahl Nitrogen (TKN) is the sum of organic nitrogen and ammonia. Sources of TKN can include release from dead or decaying organic matter, septic systems or agricultural waste. Ammonia is the primary degradation product of organic nitrogen by heterotrophic bacteria (Wetzel, 2001). Ammonia is degraded to nitrite and nitrate by autotrophic bacteria.

For this assessment, organic nitrogen was calculated (TKN minus ammonia). Inorganic nitrogen was also calculated (ammonia plus nitrates/nitrite). Total nitrogen is then the sum of organic and inorganic nitrogen forms.

Ammonia Analysis

Most of the water samples taken during the Bear Butte Creek study did not have detectable amounts of ammonia. The minimum detection limit (MDL) for the South Dakota State Health Laboratory is 0.02 mg/L. Few samples were expected to have zero ammonia, so the common assumption was to consider the existence of a trace amount (half of the MDL, 0.01 mg/L) as the default value for sample concentrations below the MDL.

Figure 10 shows the median, lower and upper quartile, and ranges of ammonia (NH_3) values for all Bear Butte Creek sites. All mainstem sites show a mean ammonia concentration of 0.01 mg/L, so little variability existed among sample concentrations. When ammonia was detected and the concentration value compared to the normal variability (non-detectable), the detected values appeared outside the range of variability as an outlier (Figure 10).

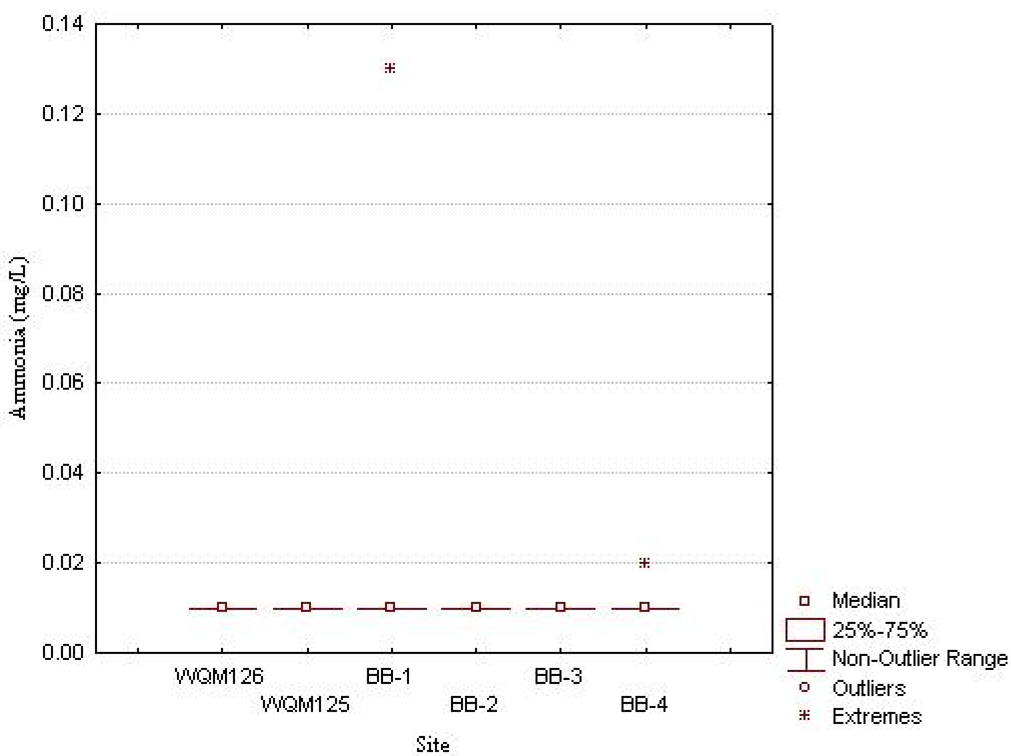


Figure 10. Box plot of ammonia concentrations by site for Bear Butte Creek mainstem sites. The highest mean concentrations were found on Strawberry Creek (WQM-116).

Table 14 shows sample values observed at Strawberry Creek (WQM-116). The mean value of ammonia from WQM-116 was 0.56 mg/L, and the median value (0.35 mg/L) was more than five times the maximum amount from any other study site (0.06 mg/L at SC-1).

Because the instances of detectable ammonia were few, statistics were heavily biased to the 0.010 mg/L value and dampened the true variability of the data set. None of the observed ammonia concentrations exceeded the un-ionized ammonia standard.

Table 14. Descriptive statistics for ammonia concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.01	22	0.00	0.01	0.01	0.01	0.01	0.01
WQM-116	0.56	22	0.72	0.01	2.90	0.01	0.35	0.80
WQM-125	0.01	22	0.00	0.01	0.01	0.01	0.01	0.01
BB-1	0.01	25	0.02	0.01	0.13	0.01	0.01	0.01
BB-2	0.01	24	0.00	0.01	0.01	0.01	0.01	0.01
BB-3	0.01	24	0.00	0.01	0.01	0.01	0.01	0.01
BB-4	0.01	24	0.00	0.01	0.02	0.01	0.01	0.01
CC-3	0.01	9	0.00	0.01	0.01	0.01	0.01	0.01
SC-1	0.02	9	0.02	0.01	0.06	0.01	0.01	0.01
SC-2	0.01	8	0.00	0.01	0.01	0.01	0.01	0.01
All Sites	0.08	189	0.30	0.01	2.90	0.01	0.01	0.01

Un-Ionized Ammonia Analysis

As discussed above, un-ionized ammonia is the ammonia concentration corrected by pH and temperature and is a calculated value. Figure 11 shows the median, lower and upper quartile, and ranges of un-ionized ammonia values for all Bear Butte Creek sites. None of the un-ionized ammonia concentrations exceeded the state standard of 0.02 mg/L.

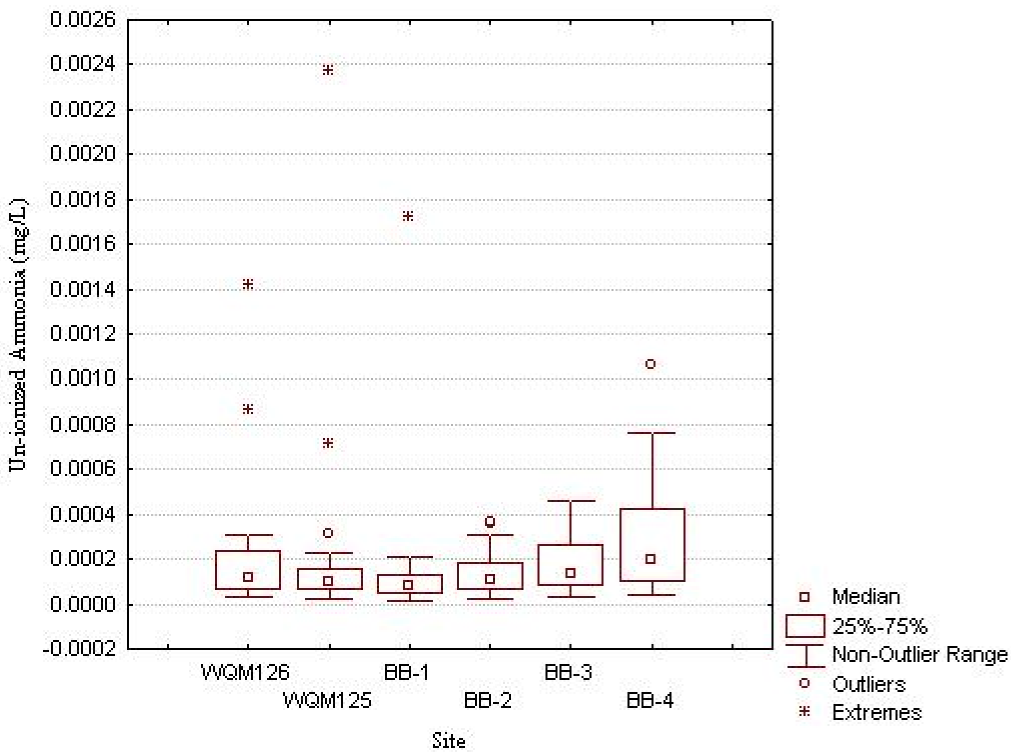


Figure 11. Box plot of un-ionized ammonia concentrations by site for Bear Butte Creek mainstem sites.

Table 15 shows no significant variation among sites, except for site WQM-116. Strawberry Creek had the highest mean value of un-ionized ammonia (0.0023 mg/L) and the highest maximum value (0.0154 mg/L) of the group. Although Strawberry Creek had the highest ammonia levels of the group, the relatively low pH helped to keep the greater amount of ammonia in the ionized form.

Table 15. **Descriptive statistics for un-ionized ammonia concentrations by site.**

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.0002	22	0.0003	0.0000	0.0014	0.0001	0.0001	0.0002
WQM-116	0.0023	22	0.0043	0.0000	0.0154	0.0001	0.0006	0.0021
WQM-125	0.0002	22	0.0005	0.0000	0.0024	0.0001	0.0001	0.0002
BB-1	0.0001	25	0.0003	0.0000	0.0017	0.0001	0.0001	0.0001
BB-2	0.0001	24	0.0001	0.0000	0.0004	0.0001	0.0001	0.0002
BB-3	0.0002	24	0.0001	0.0000	0.0005	0.0001	0.0001	0.0003
BB-4	0.0003	24	0.0003	0.0000	0.0011	0.0001	0.0002	0.0004
CC-3	0.0001	9	0.0001	0.0000	0.0002	0.0000	0.0000	0.0002
SC-1	0.0001	9	0.0002	0.0000	0.0005	0.0000	0.0000	0.0002
SC-2	0.0001	8	0.0001	0.0000	0.0003	0.0000	0.0001	0.0002
All Sites	0.0004	189	0.0016	0.0000	0.0154	0.0001	0.0001	0.0002

Nitrate/Nitrite Analysis

Figure 12 shows the median, lower and upper quartile, and ranges of nitrate/nitrite values for Bear Butte Creek sites. The nitrate/nitrite concentrations were far below the 88 mg/L limit for coldwater fisheries. Levels were lowest at the upper headwater segment (WQM-126) and become elevated and highly variable downstream from the segment WQM-116 confluence. This is likely due to the subsequent oxidation of the high ammonia concentrations contributed by Strawberry Creek.

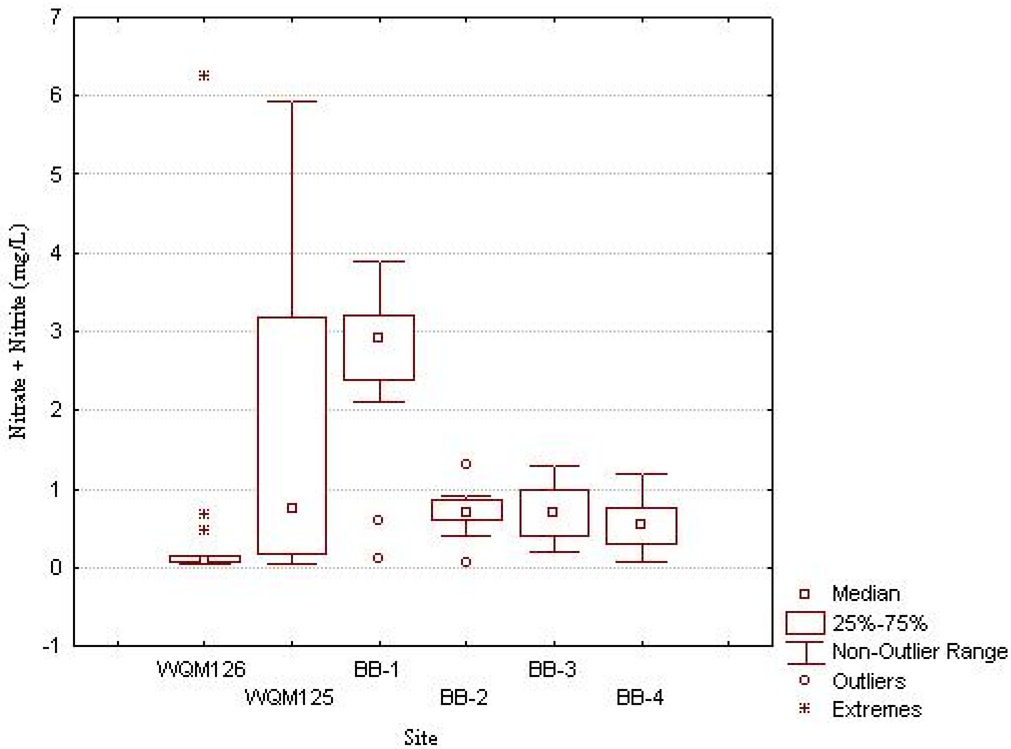


Figure 12. Box plot of nitrate/nitrite concentrations by site for Bear Butte Creek mainstem sites. Strawberry Creek heavily influences increases and variability in headwater concentrations; levels peak at site BB-1 followed by large declines at site BB-2.

Among mainstem sites, mean and median nitrate/nitrate concentrations peak at site BB-1 and decline noticeably at site BB-2. The mechanism(s) of nitrate/nitrite decline are not specifically known. Nitrate/nitrite concentrations remained nearly steady from BB-2 to the mouth of Bear Butte Creek.

Table 16 lists the descriptive statistics for nitrate/nitrite concentrations, which were the highest and most variable in Strawberry Creek. The mean value at site WQM-116 was 12.38 mg/L and the maximum value was 38.30 mg/L. These concentrations appeared to have strongly affected the mean nitrate/nitrite levels at WQM-125 (1.60 mg/L).

Table 16. Descriptive statistics for nitrate/nitrite concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.42	22	1.31	0.05	6.25	0.06	0.09	0.15
WQM-116	12.38	22	13.27	0.10	38.30	1.26	3.84	21.80
WQM-125	1.60	22	1.81	0.05	5.93	0.18	0.75	3.18
BB-1	2.69	25	0.85	0.10	3.90	2.40	2.90	3.20
BB-2	0.71	24	0.23	0.06	1.30	0.60	0.70	0.85
BB-3	0.70	24	0.34	0.20	1.30	0.40	0.70	1.00
BB-4	0.55	24	0.30	0.06	1.20	0.30	0.55	0.75
CC-3	0.09	9	0.02	0.06	0.10	0.10	0.10	0.10
SC-1	0.70	9	0.17	0.40	1.00	0.60	0.70	0.80
SC-2	0.53	8	0.22	0.20	0.90	0.40	0.50	0.65
All Sites	2.34	189	5.85	0.05	38.30	0.23	0.70	1.82

The mean concentration value for BB-1 (2.69 mg/L) was higher than that of WQM-125 (1.60 mg/L). Of the mainstem sites, values at BB-2 were the least variable (standard deviation was 0.23). Besides the strong influence upon headwaters by Strawberry Creek, mainstem concentrations made the biggest changes between BB-1 and BB-2 with a median concentration difference of 2.20 mg/L between the two sites.

The lowest mean value (0.09 mg/L) and median value (0.10 mg/L) was observed at CC-3, largely due to several non-detectable measurements. Spring and Cottle Creeks concentrations showed the least variability of the group, with the lowest standard deviation at CC-3 (0.02 mg/L).

Total Kjeldahl Nitrogen (TKN) Analysis

Figure 13 shows the median, lower and upper quartile, and ranges of TKN values Bear Butte Creek sites. TKN concentrations showed very little variability at the upper headwater site (WQM-126) with the exception of two extreme values. The site below the Strawberry Creek confluence was slightly variable. Median concentrations at these two locations were found at the minimum detection limit of 0.11 mg/L. Median concentrations at the mainstem sites accumulated from upstream to downstream.

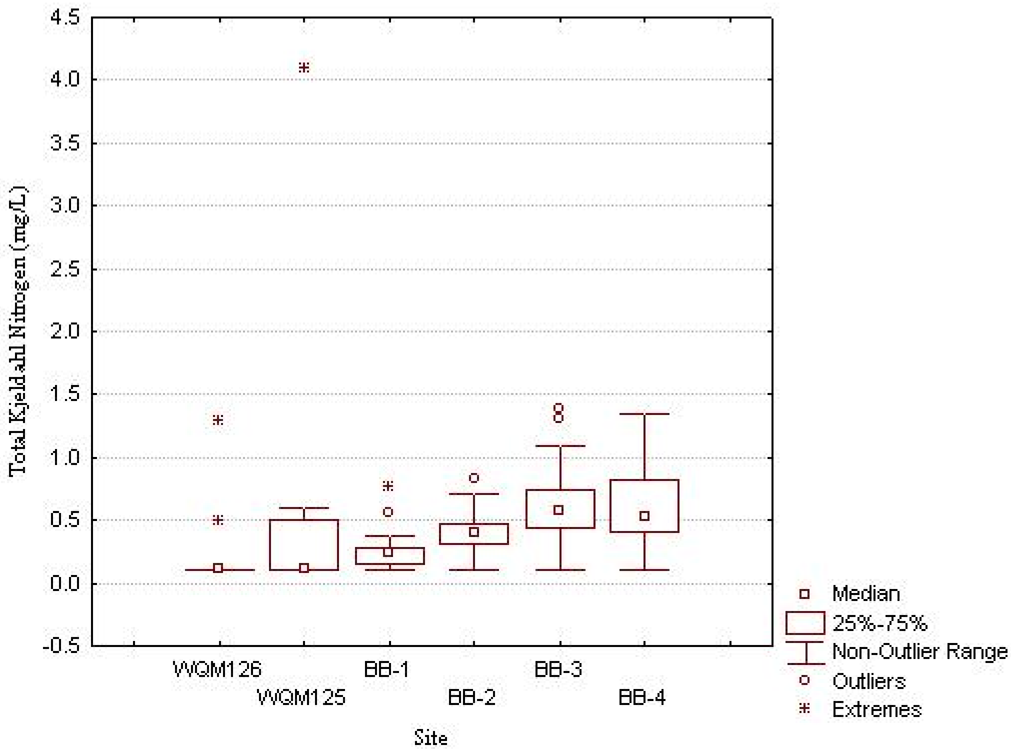


Figure 13. Box plot of TKN concentrations by site for Bear Butte Creek mainstem sites.

Table 17 shows the descriptive statistics for TKN concentrations by site and for all sites. The highest mean values (0.69 mg/L) occurred in the BB-3 and BB-4 segments. The highest mean concentration was observed at SC-2 (0.75 mg/L), followed by WQM-116 (0.68 mg/L). The highest observed maximum value (4.10 mg/L) was observed at WQM-125.

Many samples had no detectable levels of TKN, which resulted in several minimum values of 0.11 mg/L (half the detection limit of 0.21 mg/L). For some samples, high nitrate/nitrite concentrations (10X the TKN level) may have resulted in low TKN values. Several samples from site WQM-116 were flagged for nitrate/nitrite concentrations that interfered with TKN assays (Kindt, 2004).

Table 17. Descriptive statistics for Total Kjeldahl Nitrogen concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.18	22	0.26	0.11	1.30	0.11	0.11	0.11
WQM-116	0.68	22	0.79	0.11	3.20	0.11	0.11	1.20
WQM-125	0.40	22	0.85	0.11	4.10	0.11	0.11	0.50
BB-1	0.25	25	0.15	0.11	0.77	0.15	0.24	0.28
BB-2	0.41	24	0.17	0.11	0.83	0.31	0.40	0.48
BB-3	0.65	24	0.31	0.11	1.38	0.45	0.57	0.75
BB-4	0.63	24	0.31	0.11	1.35	0.41	0.54	0.82
CC-3	0.39	9	0.23	0.11	0.81	0.21	0.37	0.54
SC-1	0.56	9	0.21	0.11	0.85	0.51	0.53	0.66
SC-2	0.75	8	0.18	0.54	1.06	0.61	0.72	0.86
All Sites	0.47	189	0.48	0.11	4.10	0.11	0.39	0.60

Organic Nitrogen Analysis

Figure 14 shows the median, lower and upper quartile, and ranges of organic nitrogen values for Bear Butte Creek sites. Organic nitrogen values were calculated by subtracting ammonia concentrations from TKN values. Since most of the ammonia readings were below detection limits, the organic nitrogen values closely approximate results from the TKN examination. These results show low median values in the headwaters, with increasing variability below Strawberry Creek, and accumulation upstream to downstream. Generally, the highest concentrations were at BB-3 and BB-4.

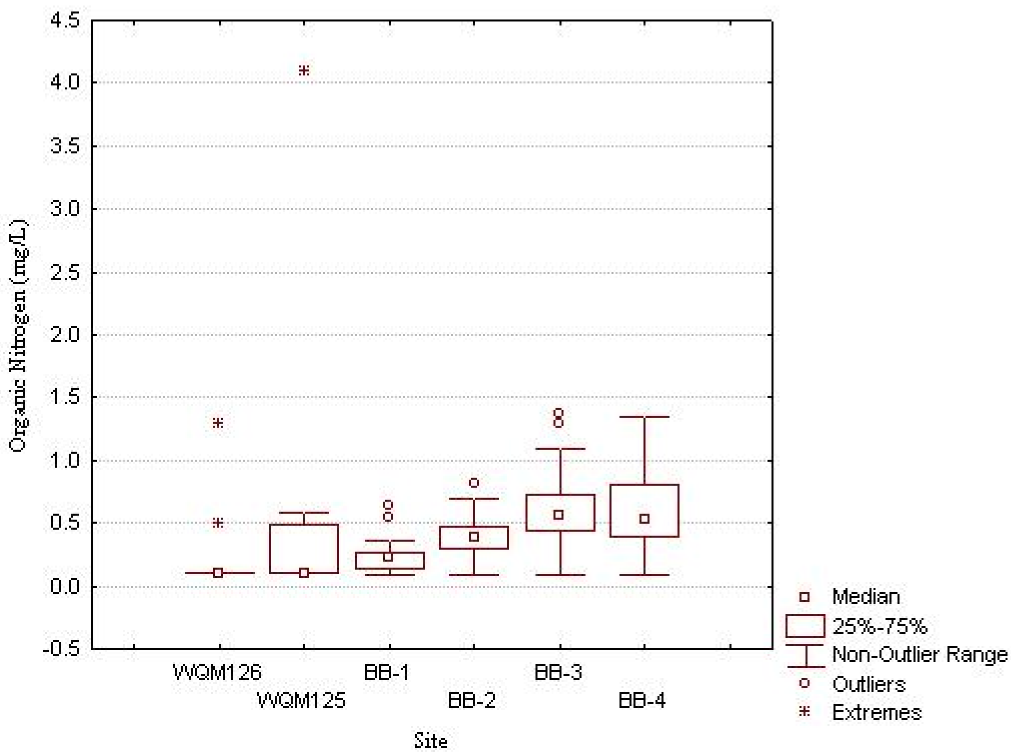


Figure 14. Box plot of organic nitrogen concentrations by site for Bear Butte Creek mainstem sites.

Table 18 shows the descriptive statistics for organic nitrogen concentrations for all sites. The results were quite similar to the TKN concentrations. The highest mean and median concentrations were observed at SC-2 (0.74 and 0.71 mg/L, respectively). The greatest variability occurred at WQM-125 (standard deviation of 0.85), which also had the highest observed maximum value (4.09 mg/L). The least variable site was BB-1 (standard deviation of 0.13).

Organic nitrogen values for site WQM-116 were calculated to be negative and instead set to zero for twelve sampling events. The negative values were the result of subtracting relatively high ammonia values from TKN values measured to be below the minimum detection limit. As mentioned in the TKN summary, several of these samples were flagged for nitrate/nitrite interference of TKN detection.

Table 18. Descriptive statistics for organic nitrogen concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.17	22	0.26	0.10	1.29	0.10	0.10	0.10
WQM-116	0.27	22	0.34	0.00	1.19	0.00	0.10	0.50
WQM-125	0.39	22	0.85	0.10	4.09	0.10	0.10	0.49
BB-1	0.23	25	0.13	0.10	0.64	0.14	0.23	0.27
BB-2	0.40	24	0.17	0.10	0.82	0.30	0.39	0.47
BB-3	0.64	24	0.31	0.10	1.37	0.44	0.56	0.74
BB-4	0.62	24	0.31	0.09	1.34	0.40	0.53	0.81
CC-3	0.38	9	0.23	0.10	0.80	0.20	0.36	0.53
SC-1	0.54	9	0.21	0.10	0.84	0.50	0.52	0.65
SC-2	0.74	8	0.18	0.53	1.05	0.60	0.71	0.85
All Sites	0.41	189	0.41	0.00	4.09	0.10	0.36	0.57

Inorganic Nitrogen Analysis

Figure 15 shows the median, lower and upper quartile, and ranges of inorganic nitrogen concentrations for Bear Butte Creek sites. Inorganic nitrogen was calculated as the sum of ammonia and nitrate/nitrite concentrations. Only relatively small amounts of ammonia were detected in water samples; as a result, the inorganic nitrogen graph resembles the nitrate/nitrite graph. Inorganic nitrogen concentrations were shown to be lowest in the upper headwater segment, higher and extremely variable below Strawberry Creek, and highest at BB-1 before dropping to headwater-level concentrations in the lower mainstem segments.

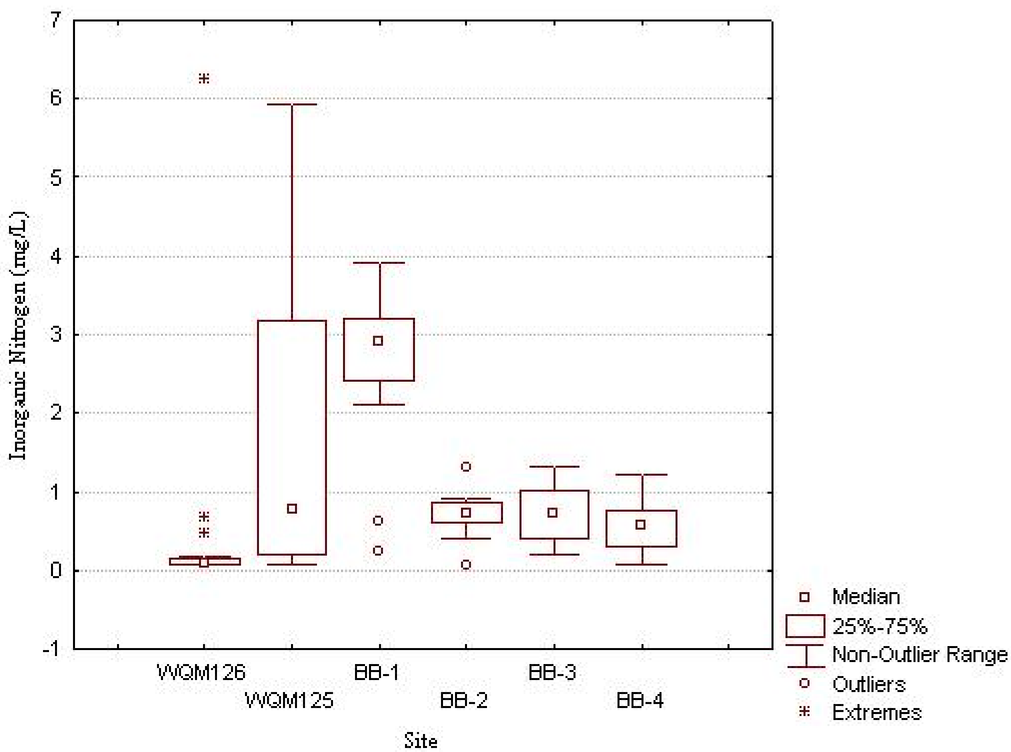


Figure 15. Inorganic nitrogen concentrations by site for Bear Butte Creek watershed mainstem sites.

Table 19 lists the descriptive statistics for inorganic nitrogen concentrations, which were the highest and most variable in Strawberry Creek. The mean value at site WQM-116 was 12.94 mg/L and the maximum value was 38.80 mg/L. These concentrations appeared to have strongly affected the mean inorganic nitrogen levels at WQM-125 (1.61 mg/L), compared to mean levels above Strawberry Creek at site WQM-126 (0.43 mg/L).

Table 19. Descriptive statistics for inorganic nitrogen concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.43	22	1.31	0.06	6.26	0.07	0.10	0.16
WQM-116	12.94	22	13.79	0.11	38.80	1.66	3.85	22.90
WQM-125	1.61	22	1.81	0.06	5.94	0.19	0.76	3.19
BB-1	2.70	25	0.84	0.23	3.91	2.41	2.91	3.21
BB-2	0.72	24	0.23	0.07	1.31	0.61	0.71	0.86
BB-3	0.71	24	0.34	0.21	1.31	0.41	0.71	1.01
BB-4	0.56	24	0.30	0.08	1.21	0.31	0.56	0.76
CC-3	0.10	9	0.02	0.07	0.11	0.11	0.11	0.11
SC-1	0.72	9	0.16	0.41	1.01	0.66	0.71	0.81
SC-2	0.54	8	0.22	0.21	0.91	0.41	0.51	0.66
All Sites	2.41	189	6.10	0.06	38.80	0.31	0.71	1.91

Of the mainstem sites, values at BB-2 were the least variable (standard deviation was 0.23). Mean mainstem inorganic concentrations made the biggest declines between BB-1 and BB-2, with a mean concentration difference of 1.98 mg/L.

Spring and Cottle Creeks concentrations showed the least variability among all sites, with the lowest standard deviation at CC-3 (0.017 mg/L).

The lowest mean value was observed at CC-3 (0.10 mg/L), and the lowest median value was observed at WQM-126 (0.10 mg/L), due in part to several sample results at the minimum detection limit. The mean value for all sites, including the extreme values from Strawberry Creek, was 2.41 mg/L.

Total Nitrogen Analysis

Total nitrogen is the sum of organic and inorganic nitrogen concentrations. In the Bear Butte Creek system, the composition of organic nitrogen was mostly TKN; inorganic nitrogen was almost completely nitrate/nitrite. TKN was present in smaller concentrations; as a result, total nitrogen was represented chiefly by nitrate/nitrite concentrations.

The graph of total nitrogen in Figure 16 shows the median, lower and upper quartile, and ranges of total nitrogen values for Bear Butte Creek sites. Total nitrogen was lowest at the upper headwater segment, most variable below Strawberry Creek, generally highest at BB-1, and lower and least variable in segments BB-2 to BB-4. As discussed above, the nitrate/nitrite graph has a similar appearance.

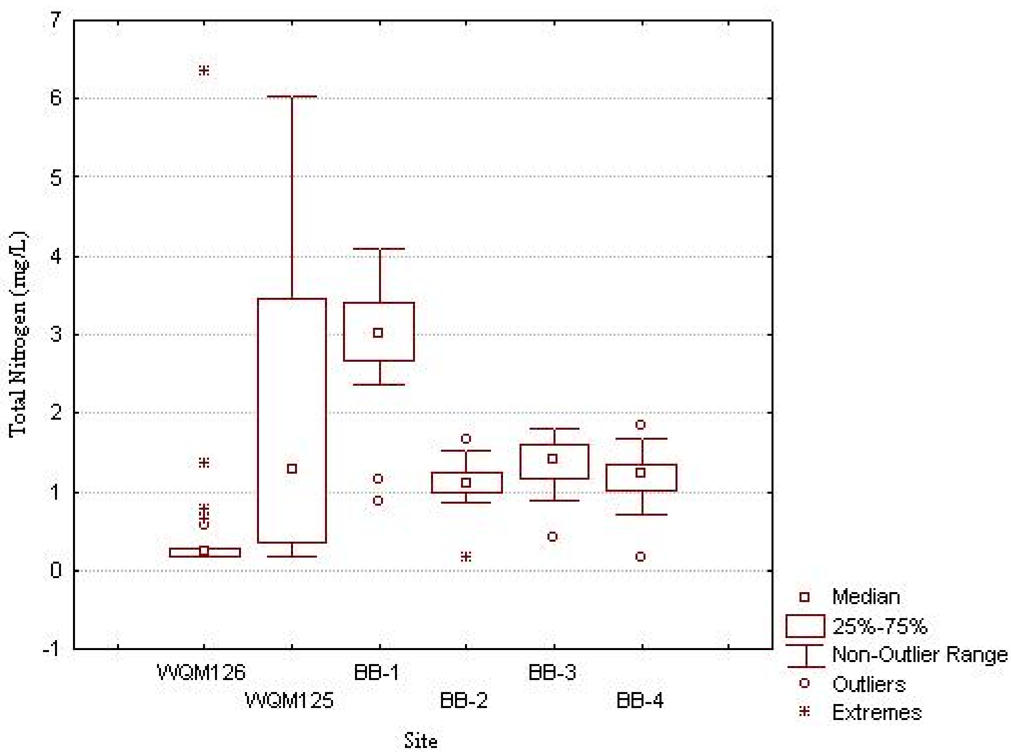


Figure 16. Total nitrogen concentrations by site for Bear Butte Creek watershed mainstem sites.

As shown in Figure 17, the composition of total nitrogen in the headwater areas and at BB-1 was mostly inorganic (nitrate/nitrate). On average, water sampling results for the headwater areas showed 92 % nitrate/nitrite and 8 % TKN. Sample records showed non-detection of TKN in 48 of 66 headwater area samples (73 %); however, high nitrate values have been known to interfere with analysis and detection of TKN (Kindt, 2004).

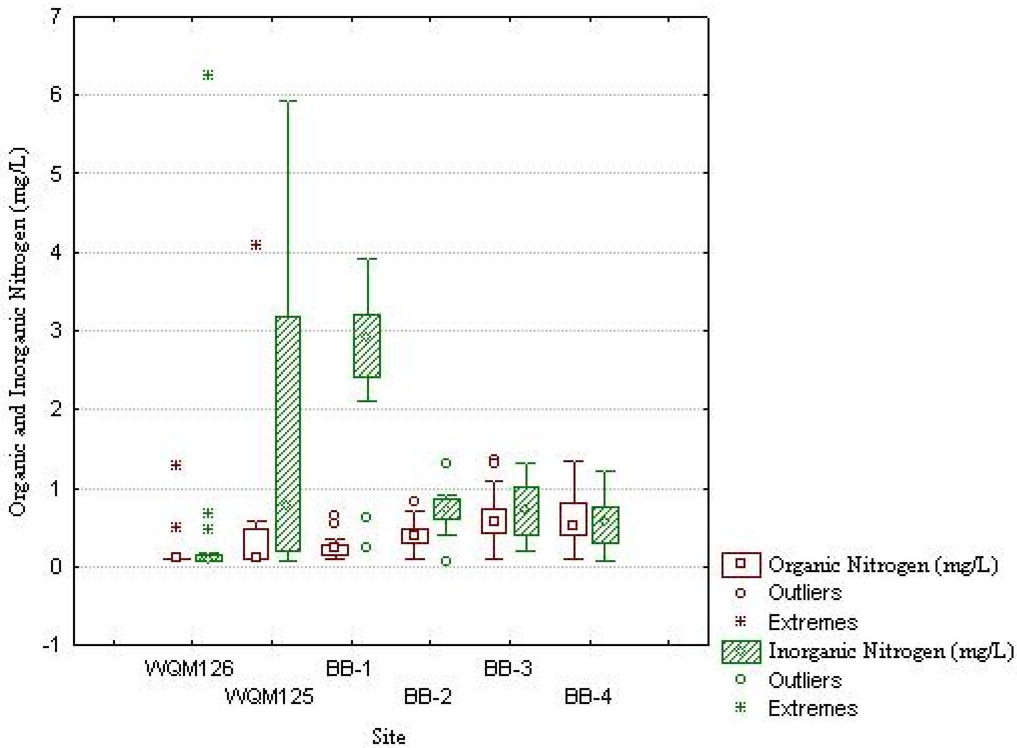


Figure 17. Total Kjeldahl Nitrogen (TKN) and nitrate/nitrite concentration comparison from upstream to downstream for Bear Butte Creek watershed mainstem sites. TKN was shown to have increased steadily while nitrate/nitrite concentrations spiked downstream from the Strawberry Creek confluence.

Total nitrogen composition at the lower mainstem sites (BB-2, BB-3, and BB-4) was nearly equal parts TKN and nitrate/nitrite. TKN (organic nitrogen) concentrations showed a tendency to accumulate and nitrate/nitrite (inorganic nitrogen) levels to decrease, so that the composition of total nitrogen in these downstream segments averaged 54 % nitrate/nitrite and 46 % TKN.

The descriptive statistics listed in Table 20 and were fairly reflective of the nitrate/nitrite and inorganic nitrogen results. The highest mean values were found in Strawberry Creek (13.21 mg/L) and at BB-1 (2.94 mg/L), which had the highest mean concentration of the mainstem sites. Cottle Creek (0.48 mg/L) and the upper headwater site, WQM-126 (0.60 mg/L), had the lowest mean concentration.

Table 20. Descriptive statistics for total nitrogen concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.60	22	1.32	0.17	6.36	0.17	0.23	0.27
WQM-116	13.21	22	13.77	0.21	38.90	1.66	4.74	22.90
WQM-125	1.99	22	1.86	0.17	6.04	0.34	1.28	3.45
BB-1	2.94	25	0.73	0.87	4.09	2.66	3.01	3.41
BB-2	1.12	24	0.28	0.17	1.67	0.99	1.10	1.24
BB-3	1.35	24	0.32	0.41	1.81	1.16	1.42	1.59
BB-4	1.19	24	0.35	0.17	1.85	1.03	1.22	1.34
CC-3	0.48	9	0.24	0.17	0.91	0.31	0.47	0.64
SC-1	1.26	9	0.33	0.51	1.55	1.23	1.33	1.51
SC-2	1.27	8	0.26	0.96	1.68	1.05	1.26	1.46
All Sites	2.83	189	6.05	0.17	38.90	0.76	1.24	2.12

The greatest variability occurred at site WQM-116 (standard deviation of 13.77 mg/L). Total nitrogen concentrations from Strawberry Creek may also have induced variability at site WQM-125 (standard deviation of 1.86 mg/L). BB-2 was the least variable of the mainstem segments (standard deviation of 0.28 mg/L). The low variability of sites CC-3 and SC-2, being the least variable segments overall, is likely due to the few (nine) samples taken.

Site CC-3 had the lowest maximum value (0.91 mg/L). Strawberry Creek (WQM-116) had the highest maximum value of all sites (38.9 mg/L). BB-1 had the highest minimum (0.87 mg/L) and maximum (4.09 mg/L) values of the mainstem sites. The lowest median value observed was at site WQM-126 (0.23 mg/L).

Phosphorus

Phosphorus differs from nitrogen in that it is not as water-soluble and will adsorb onto sediments and other particulates. Once phosphorus becomes attached, it is not readily available for uptake and utilization. Total dissolved phosphorus is the fraction of total phosphorus readily available for use by algae. Dissolved phosphorus will adsorb onto suspended materials (both organic and inorganic, if present in the water column and not already saturated with phosphorus). Phosphorus sources can be natural from geology and soil, from decaying organic matter, or waste from septic tanks or agricultural runoff.

Nutrients such as phosphorus and nitrogen tend to accumulate during low flows because they are associated with fine particles whose transport is dependent upon discharge (Allan, 1995). These nutrients are deposited and retained on stream banks and floodplains when stream flow subsides. Phosphorus will remain in the stream sediments unless released by increased stream flow.

Re-suspending phosphorus and other nutrients associated with sediment into the water column should show increased concentrations during rain events due to increased flow. Reduced flows and discharge may deposit phosphorus and other nutrients associated with sediment on the stream banks and floodplain. Rain events increase flows and re-suspend sediment and phosphorus stored in the floodplain and stream banks.

Total Phosphorus Analysis

The graph of total phosphorus (TP) in Figure 18 shows the median, lower and upper quartile, and ranges of TP for Bear Butte Creek sites. Relatively low TP concentrations were observed at all sites with little variability; outliers and extreme values were caused by event-based, high flows.

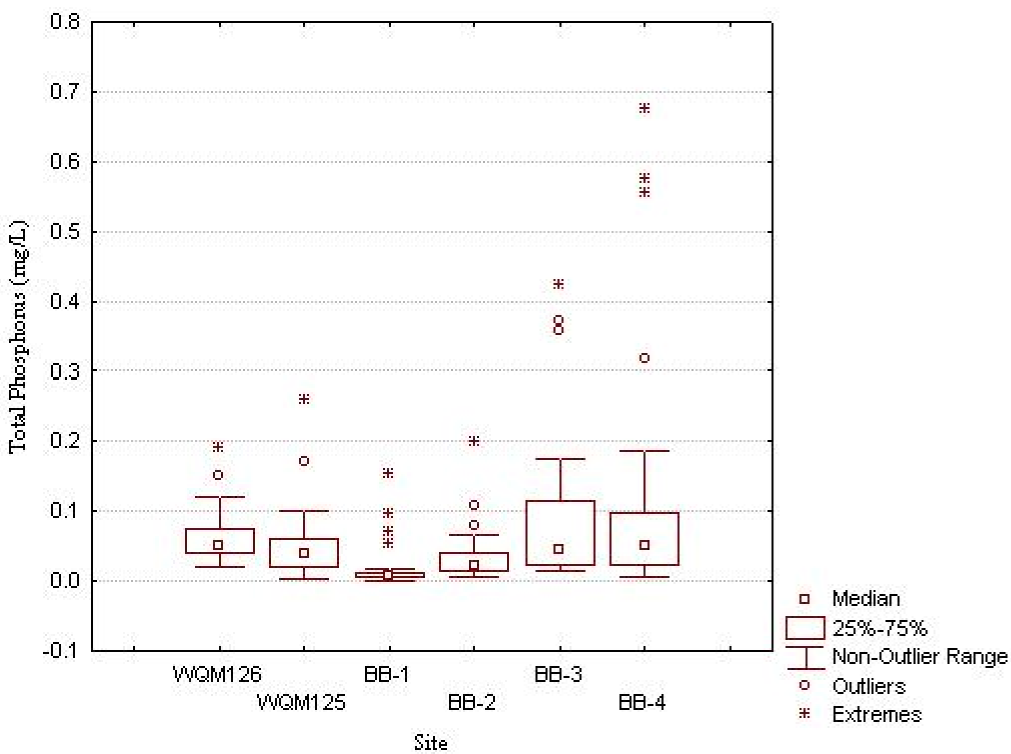


Figure 18. Total Phosphorus concentrations by site for Bear Butte Creek watershed mainstem sites.

The descriptive statistics for total phosphorus are listed in Table 21. The mean for all sites in the study was 0.07 mg/L. The highest mean site TP value was at SC-2 (0.17 mg/L); the lowest at BB-1 (0.02 mg/L). The greatest variability occurred at SC-2 (standard deviation of 0.24 mg/L); the lowest at SC-1 (0.01 mg/L). The highest maximum values were observed at SC-2 (0.74 mg/L) and BB-4 (0.68 mg/L). The sample from BB-4 was collected during a rain event on 15 June 1999, where the flow rate was approximately 265 cfs.

Table 21. Descriptive statistics for total phosphorus concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.07	20	0.04	0.02	0.19	0.04	0.05	0.08
WQM-116	0.06	20	0.12	0.00	0.48	0.01	0.03	0.05
WQM-125	0.06	20	0.06	0.00	0.26	0.02	0.04	0.06
BB-1	0.02	25	0.04	0.00	0.15	0.01	0.01	0.01
BB-2	0.04	24	0.04	0.01	0.20	0.02	0.02	0.04
BB-3	0.09	24	0.12	0.01	0.42	0.02	0.04	0.11
BB-4	0.13	24	0.20	0.01	0.68	0.02	0.05	0.10
CC-3	0.04	8	0.03	0.02	0.12	0.02	0.03	0.05
SC-1	0.03	9	0.01	0.02	0.05	0.03	0.03	0.05
SC-2	0.17	8	0.24	0.04	0.74	0.06	0.09	0.13
All Sites	0.07	182	0.11	0.00	0.74	0.02	0.04	0.06

Dissolved Phosphorus Analysis

The graph of total dissolved phosphorus (TDP) in Figure 19 shows the median, lower and upper quartile, and ranges of dissolved phosphorus values for Bear Butte Creek sites. DP sampling data was affected by the lack of TDP chemical analysis performed on the mainstem segments (only one value available for sites BB-2, BB-3, and BB-4.

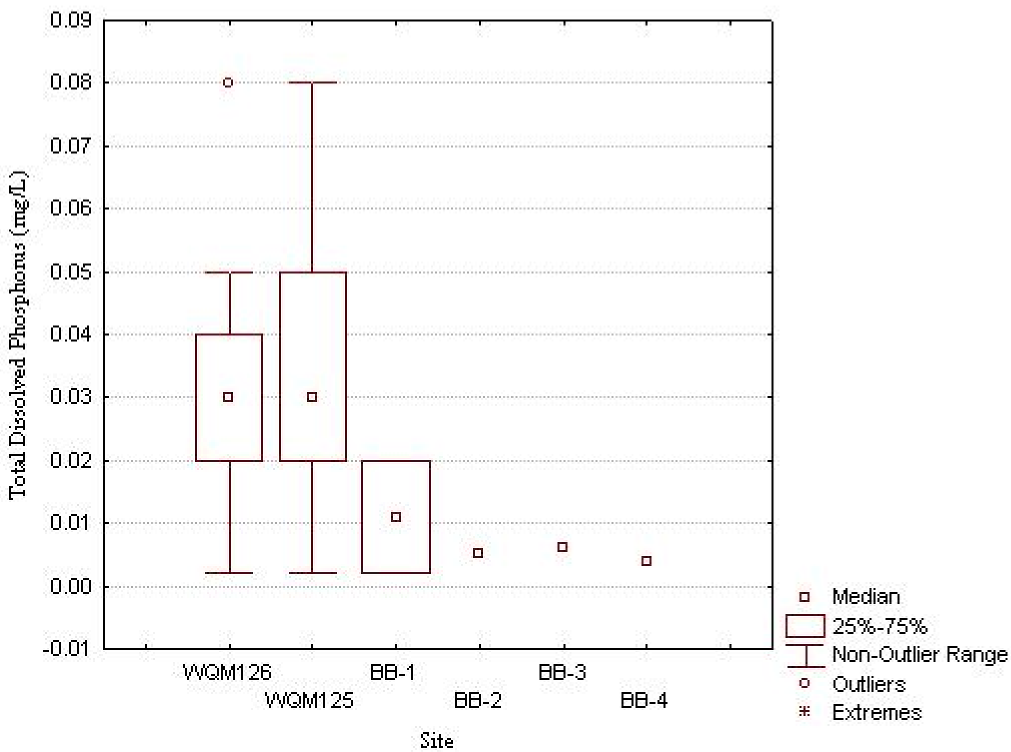


Figure 19. Box plot of total dissolved phosphorus concentrations by site for Bear Butte Creek mainstem sites.

Table 22 lists descriptive statistics for DP concentrations at all the Bear Butte Creek study sites. Concentrations at headwater sites had higher mean (0.02 to 0.03 mg/L) values than other study sites; however, more samples were collected at these sites.

Table 22. Descriptive statistics for dissolved phosphorus concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	0.03	18	0.02	0.00	0.08	0.02	0.03	0.04
WQM-116	0.02	19	0.02	0.00	0.06	0.00	0.01	0.02
WQM-125	0.03	18	0.02	0.00	0.08	0.02	0.03	0.05
BB-1	0.01	2	0.01	0.00	0.02	0.00	0.01	0.02
BB-2	0.01	1	0.00	0.01	0.01	0.01	0.01	0.01
BB-3	0.01	1	0.00	0.01	0.01	0.01	0.01	0.01
BB-4	0.00	1	0.00	0.00	0.00	0.00	0.00	0.00
CC-3	0.02	8	0.02	0.00	0.07	0.00	0.01	0.02
SC-1	0.01	9	0.00	0.00	0.01	0.01	0.01	0.01
SC-2	0.02	8	0.02	0.00	0.06	0.00	0.01	0.02
All Sites	0.02	85	0.02	0.00	0.08	0.01	0.02	0.03

Total Solids Analysis

"Solids" is a general term that refers to suspended or dissolved materials present in the waterbody. Three solids parameters were examined in this assessment: total solids (TS), total suspended solids (TSS), and total dissolved solids (TDS). Total solids include the sum of dissolved and suspended material. The suspended materials include both organic and inorganic forms.

Figure 20 shows the median, lower and upper quartile, and ranges of TS for Bear Butte Creek sites. TS concentrations appeared to accumulate within the waterbody, as shown by the values increasing in a downstream direction.

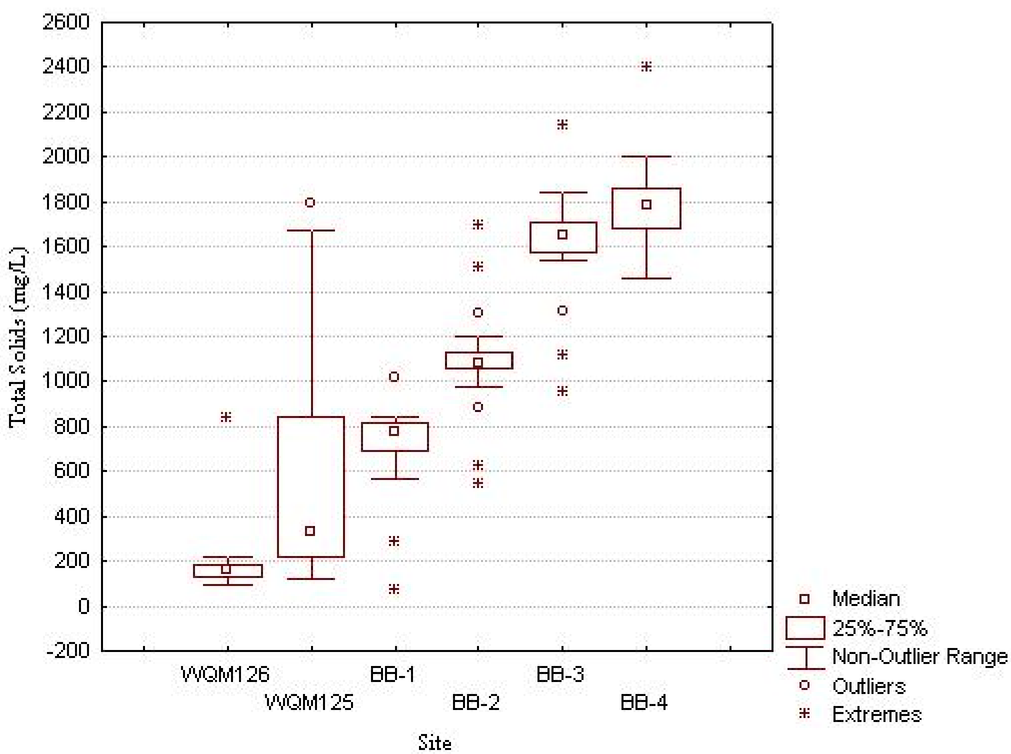


Figure 20. Total solids (TS) concentrations by site for Bear Butte Creek watershed mainstem sites.

Table 23 is a list of descriptive statistics for TS concentrations at all the Bear Butte Creek study sites. Strawberry Creek had the highest mean concentration of TS in the study (3,479 mg/L); SC-2 was the next highest at 2,504 mg/L; WQM-126 had the lowest concentration (186 mg/L).

The Strawberry Creek segment, WQM-116, had the highest maximum concentration (8,970 mg/L) and WQM-126 had the lowest maximum concentration (839 mg/L). The highest minimum value of the mainstem sites was observed at SC-1 (2,298 mg/L).

Table 23. Descriptive statistics for total solids concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	186	22	150	93	839	126	161	182
WQM-116	3,479	22	3,252	330	8,970	600	1,851	6,670
WQM-125	605	22	529	122	1,791	222	332	846
BB-1	721	25	189	74	1,015	692	776	815
BB-2	1,089	24	228	542	1,695	1,056	1,082	1,133
BB-3	1,617	24	230	953	2,142	1,579	1,655	1,712
BB-4	1,793	24	185	1,463	2,400	1,687	1,785	1,858
CC-3	1,875	7	49	1,809	1,940	1,842	1,858	1,934
SC-1	2,410	8	85	2,298	2,514	2,341	2,408	2,486
SC-2	2,504	7	217	2,203	2,797	2,295	2,465	2,703
All Sites	1,459	185	1,494	74	8,970	626	1,101	1,791

Total Dissolved Solids Analysis

The concentration of total dissolved solids (TDS) is a measure of the dissolved minerals in the sample and can be correlated with the electrical conductivity of the water. Water quality samples gathered by the United States Geological Survey were not assayed for TDS. Instead, the TDS concentrations were calculated from the constituent concentrations acquired from the lab report.

Overall, the calculated values for TDS were high compared to those for suspended solids. As a result, TDS concentrations were often near those for total solids. The graph in Figure 21 shows the median, lower and upper quartile, and ranges of TDS values for Bear Butte Creek sites. TDS accumulated in Bear Butte Creek, as shown by the increasing median and quartile values along the mainstem sites.

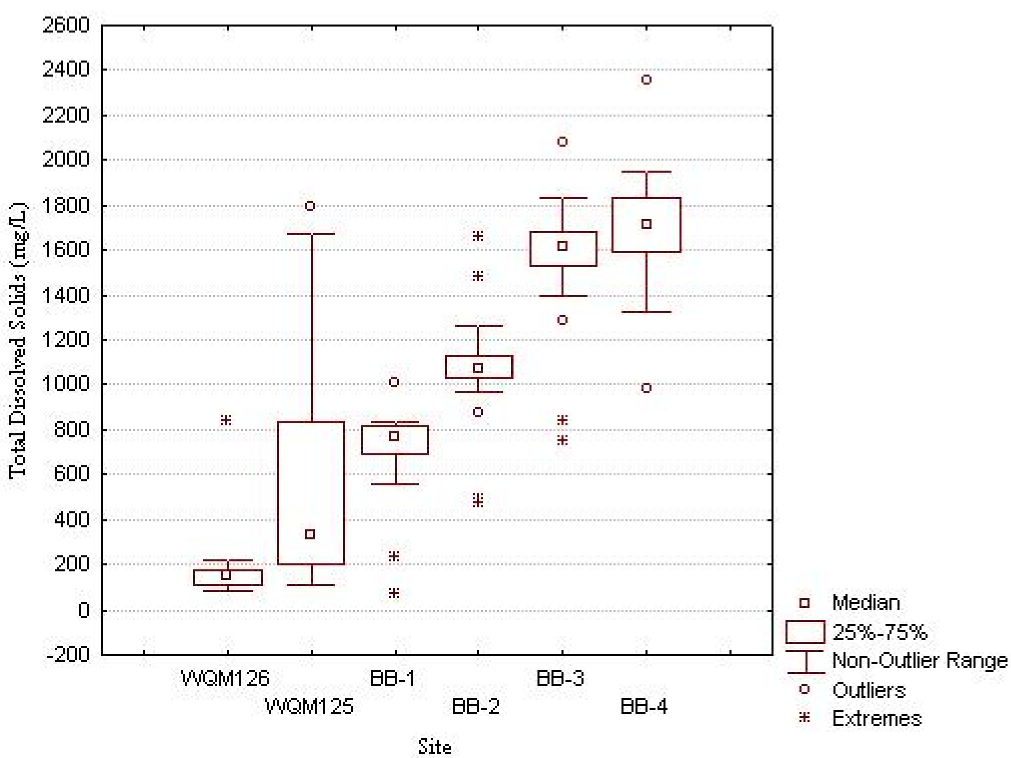


Figure 21. Box plot of total dissolved solids concentrations by site for Bear Butte Creek mainstem sites.

Table 24 is a list of descriptive statistics for TDS concentrations at all the Bear Butte Creek study sites. WQM-116 had the highest mean concentration of TDS in the study (3,460 mg/L) and SC-1 was the next highest at 2,390 mg/L. WQM-126 had the lowest mean concentration (178 mg/L). WQM-116 also had the highest maximum TDS concentration (8,955 mg/L) among all sites. WQM-126 had the lowest maximum concentration (838 mg/L). SC-1 had the highest minimum concentration (2,281 mg/L).

Strawberry Creek concentrations were the most variable (standard deviation of 3,258 mg/L), followed by WQM-125 (standard deviation of 532 mg/L). The segment with the least variability was CC-3 (standard deviation of 51 mg/L); however, the analysis is based only on eight water quality sampling events.

Table 24. Descriptive statistics for total dissolved solids concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	178	22	152	86	838	110	149	177
WQM-116	3,460	22	3,258	324	8,955	586	1,842	6,655
WQM-125	599	22	532	110	1,790	204	331	837
BB-1	717	25	194	73	1,012	690	772	814
BB-2	1,067	24	241	478	1,663	1,035	1,068	1,129
BB-3	1,558	24	278	753	2,079	1,532	1,612	1,681
BB-4	1,692	24	257	985	2,355	1,589	1,714	1,832
CC-3	1,857	7	51	1,798	1,927	1,806	1,844	1,914
SC-1	2,390	8	88	2,281	2,504	2,315	2,380	2,471
SC-2	2,376	7	188	2,164	2,667	2,213	2,365	2,574
All Sites	1,424	185	1,490	73	8,955	588	1,091	1,745

Total Suspended Solids Analysis

The graph of TSS in Figure 22 shows the median, lower and upper quartile, and ranges of TSS values for Bear Butte Creek sites. Generally, TSS concentrations increased in a downstream direction. Several extreme values were observed during event-based flows. At site BB-3, three out of 24 (13%) samples exceeded the TSS standard (158 mg/L). At site BB-4, four out of 24 (17%) samples exceeded the standard.

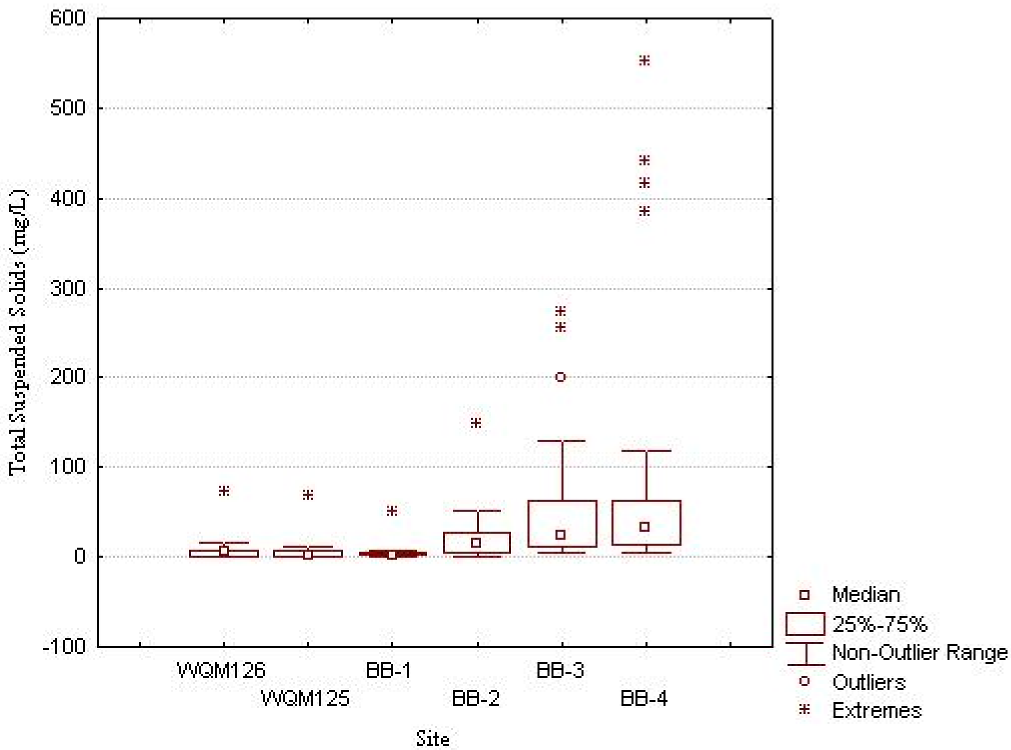


Figure 22. Box plot of total suspended solids concentrations by site for Bear Butte Creek mainstem sites.

Table 25 lists descriptive statistics of the TSS data. The highest mean and median TSS concentrations and greatest variability were observed at SC-2 (mean = 128 mg/L, median = 58 mg/L, and s.d. = 201) and BB-4 (mean = 101 mg/L, median = 34 mg/L, and s.d. = 162). These high mean and standard deviation values were caused by event-driven, high flows. The highest minimum value was also observed at SC-2 (36 mg/L).

Table 25. Descriptive statistics for total suspended solids concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	8	22	15	1	72	1	5	7
WQM-116	19	22	32	1	156	6	14	16
WQM-125	7	22	14	1	68	1	1	7
BB-1	5	25	10	1	51	2	2	4
BB-2	22	24	30	1	148	6	15	28
BB-3	59	24	78	4	274	11	25	63
BB-4	101	24	162	4	552	14	34	62
CC-3	18	7	13	3	44	10	14	22
SC-1	20	8	9	9	33	14	20	27
SC-2	128	7	201	36	584	39	58	70
All Sites	35	185	84	1	584	3	10	27

The mean TSS values at several sites, especially SC-2 and BB-4, were several times higher than the median values from these sites due to samples collected during event-based flows. Because these event flows caused exceedances of water quality standard and impacted the beneficial uses of the waterbody at sites BB-3 and BB-4, data were examined more closely to determine whether a significant relationship existed between TSS and stream flow.

Mainstem TSS data were plotted as a function of stream flow for each of the lower mainstem sites (BB-1, BB-2, BB-3, and BB-4). A linear regression method was used to determine how well TSS concentrations were correlated to stream flow at each site (Figure 23). The resulting equations were used to associate stream flow rates with TSS concentrations expected to exceed the water quality standards criteria of 158 mg/L for sites classified as coldwater marginal fisheries (BB-2, BB-3, and BB-4) and 53 mg/L for sites classified as coldwater permanent fisheries (BB-1). For site BB-1, a flow rate of approximately 97 cfs would result in exceeding the TSS criterion. Flow rates of approximately 130, 93, and 64 cfs for sites BB-2, BB-3, and BB-4, respectively, would result in exceeding the TSS criterion. Among sites classified as marginal coldwater fisheries, the flow rate at which TSS concentrations exceed the criterion decreases in a downstream direction. In other words, less stream flow is needed to suspend sediment at a level that will exceed water quality standards in downstream sites than upstream sites. This is partly due to the composition of the stream bed substrate and eroded material present, as the percent of streambed substrate composed of silt increases in a downstream direction.

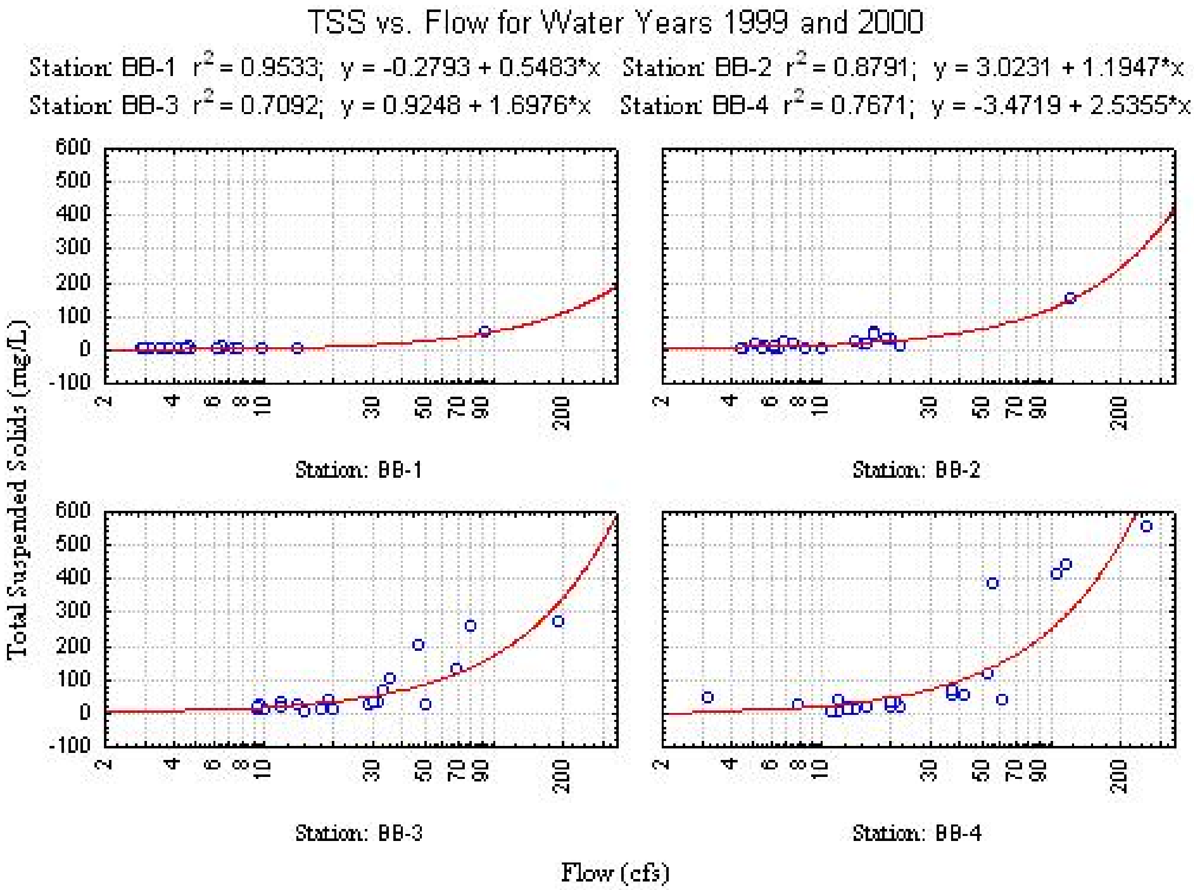


Figure 23. TSS concentrations vs. stream flow rate categorized by site for water years 1999 and 2000. TSS concentration and flow were correlated using a linear regression method (note the log scale on x-axis). The resulting regression equations and coefficients of determination (r^2) for each site are shown in the graph subtitle.

Total Suspended Solids Loadings

FLUX-modeled seasonal loadings of TSS are presented in Table 26 and shown graphically in Figure 24. The loading results show the accumulation of TSS within Bear Butte Creek throughout the year. TSS loads peak during summer months when most sites experience maximum stream flow rates (Table 9) and receive runoff from areas experiencing greater landuse activity. However, TSS loadings were highest during spring months at site WQM-125, possibly due to snowmelt runoff from areas of higher elevation. Highest annual TSS load among all sites was observed at BB-4 (5,611,373 kg). The lowest annual TSS load among all sites was observed at CC-3 (18,685 kg).

Table 26. Seasonal and annual TSS loads by site for water years 1999-2000.

Site	Season	Load (kg)	Percent
WQM125	Winter	1,281	1.2%
	Spring	57,878	55.6%
	Summer	32,466	31.2%
	Fall	12,465	12.0%
	Total	**104,089**	
SC1	Winter	5,959	18.7%
	Spring	6,394	20.1%
	Summer	10,458	32.9%
	Fall	8,972	28.2%
	Total	**31,784**	
SC2	Winter	133,479	15.6%
	Spring	231,881	27.1%
	Summer	240,278	28.1%
	Fall	250,915	29.3%
	Total	**856,553**	
CC3	Winter	3,529	18.9%
	Spring	4,851	26.0%
	Summer	5,172	27.7%
	Fall	5,133	27.5%
	Total	**18,685**	

Site	Season	Load (kg)	Percent
BB1	Winter	3,409	7.1%
	Spring	14,580	30.4%
	Summer	20,333	42.4%
	Fall	9,619	20.1%
	Total	**47,942**	
BB2	Winter	11,299	3.3%
	Spring	61,941	17.8%
	Summer	171,988	49.5%
	Fall	102,134	29.4%
	Total	**347,363**	
BB3	Winter	78,556	5.4%
	Spring	345,755	23.7%
	Summer	723,148	49.5%
	Fall	313,803	21.5%
	Total	**1,461,261**	
BB4	Winter	74,004	1.3%
	Spring	686,608	12.2%
	Summer	2,273,218	40.5%
	Fall	2,577,544	45.9%
	Total	**5,611,373**	

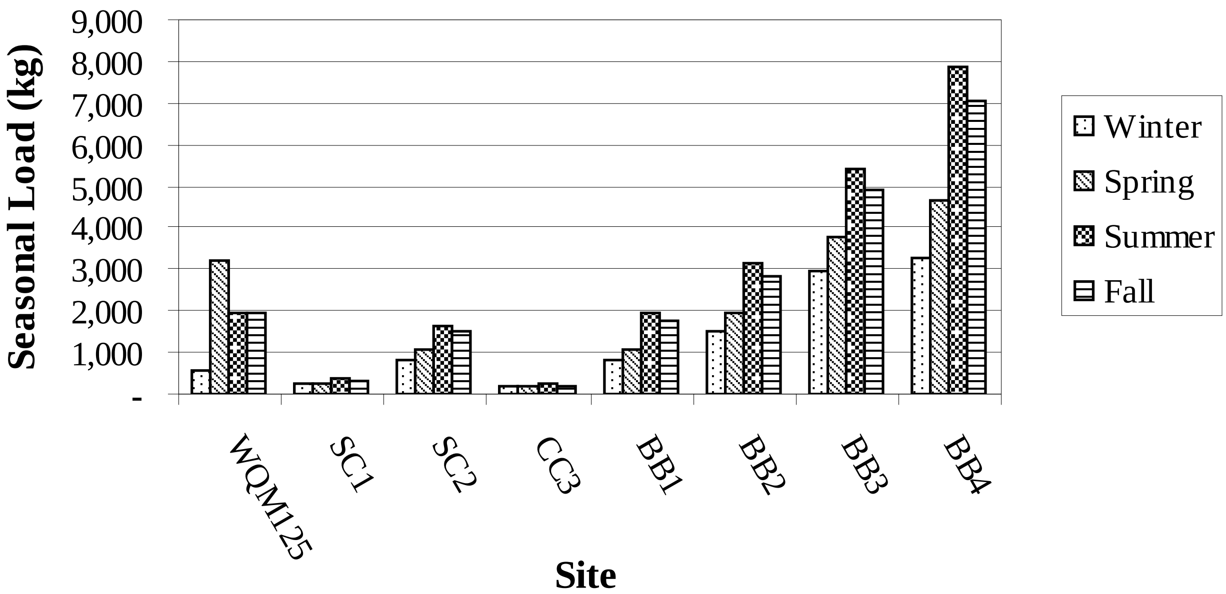


Figure 24. Seasonal TSS loads by site for water years 1999-2000.

To determine the amount of TSS load reduction required to meet water quality standards, the FLUX model was rerun for each assessment site, replacing TSS concentrations exceeding the 158 mg/L daily maximum standard with the actual daily maximum standard value. FLUX model results from site BB-4 were used to set the TMDL goal, as this site required the greatest level of TSS load reduction and provides a conservative TMDL goal. At site BB-4, the original modeled load was 5,611,373 kg/yr, and the modeled load with replacement concentrations was 2,177,370 kg/yr. Based on these results, an estimated 61% reduction of TSS load is required to meet the TSS water quality standard at site BB-4. This goal should be applied to the impaired stream reach shown in Figure 25.

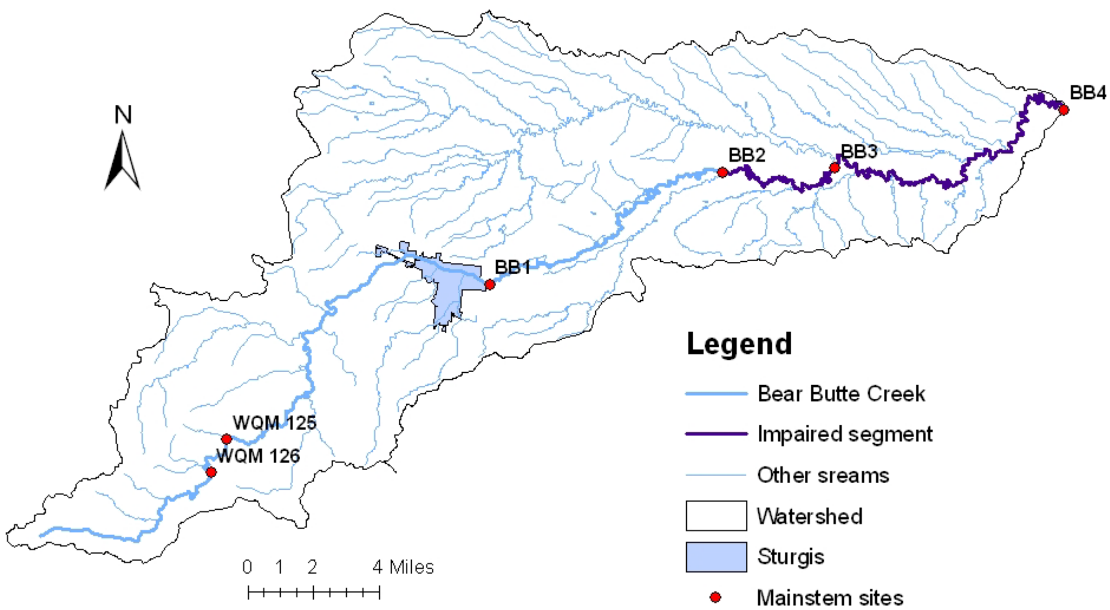


Figure 25. Location of Bear Butte Creek stream segment impaired by TSS concentrations.

TSS contributions of each subwatershed were divided by their respective land areas to obtain the TSS export coefficients for each area (Table 27 and Figure 26). These coefficients were used to attribute a fraction of the TSS contribution to each acre in the subwatershed and are reported as kilograms of TSS delivered per year per acre of land (kg/yr/acre). Subwatershed areas with higher export coefficients should be targeted for implementation of management practices. A map of subwatershed areas is presented in Figure 27.

Table 27. Seasonal and annual export coefficients (kg/acre) by site for water years 1999-2000.

Site	Season	Export Coefficient
WQM125	Winter	0.14
	Spring	6.52
	Summer	3.66
	Fall	1.41
	Annual	**11.73**
SC1	Winter	1.24
	Spring	1.33
	Summer	2.17
	Fall	1.86
	Annual	**6.60**
SC2	Winter	2.98
	Spring	5.18
	Summer	5.36
	Fall	5.60
	Annual	**19.12**
CC3	Winter	0.69
	Spring	0.95
	Summer	1.02
	Fall	1.01
	Annual	**3.68**

Site	Season	Export Coefficient
BB1	Winter	0.07
	Spring	0.31
	Summer	0.43
	Fall	0.20
	Annual	**1.01**
BB2	Winter	0.19
	Spring	1.03
	Summer	2.86
	Fall	1.70
	Annual	**5.78**
BB3	Winter	1.26
	Spring	5.54
	Summer	11.58
	Fall	5.02
	Annual	**23.40**
BB4	Winter	0.52
	Spring	4.86
	Summer	16.10
	Fall	18.25
	Annual	**39.73**

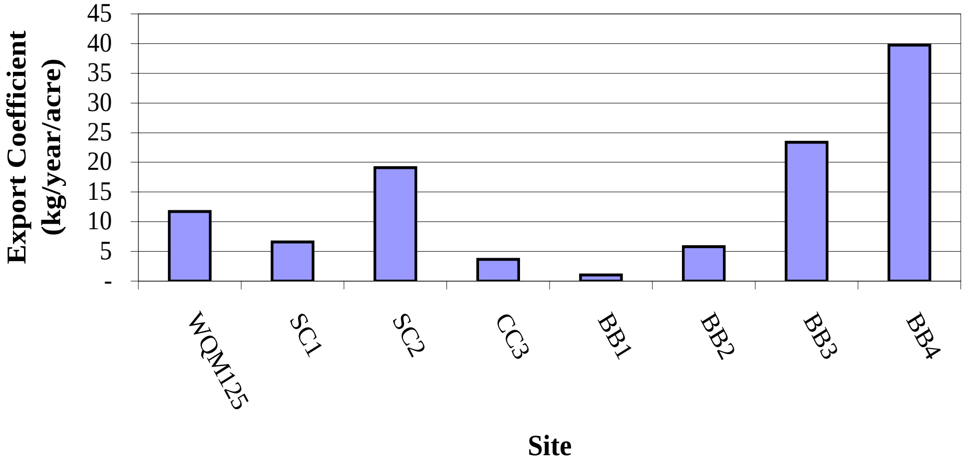
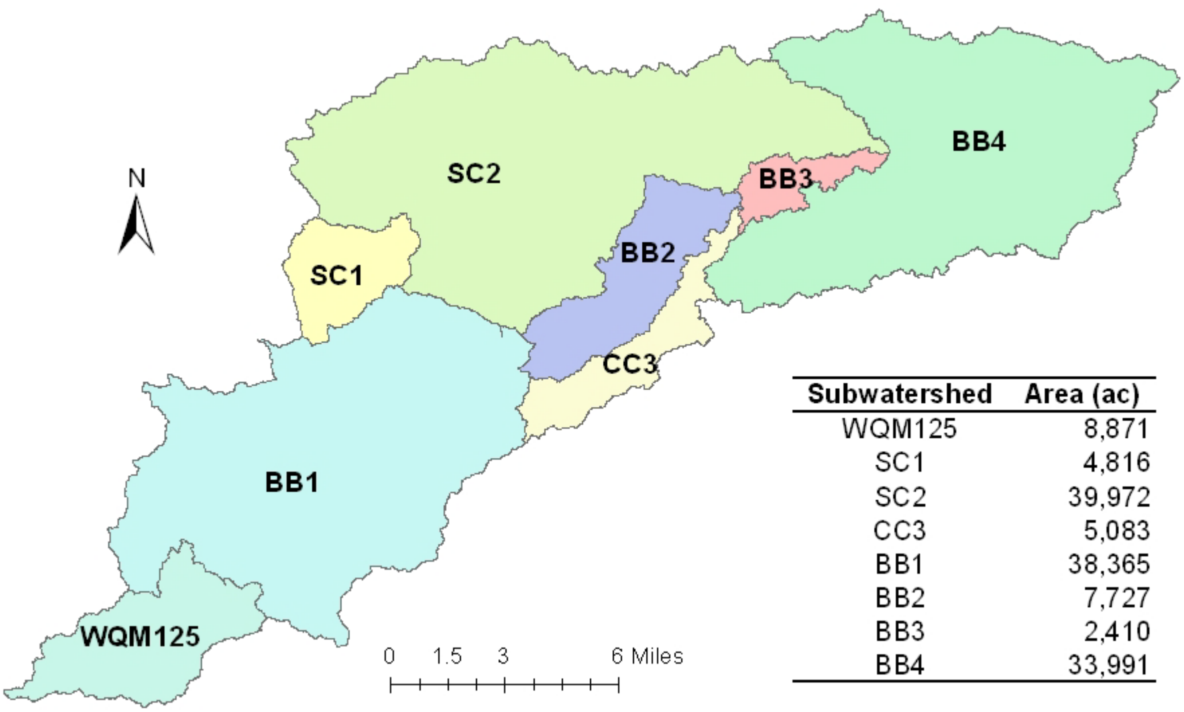


Figure 26. Annual export coefficients (kg/acre) by site for water years 1999-2000.



Subwatershed	Area (ac)
WQM125	8,871
SC1	4,816
SC2	39,972
CC3	5,083
BB1	38,365
BB2	7,727
BB3	2,410
BB4	33,991

Figure 27. Location of Bear Butte Creek subwatersheds and calculated areas (acres) of each subwatershed.

The subwatershed contributing to site BB-1 includes the City of Sturgis. This subwatershed experienced the lowest annual export coefficient (1.01 kg/acre), which may indicate that the City does not contribute a significant amount of TSS to the system.

Forest management and recreational use of the Black Hills National Forest has caused habitat destruction similar to that for cultivation. In addition, natural ecological processes (e.g. fire and dead fall trees) have also been limited. The largely forested subwatershed (WQM-125) had the fourth highest TSS export coefficient among all subwatersheds.

Highest annual export coefficient values among all subwatersheds were observed at BB-4 (39.73 kg/acre), BB-3 (23.40 kg/acre), and SC-2 (19.12 kg/acre). The subwatersheds contributing to these sites should be targeted for implementation of primarily agricultural management practices. As stated in the introduction, roughly 70% of landuse in the Bear Butte Creek watershed is agricultural, including rangeland and cropland; a majority of the remaining watershed land area is managed by the Black Hills National Forest. Crop and livestock production in the Bear Butte Creek watershed has altered drainage and channel characteristics, decreased riparian cover and habitat, and served as a conduit for increased siltation, nutrient, and other contaminant loading.

Water Temperature Analysis

Water temperature is an influential variable in biological, chemical, and physical processes and can influence metabolic rates of aquatic organisms, toxicity of pollutants, and solubility of dissolved oxygen. Water temperature is a measure of the intensity of heat energy in the stream (Wetzel and Likens, 2000). The greatest source of heat in freshwaters is solar radiation, especially in waterbodies directly exposed to the sun (Hauer and Lamberti, 1996), which induces rapid daily temperature fluctuations. This section is devoted to the analysis of Bear Butte Creek water temperature data and collection methods.

The graph of temperature values in Figure 28 shows the median, lower and upper quartile, and ranges of observed temperatures for Bear Butte Creek sites. Of the 284 water quality samples collected, 138 samples from sites WQM-116, WQM-125, and WQM-126 did not include the time the samples were taken. However, the remaining water quality sampling records contained enough time data to perform a satisfactory analysis.

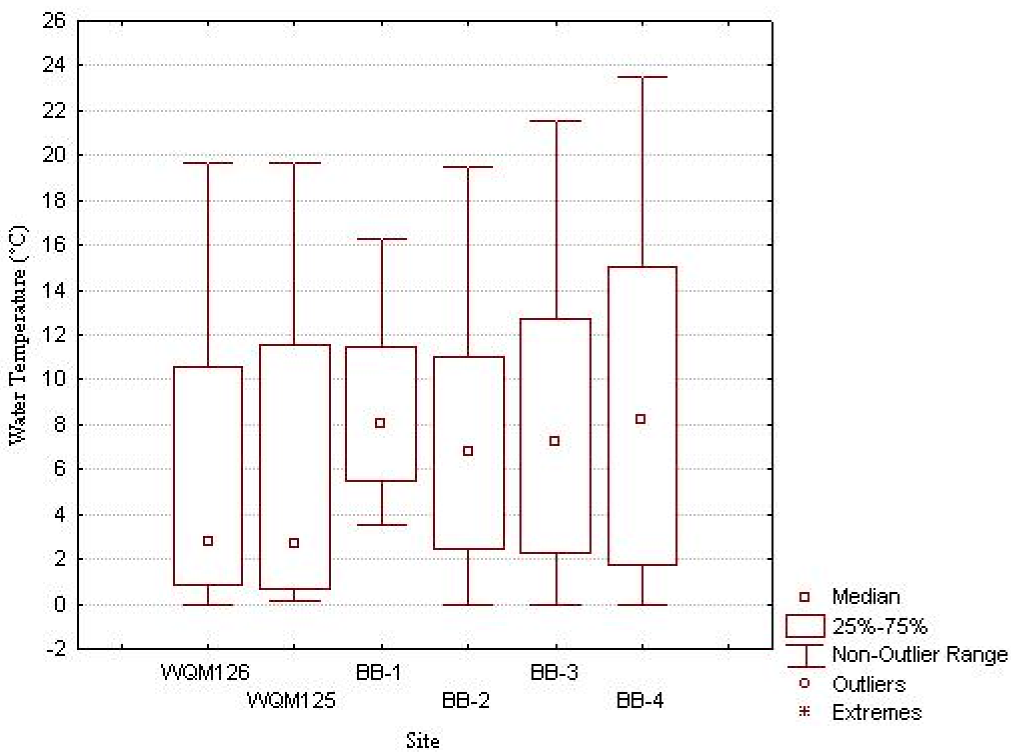


Figure 28. Water temperature values during the study period by site for Bear Butte Creek watershed mainstem sites.

The data exhibited the highly variable water temperatures expected in lotic (flowing water) systems. Typically, lower water temperatures in the upper reaches of the watershed could be attributed to the colder water originating from headwater springs or snow melt runoff; spring snow-melt water can keep stream water temperatures below air temperatures for several days (Hynes, 1970). The data showed a trend to higher median temperatures from upstream to downstream, indicating an accumulation of heat. While generally accepted as a characteristic of lotic systems, the cause of the heating was not differentiated between natural and man-made causes (Poole, et al, 1999).

Table 28 lists the descriptive statistics of the temperature data for the Bear Butte Creek study. Water temperatures were most variable at site BB-4 and showed a warming influence caused by hydrologic input from the upstream mainstem site (BB-3) and the Spring Creek tributary (SC-2). Spring and Cottle Creeks had the highest mean and median values, but also the fewest recorded measurements. Temperature variability at the mainstem sites BB-1 to BB-4, along with the mean and maximum values, increased from upstream to downstream, indicating an accumulation of heat.

Table 28. Descriptive statistics for water temperature by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	5.9	23	6.2	0.0	19.7	0.9	2.8	10.6
WQM-116	9.0	22	5.1	0.0	19.1	5.4	8.3	12.4
WQM-125	5.8	23	6.2	0.1	19.7	0.7	2.7	11.6
BB-1	8.6	25	3.8	3.5	16.3	5.5	8.0	11.5
BB-2	7.9	24	6.1	0.0	19.5	2.5	6.8	11.0
BB-3	8.5	24	6.9	0.0	21.5	2.3	7.3	12.8
BB-4	9.2	24	7.7	0.0	23.5	1.8	8.3	15.0
CC-3	11.3	9	5.5	5.0	18.8	7.3	9.5	15.5
SC-1	12.2	9	4.6	6.0	18.5	10.0	11.0	16.0
SC-2	11.6	7	6.1	4.0	19.5	6.0	12.0	17.0
All Sites	8.4	190	6.1	0.0	23.5	3.5	7.6	12.4

The two headwater sites had lower mean and median values than other sites in the study, and had higher sample variability and maximum temperatures than most of the other study sites. However, the headwater and mainstem temperature data sets were recorded over different time periods, so a correlation resulting from a direct comparison will not be representative of actual temperature variations between the headwater and mainstem areas.

The discrete sample timing seemed to have the greatest bearing upon water temperature analysis. For all sites, the mean and median sample time was 11:30 am. However, the mean and median times for individual sites were apparently the result of the sampling collection patterns, i.e. upstream samples were collected earlier in the day than downstream samples. Therefore, the determination of heating influences between the headwater and mainstem sites becomes less reliable.

The results of the collected water temperature data may, because of the sample collection times and intervals, have inaccurately represented the peak and mean water temperatures. Because water temperature measurements in Bear Butte Creek have exceeded standards, more reliability must be incorporated into the data collection techniques. For instance, continuous (15-minute intervals) water temperature readings (to +/- 0.1 ^{o}C) by use of modern remote thermistors (resistors calibrated to temperature) at the current study locations would have provided reliable estimations of the mean and maximum stream temperatures.

Estimating the total heat transferred to a stream is a question of determining the accumulation of heat energy within the water body. Because the conditions at each section will be dynamic and highly variable, modern temperature modeling software can be used to estimate and analyze heating by incorporating the physical habitat and regional environmental data. Results could be used to predict heating events.

Habitat surveys may be the easiest and most cost-effective means of determining the potential for solar heating in wadeable streams with temperature problems. These studies serve to compile physical habitat data, such as the dimensions of the stream channel, flow regime, canopy cover, substrate type, and amount of woody debris in the water for various stream segments. LANDSAT imagery or other remote-sensing techniques can be used to view vegetated or developed areas. This data could be used to prioritize restoration of habitat in stream segments vulnerable to heating.

Fecal Coliform Bacteria Analysis

Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and are used as indicators of recent fecal contamination and presence of pathogens in a recreational waterbody (American Water Works Association, 1999). Many environmental factors, including exposure, temperature, etc., can influence the fecal coliform growth and death rates. Fecal coliform survival in fresh water (20 to 30 ^{o}C) is less than 60 days, but typically less than 30 days (Tchobanoglous et al., 2003). South Dakota water quality standards for fecal coliform are in effect from May 1 through September 30 (SD DENR, 2002).

The graph of fecal coliform bacteria concentrations in Figure 29 shows the median, lower and upper quartile, and ranges of fecal coliform bacteria concentrations in colonies per 100 mL sample water (col/100 mL) for Bear Butte Creek sites. The extreme values of fecal concentrations were observed during or after storm events, when the greatest potential for runoff existed.

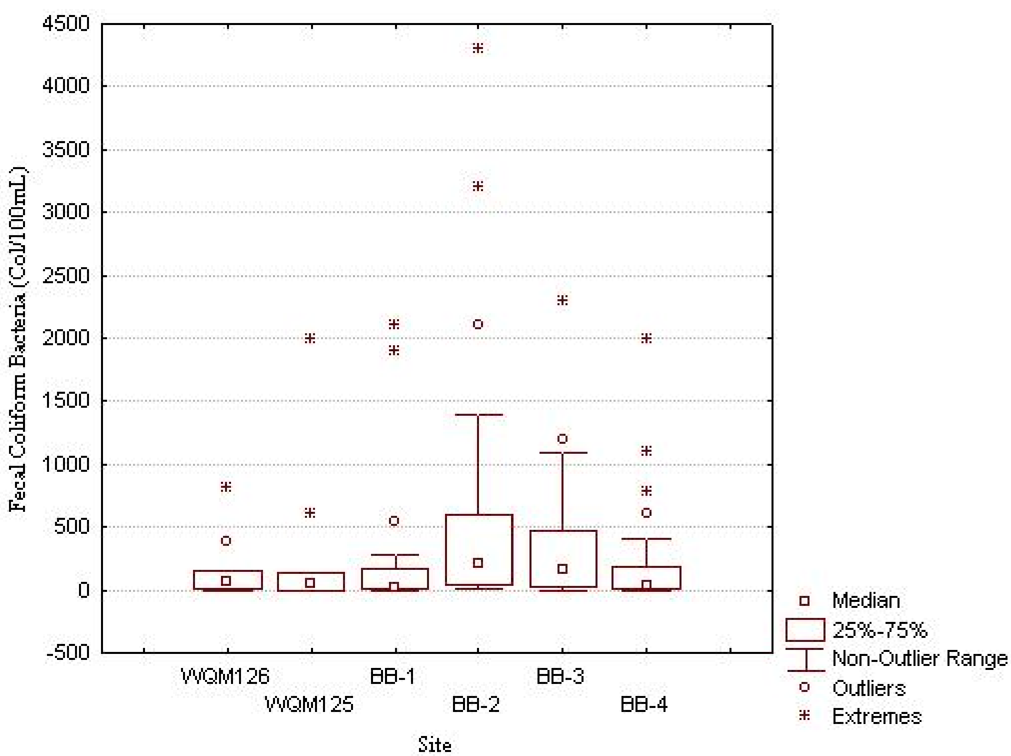


Figure 29. Box plot of fecal coliform bacteria concentrations by site for the Bear Butte Creek study area. The highest mean concentrations were found at BB-1, BB-2, and BB-3.

Table 29 shows the highest mean fecal coliform concentration was observed at BB-2 (645 col/100 mL). The lowest mean value was observed at WQM-116 (2 col/100 mL). The greatest variability also occurred at BB-2 (standard deviation of 1,096), and was likely driven by the highest maximum value observed during the study (4,300 col/100 mL). The highest minimum value was observed at SC-2 (40 col/100 mL).

Table 29. Descriptive statistics for fecal coliform bacteria concentrations by site.

Site	Mean Value	Number of Samples	Standard Deviation	Minimum Value	Maximum Value	25th Quartile Ranking	Median Value	75th Quartile Ranking
WQM-126	182	9	265	1	810	10	66	160
WQM-116	2	9	2	1	6	1	2	4
WQM-125	326	9	655	1	2,000	1	55	135
BB-1	241	24	557	1	2,100	5	11	170
BB-2	645	24	1,096	4	4,300	35	210	595
BB-3	375	24	539	1	2,300	33	165	465
BB-4	241	24	469	1	2,000	5	40	190
CC-3	186	7	254	5	720	5	140	230
SC-1	608	8	832	5	2,500	5	395	780
SC-2	303	7	261	40	850	190	210	380
All Sites	337	145	650	1	4,300	5	66	280

Annualized AGNPS Pollutant Loading Model

Three landuse management scenarios were modeled for the Bear Butte Creek watershed using the Annualized AGNPS Pollutant Loading Model. These modeled scenarios allow for an estimation of the potential sediment load reductions for this watershed. Model-predicted sediment loads represent accumulated loads at the watershed outlet for a 25-year simulation period.

One simulation represents the watershed in a pristine condition as it may have existed prior to settlement. All cells, except those with landuse classifications of water or forest, were assigned a landuse of rangeland in good condition. With this scenario, the sediment load delivered from the watershed is estimated to be approximately 2,600 tons/yr.

Another simulation used landuse classifications of current croplands as determined by the LANDSAT derived dataset and all pasture in poor condition. With this scenario, the sediment load delivered from the watershed is estimated to be approximately 12,500 tons/yr.

The third simulation represents the watershed with its current cropping practices and all pasture in good condition. The sediment load delivered from the watershed with pastures in good condition is estimated to be approximately 3,800 tons/yr.

Results indicate that improving the pasture condition from poor to good would reduce the annual sediment load by approximately 70%. Current condition of all rangelands in the Bear Butte Creek watershed is unknown. However, the large difference in predicted sediment load between poor and good condition pasture suggests the importance of well-managed rangelands in this watershed. A much smaller difference between the good condition pasture scenario and the pristine/pre-settlement condition scenario may indicate that landuses in this drainage other than rangeland (e.g. urban/residential, cropland, forest, mines, etc.) contributes less sediment in comparison to rangelands. On average, one watershed acre contributes approximately 83 pounds (0.042 tons) of sediment annually. On average, one acre of impaired rangeland contributes roughly 177 pounds (0.090 tons) of sediment annually.

Priority areas identified by the model as producing excessive sediment loads are shown in Figure 30. The priority areas account for approximately 36,000 acres (25%) of the total watershed area. The landuse classification for a majority of the priority areas is pastureland, and nearly all croplands in the watershed are identified as priority areas. Of the 36,000 acres of priority areas, approximately 58% or 21,000 acres are rangeland, approximately 35% or 12,500 acres are cropland, and approximately 7% or 2,500 acres are classified as some landuse other than cropland or rangeland.

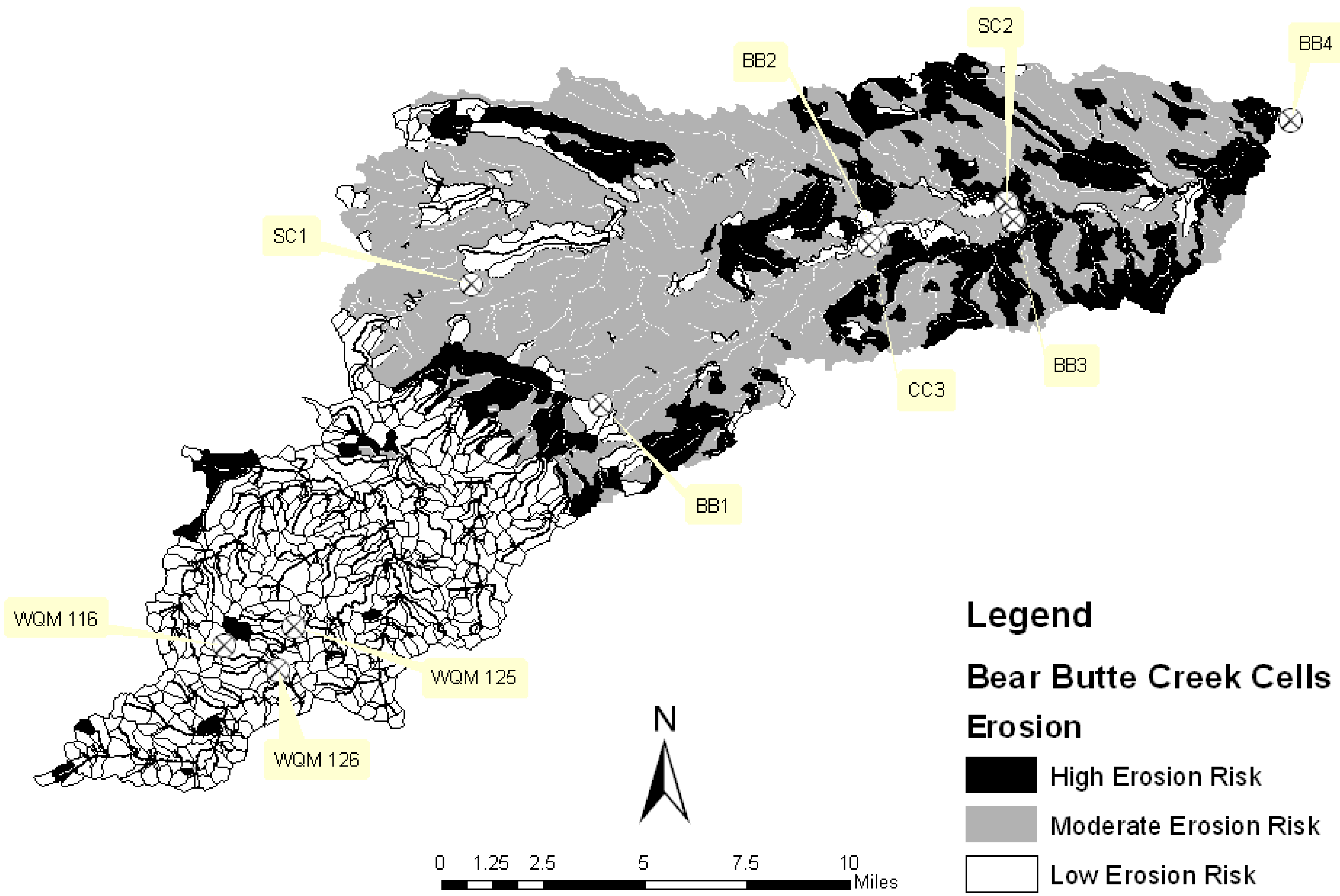


Figure 30. High erosion risk (priority) areas for the Bear Butte Creek watershed.

Model results show that most high erosion risk areas are found in the lower portion of the watershed. Runoff from more than half of the high erosion risk areas drains into Bear Butte Creek below site BB-2. These model results mirror the results of water quality monitoring completed for this study. Bear Butte Creek from site BB-2 to the outlet was identified as impaired based on high TSS concentrations in samples collected from this reach (Figure 25).

The AGNPS model accounts for sediment loads originating from erosion of uplands. However, a portion of the sediment load in Bear Butte Creek originates from streambed and bank erosion. High peak flows during snowmelt and rainfall events contribute to channel erosion and transport of sediment. The driving forces of stream flow and channel erosion due to undercutting, desiccation, block failure and mass wasting interact to produce in-stream fluxes of suspended sediment. The effects of these erosive events are further exacerbated by steep banks, poor vegetative cover, and livestock access to the stream channel.

Riparian degradation appears to be a major cause of channel erosion in the Bear Butte Creek watershed. In many identified rangeland priority areas adjacent to stream channels, livestock are allowed access to the streams. Livestock activity within the channel and along stream banks serves to accelerate bank erosion and loss of riparian vegetation. Little woody vegetation exists along the impaired reach of Bear Butte Creek (below site BB-2), as well as the tributaries to this reach (Figure 31).

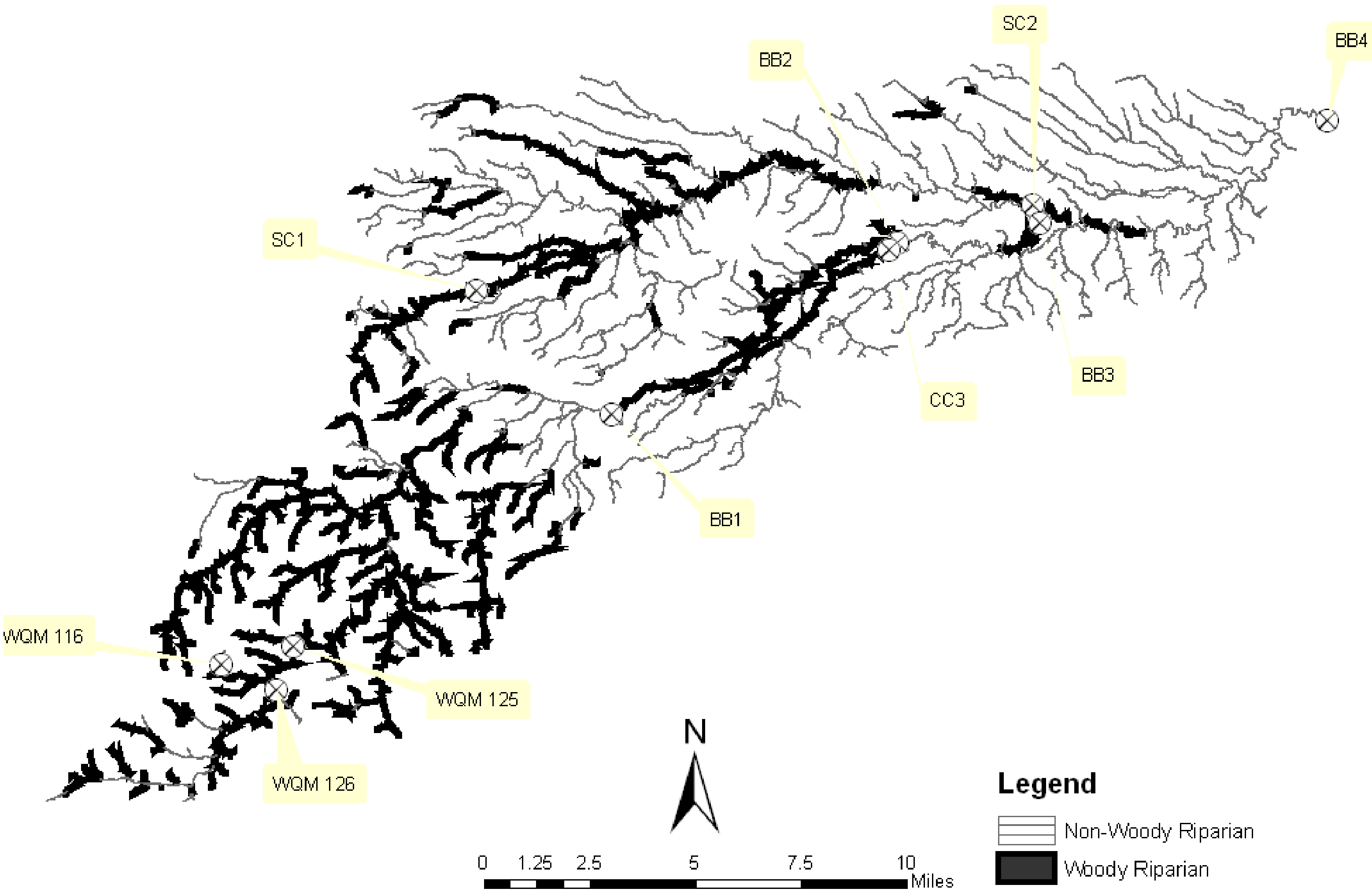


Figure 31. Stream segments with woody riparian zones in the Bear Butte Creek watershed. Wooded riparian zones were identified using LANDSAT imagery data.

Groundwater Monitoring

No groundwater monitoring was performed for this study; however, flow in Bear Butte Creek reemerges from a spring (slow seep) east of Woodle Field in Sturgis, SD. Flow is generally continuous from this spring to the Belle Fourche River. An overhead view of the spring can be seen in Figure 32 and a view looking upstream in Figure 33.

The source for the water at the reemergence zone has not been proved, though water quality data gathered from Bear Butte Creek segments upstream from the loss zones and downstream of the spring share similar water chemistry characteristics. The possibility is likely that the spring may not originate only from the creek alluvium, but from the aquifer beneath Sturgis, SD (Rahn, 2004). This would indicate that Bear Butte Creek may be the primary, but not the sole, source of water for the spring (Deadman and Vanocker Creeks, plus other unnamed tributaries in the Sturgis, SD area, flow to Bear Butte Creek upstream from the spring).

Figure 32. View of the Bear Butte Creek spring taken from a Sly Hill overlook as the stream channel flows into the Sly Hill gap; the spring can be seen just to the left of dead center.

According to the United States Geological Survey Ft. Meade and Sturgis 7.5 Minute Quadrangle maps (USGS, 1955 and 1979), the land surface elevation of the Bear Butte Creek streambed drops steadily as the creek passes through Sturgis. The elevation falls 180 feet from the point where Bear Butte Creek crosses underneath Interstate 90 to where the creek diverges from SD Highway 79 as it flows through a narrow gap in Sly Hill. The topography over this distance also becomes constricted by the Sly Hill gap to room only for the highway and the creek to run through the gap. The topographical changes may cause the Sturgis alluvium to simply overflow within this area, causing a surface spring near the Sly Hill gap.

Figure 33. View of the Bear Butte Creek spring taken at the foot of Sly Hill looking east to Woodle Field.

During a watershed tour in September 2003, the creek flow was observed to persist as the creek passed through the gap; however, as the creek flowed beyond the gap, the surface flow ceased, presumably as a result of the water's return to the subsurface alluvial channel.

A source water study, using tracer testing of groundwater between the loss and reemergence zones, has been recommended in the Future Activity Recommendations section of this report.

Physical Habitat Analysis

A physical habitat study was performed at sites BB-1, BB-2, BB-3, BB-4, SC-1, and CC-3 by WRAP personnel. Data sheets from Appendix A-1 of the Rapid Bioassessment Protocol (RPB) (Barbour et al, 1999) were used to compile habitat data. The assessment of habitat was based upon the following habitat condition category (Optimal, Suboptimal, Marginal, and Poor) criteria:

Epifaunal Substrate/Available Cover

Optimal: Greater than 50 % of the substrate favorable for epifaunal colonization and fishcover, with a favorable mix of woody debris types, undercut banks, and cobble.
Suboptimal: 30 to 50 % mix of stable habitat; well suited for full colonization potential; adequate habitat to support populations.
Marginal: 10 to 30 % mix of stable habitat; habitat availability less than desirable; substrate frequently moved or disturbed.
Poor: Less than 10 % stable habitat; substrate unstable or lacking.

Pool Substrate Characterization

Optimal: A mixture of substrate materials, with gravel and firm sand prevalent, with root mats and submerged vegetation common.
Suboptimal: A mixture a soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.
Marginal: All mud or clay or sand bottom; little or no root mat; no submerged vegetation.
Poor: Hard pan clay or bedrock; no root mat or vegetation.

Pool Variability

Optimal: An even mix of large-shallow, large-deep, small-shallow, and small-deep pools present.
Suboptimal: The majority of pools are large-deep, very few shallow.
Marginal: The shallow pools are much more prevalent than deep ones.
Poor: The majority of pools are small-shallow or pools are absent.

Sediment Deposition

Optimal: Little or no enlargement of islands or point bars and less than 20 % of the bottom is affected by sediment deposition.
Suboptimal: Some new increase in bar formation, mostly from gravel, sand, or fine sediment. Twenty to 50 % of the bottom affected; slight deposition in pools.

Marginal: Moderate deposition of new gravel, sand, or fine sediment on old and new bars. Fifty to 80 % of the bottom affected; sediment deposits at obstruction, constrictions, and bends. Moderate deposition of pools is prevalent,

Poor: Heavy deposits of fine silt material, increased bar development; more than 80 % of the bottom changing frequently. Pools almost absent due to sediment deposition.

Channel Flow Status

Optimal: Water reaches the base of both banks; a minimal amount of channel substrate was exposed.

Suboptimal: Water fills more than 75 % of the available channel, with less than 25 % of the substrate exposed.

Marginal: Water fills 25 - 75 % of the available channel and/or riffle substrates are mostly exposed.

Poor: Very little water in channel and mostly present as standing pools.

Channel Alteration

Optimal: Channelization or dredging absent or minimal; stream has a normal pattern.

Suboptimal: Some channelization present, usually in areas of bridge abutments; evidence of past channelization (greater than past 20 years) may be present, but recent channelization is not present.

Marginal: Channelization may be extensive; embankments or shoring structures present on both banks; and 40 – 80 % of stream channel reach channelized or disrupted.

Poor: Banks shored with gabion or cement; over 80 % of the stream reach is channelized or disrupted. Instream habitat greatly altered or removed entirely.

Channel Sinuosity

Optimal: The bends in the stream increase the stream length three to four times longer than if it was in a straight line.

Suboptimal: The bends in the stream increase the stream length one to two times longer than if it was in a straight line.

Marginal: The bends in the stream increase the stream length one to two times longer than if it was in a straight line.

Poor: The channel is straight and the waterway has been channelized for a long distance.

Bank Stability

Optimal: Banks stable with evidence of bank failure absent or minimal; little potential for future problems. Less than five percent of bank affected.

Suboptimal: Banks moderately stable; infrequent, small areas of erosion mostly healed over. Five to thirty percent of bank in reach has areas of erosion.

Marginal: Banks moderately unstable; 30 – 60 % of bank in reach has areas of erosion. Reach has high erosion potential during floods.

Poor: The banks are unstable and has many eroded areas, with ‘raw” areas frequent along straight sections and bends; obvious bank sloughing. Sixty to 100 % of the bank has erosional scars.

Vegetative Protection

Optimal: More than 90 % of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident. Almost all of the plants are allowed to grow naturally.

Suboptimal: Seventy to 90 % of the streambank surfaces covered by native vegetation, but one class of plants is not well represented. Disruption is evident but not affecting full plant growth potential to any great extent. More than one-half of the potential plant stubble height is remaining.

Marginal: Fifty to70 % of the streambank surfaces covered by native vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common. Less than one-half of the potential plant stubble height is remaining.

Poor: Less than 50 % of the streambank surfaces are covered by vegetation; disruption of streambank vegetation is very high. Vegetation has been removed to 5 centimeters or less in average stubble height.

Riparian Vegetative Zone Width

Optimal: Width of the riparian zone is greater than 18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted the zone.

Suboptimal: Width of the riparian zone is 12 -18 meters; human activities have impacted the zone only marginally.

Marginal: Width of the riparian zone 6 - 12 meters; human activities have impacted the zone a great deal.

Poor: Width of the riparian zone is less than 6 meters; little or no riparian vegetation due to human activities.

Percent comparability to ideal habitat conditions is graphed in Figure 34 with the sites shown in an upstream to downstream order. The best quality habitat in the study was site BB-2, which scored 79% of the ideal reference score (157 out of 200 points). The worst quality habitat in the study was SC-1, which scored 55 % of the ideal reference score (110 of 200). Habitat parameter scores for sites BB-1 and BB-4 were above the mean (69 %) for the Bear Butte Creek study area.

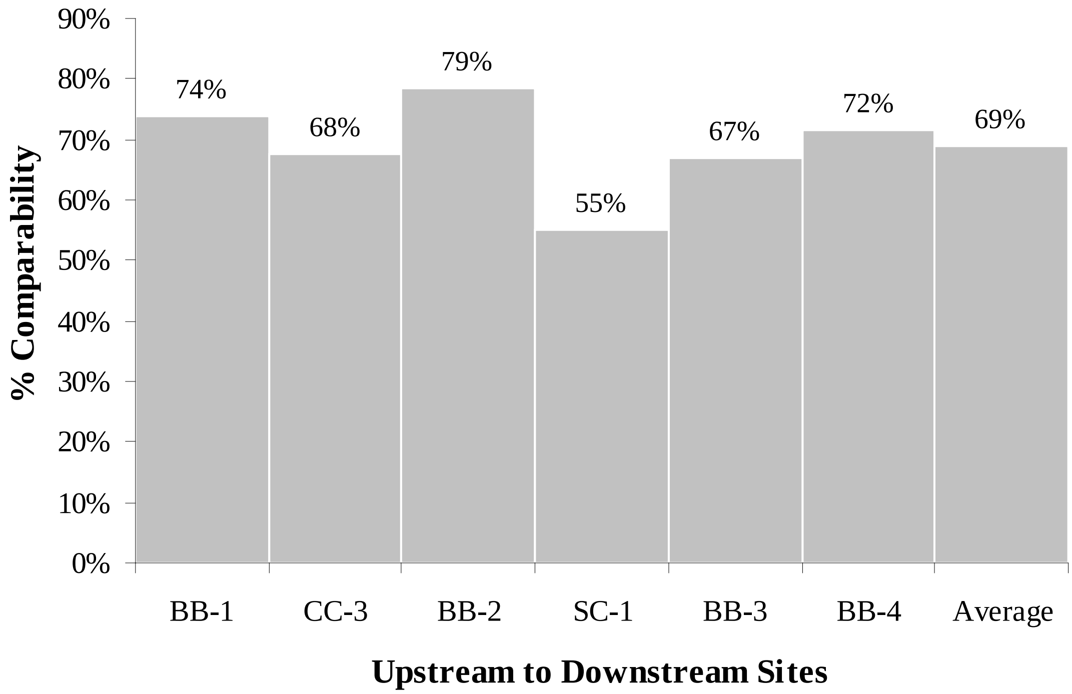


Figure 34. Percent comparability to ideal habitat conditions (i.e. percent of maximum possible score).

Substrate Analysis

A substrate analysis was performed during the habitat survey at sites BB-1, BB-2, BB-3, BB-4, SC-1, and CC-3. Modified pebble counts were performed at three locations per site. Substrate particle diameters were measured and characterized within eight categories as percent cobble, coarse gravel, fine gravel, silt, sand, clay, organic, and precipitate (diameter categories are listed in Table 30). Site values were totaled and averaged to arrive at a percentage of substrate types for each site. The percent fines result was calculated from the substrate portion with average particle diameter values of less than .3 inches (7.62 mm).

Table 30. Particle diameter values for categories of stream channel substrate.

Substrate Diameter	Category	
2.5 to 10 inches	Cobble	
1.0 to 2.5 inches	Coarse Gravel	
0.3 to 1.0 inches	Fine Gravel	
Less than 0.3 inches	Silt (soft, fine; not gritty)	Fines
Less than 0.3 inches	Sand (gritty)	
Solid, slick	Clay	
Fine, black w/ odor	Organic	

By comparing the types of substrate among the mainstem sites studied, it was determined that the percentage of coarse gravel decreased from upstream to downstream and that of silt increased over the same length. The percentage of fine gravel increased at most mainstem sites (11 % at BB-1, 20 % at BB-2, and 41 % at BB-3) until reaching BB-4, where it decreased to 26 %. The largest percentages of silt were found at the tributary sites (73 % at CC-3 and 96 % at SC-1).

The extent of substrate embeddedness was also distinguished, using a five-number rating system, according to the percent surface covered by silt (higher embeddedness resulted in lower number scores). The criteria for embeddedness are listed at Table 31. Generally, coarse gravel and cobble comprised over 50 % of the substrate at the mainstem sites. The percentage of silt increased from upstream to downstream and made up the largest fraction of substrate (greater than 70 %) at each of the tributary sites. The embeddedness of substrate at each of the sites also increased from upstream to downstream.

Table 31. Embeddedness rating values for stream channel substrate.

Embeddedness Rating	Criteria
5	< 5 % Surface Covered or Surrounded by Silt
4	5 % to 25 % Surface Covered or Surrounded by Silt
3	25 % to 50 % Surface Covered or Surrounded by Silt
2	50 % to 75 % Surface Covered or Surrounded by Silt
1	> 75 % Surface Covered or Surrounded by Silt

Sites WQM-126, WQM-126, and WQM-125

The headwater area of Bear Butte Creek is located within the historic Galena mining district and was not part of the original habitat study. Several studies, including Gries (1971), Sorensen (1998), and most recently, USEPA (2001), have focused on issues of water quality in the Galena district and the Gilt Edge Mine Site and remain excellent resources. Included are general observations of habitat quality made and pictures taken during a watershed tour (26-27 August 2003) by DENR.

These headwaters originate in the forested highlands southwest of Strawberry Hill, where the creek runs northeast along Highway 385 and through the Fish N Fry campground. After flowing through the campground, the creek flows through thick pine stands in shallow, wide pools of dark slate bedrock. The creek flows underneath the road (FS 534) several times through installed culverts. Along this road, a few stream segments were assessed to have less than adequate canopy and riparian vegetation, which made these areas vulnerable to heating (See Figure 35).

Figure 35. Photograph of site WQM-126, looking upstream (27 August 2003).

Site WQM-126, the uppermost sampling site, was located next to the main road. The stream was fully exposed at this location and flowed across a bed of dark fractured slate. The water was quite clear and the streambed had very little sediment deposition. Downstream from this site, the water cascades down small falls (See Figure 36). Many small pools were observed within this stream reach.

Except for the lack of canopy cover, the habitat conditions below WQM-126 were fair. The creek flowed from this point down to the bottom of the hill, where it was joined by Strawberry Creek. Beyond this confluence, the stream was essentially a ditch beside the road. Cattle were seen actively feeding and drinking in the vicinity of this site.

Figure 36. Photograph of site WQM-126, looking downstream (27 August 2003).

The substrate was found to be composed chiefly of slate boulders and cobbles over large boulders and solid bedrock. The substrate near site WQM-126 was less than 5 % embedded. Substrate below the confluence of Strawberry Creek (WQM-116) was 5 to 25 % embedded. Accumulated sediment at site WQM-125 was easily resuspended by minor disturbances.
From the confluence of Strawberry Creek, Bear Butte Creek flowed down into the small town of Galena, SD. The stream bed at this point was still quite rocky, and the creek became shallow due to the widening of the stream channel. Figure 37 shows the creek as it flows behind some of the properties that make up the town of Galena. At this point, the creek flows through a large culvert under the road and to a confluence with an unnamed tributary.

Figure 37. Photograph of Bear Butte Creek at Galena, SD, looking upstream from a large culvert area at the end of a row of homes (27 August 2003).

North of Galena, the creek flowed through some wide culverts on its way out of town. The stream channel became very wide at this point and the only fish seen were trapped in the culvert pools. Figure 38 shows the creek at the exit of the last large culvert, on the east side of the road and across from the abandoned Branch Mint mine site.

Figure 38. Photograph of site WQM-125 (below Strawberry Cr.), looking downstream (27 August 2003).

Site BB-1

The assessed reach was estimated to be 100 m long. The predominant surrounding land is a walk-in recreational area. The riparian buffer included box elder trees, shrubs, and grasses. The entire reach was vegetated with a rooted emergent species thought to be Yellow Crowfoot (*Ranunculus sp*.). Trout (presumably brook trout) were seen in abundance and filamentous algae covered the substrate. Figure 39 is a picture of the BB-1 site reach; canopy cover is adequate but the stream is wide and shallow. Consequently, the brook trout seen were essentially trapped in the larger pools.

Figure 39. Photograph of site BB-1 (27 August 2003).

Figure 40 shows a graph of BB-1 habitat assessment scores compared to scores from the ideal habitat score. Site BB-1 was scored optimal for available cover/substrate and pool substrate. A marginal rating was given for pool variability. For sediment deposition, BB-1 scored in the optimal range. The channel flow status was rated suboptimal, alteration scored in the optimal range, and sinuosity was deemed marginal (channel was nearly straight with no meander). Bank stability and vegetative protection was rated optimal. Although the quality of canopy cover along the mainstem stream segments was highest at BB-1, the riparian zone width was rated suboptimal, primarily due to human impact.

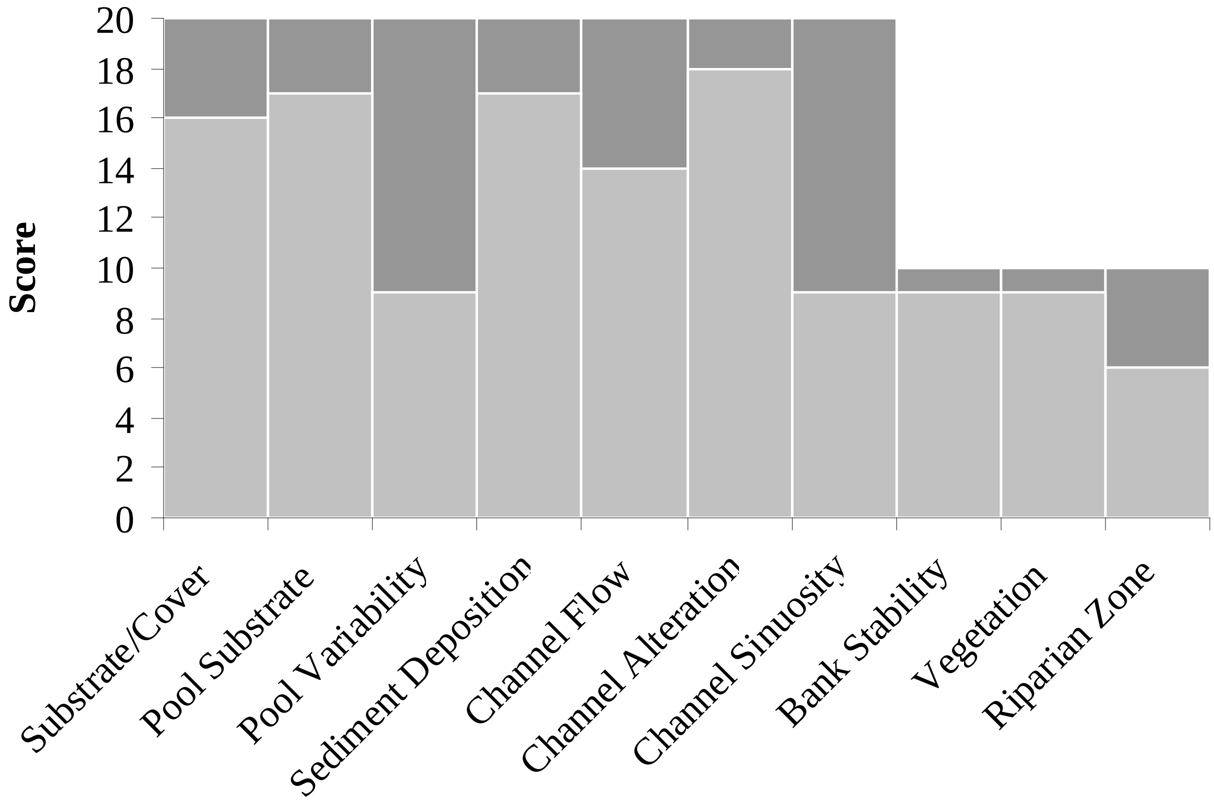


Figure 40. Site BB-1 physical habitat scores; BB-1 was rated the second-highest habitat quality of the sites studied.

The general characterization of substrate types for BB-1 is shown at Figure 41, with coarse gravel (66 %) comprising the bulk of the substrate (highest percentage in the study). Coarse gravel, cobble (14.3 %), and fine gravel (11 %) made up over 90 % of all substrate types at this site. Fines accounted for 8.4 % of the total substrate. The substrate embeddedness rating for BB-1 averaged 4.4, with an average of five to 25 % of the substrate surface covered with silt.

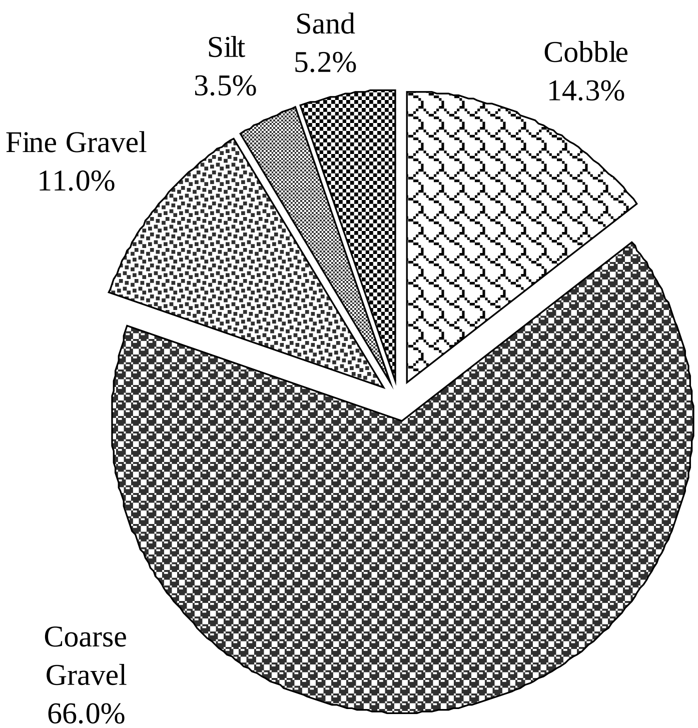


Figure 41. Substrate types at site BB-1 as percentages of total substrate characterized.

Site CC-3

The assessed reach was estimated to be 100 m long. The predominant surrounding land use was field/pasture with potential non-point pollution sources and moderate to heavy erosion. The riparian buffer included willow shrubs and grasses, with brome and sedge dominant. The stream channel segment was classified as 60 % riffle and 40 % pool. The site had steep but well-vegetated banks, though types and extent of vegetation were not indicated. No large woody debris was observed.

Figure 42 shows a graph of CC-3 habitat assessment scores compared to scores from the ideal habitat score. Site CC-3 scored poorly for available cover/substrate and sediment deposition, because the substrate was judged to be mainly silt. A suboptimal rating was given for pool substrate, and an optimal rating for pool variability. The channel flow status and sinuosity was rated optimal and alteration suboptimal. Bank stability was rated optimal and vegetative protection was rated suboptimal. The riparian zone width was rated suboptimal due to a minimum of human activity.

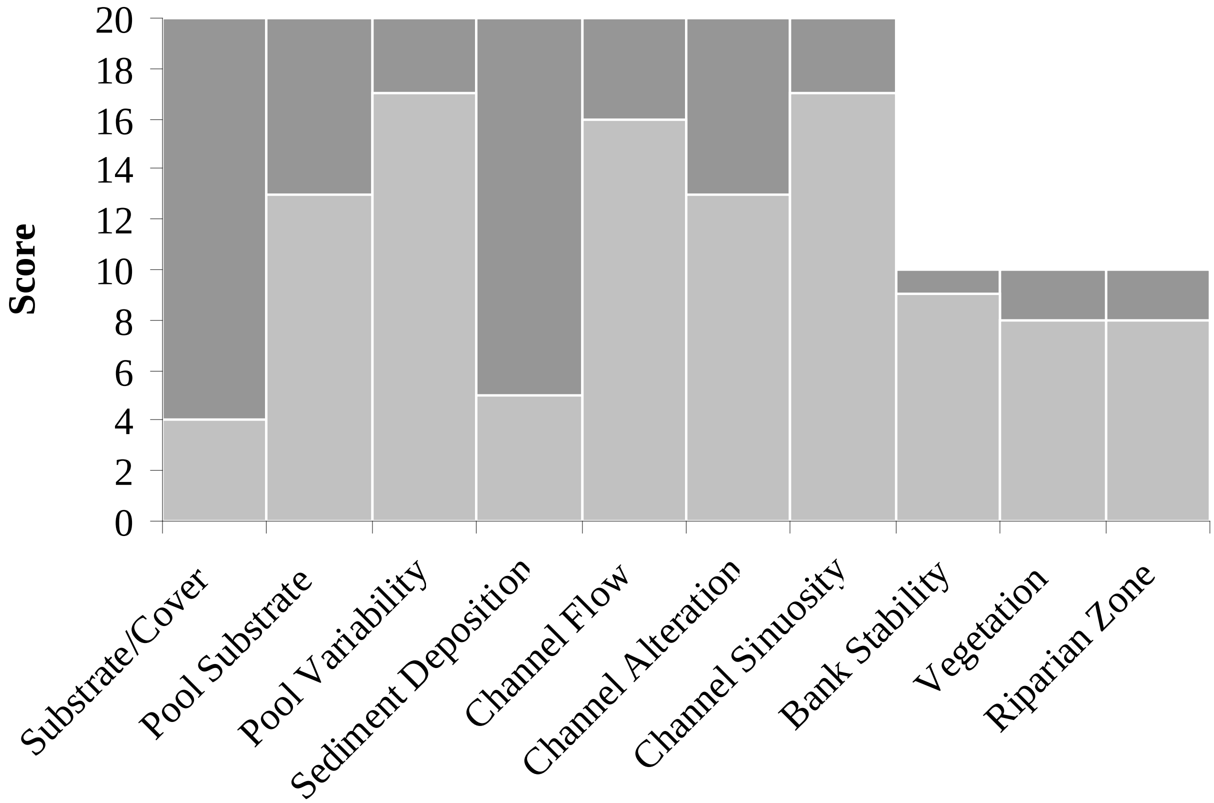


Figure 42. Site CC-3 physical habitat scores; problems at this tributary site were due to a substrate composed chiefly of silt.

The general characterization of substrate types for CC-3 is shown at Figure 43, with silt (73 %) comprising the bulk of the substrate. Coarse gravel (15 %), together with fine gravel (7.0 %) and organic debris (1.0 %), made up 23 % of the substrate types at this site. No cobble was observed. Fines accounted for over 78 % of the total substrate. The substrate embeddedness rating for CC-3 averaged 1.1, with an average of greater than 75 % of the substrate surface covered with what was characterized as organic fines.

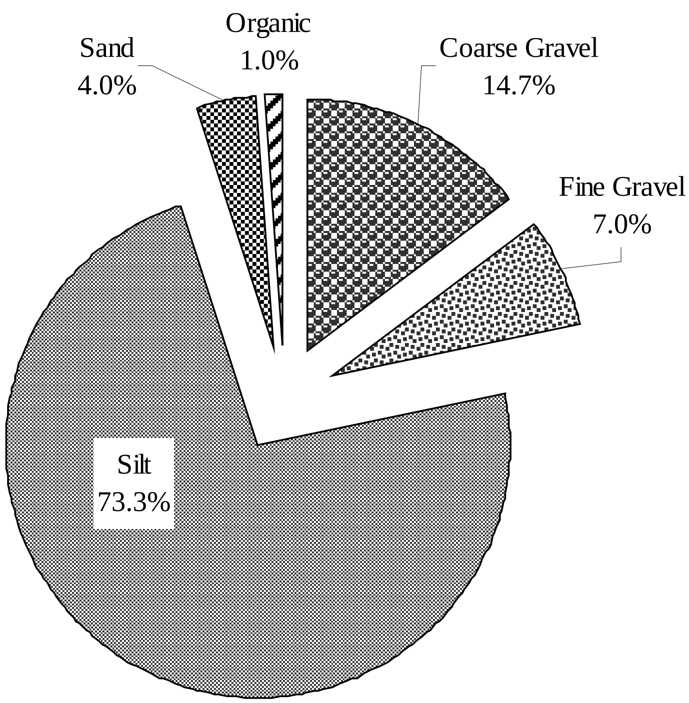


Figure 43. Substrate types at site CC-3 as percentages of total substrate characterized.

Site BB-2.

The reach was estimated to be 100 m long. The predominant surrounding land use was field/pasture. The riparian buffer included elm trees, raspberry shrubs, and grasses, with brome dominant. The instream features were not indicated. The channel of the stream segment was classified as 50 % run, 30 % riffle, and 20 % pool, with a large scour pool about halfway into the reach. Thirty percent of the reach was vegetated with a rooted submergent species (*Potomageton sp*.).

Figure 44 is a picture of Bear Butte Creek at BB-2, downstream from the Cottle Creek confluence. Both waterbodies were dry gullies, with the streambed firm enough to walk on in most places.

Figure 44. Photograph of site BB-2, looking upstream to the Cottle Creek confluence (Aaron Larson, 27 August 2003).

Figure 45 shows a graph of BB-2 habitat assessment scores compared to scores from the ideal habitat score. Site BB-2 scored suboptimally for available cover/substrate. Pool substrate, variability, and sediment deposition were all rated in the optimal range. Channel flow status and channel alteration were rated optimal and sinuosity was rated suboptimal. The left bank was judge to be very stable, while the right bank was thought to exhibit only moderate stability. Vegetative protection was rated optimal and the riparian zone width was rated suboptimal due to regular access by livestock.

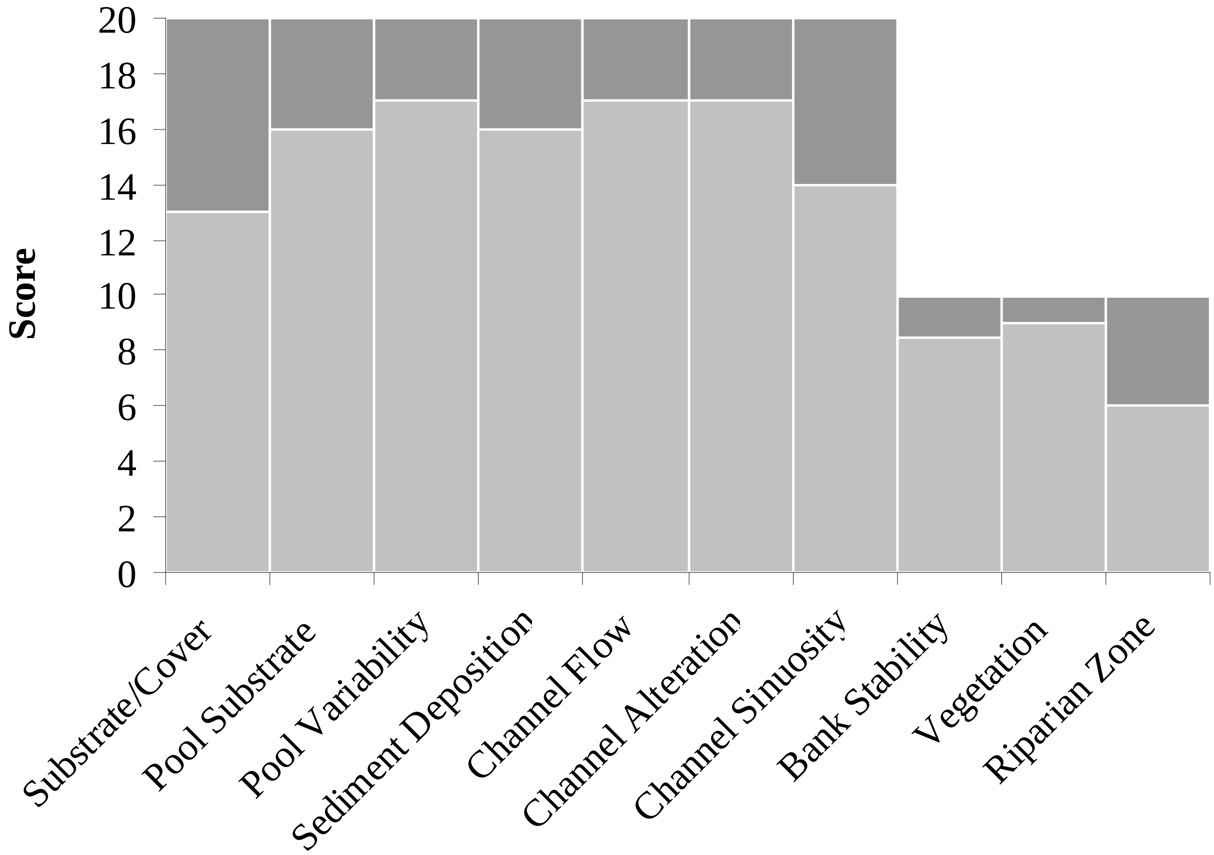


Figure 45. Site BB-2 physical habitat scores; BB-2 was rated the highest habitat quality of the sites studied.

The general characterization of substrate types for BB-2 is shown at Figure 46, with coarse gravel (40 %) comprising the bulk of the substrate. Coarse gravel, together with cobble (30 %) and fine gravel (20 %), made up 90 % of the substrate types at this site. Site BB-2 had the highest percentage of cobble in the study. Fines accounted for ten percent of the total substrate. The substrate embeddedness rating for BB-2 averaged 4.0, with an average of five to 25 % of the substrate surface covered with silt. The presence of oils was not seen, however, anaerobic odors were detected and black deposits were seen on the underside of the substrate.

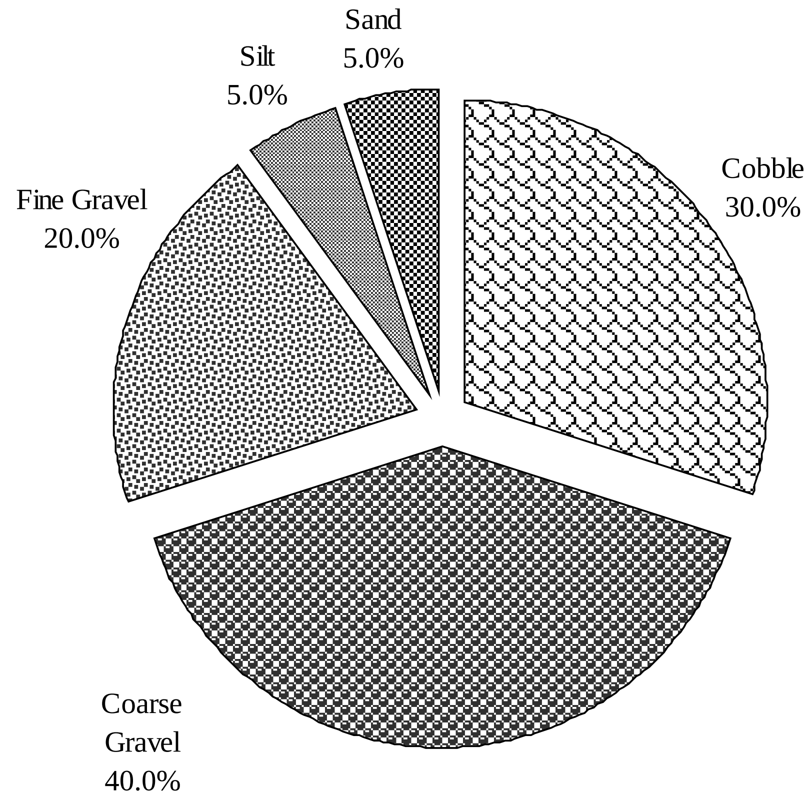


Figure 46. Substrate types at site BB-2 as percentages of total substrate characterized.

Site SC-1

The reach was estimated to be 100 m long and is shown in Figure 47. The predominant surrounding land use was field/pasture with potential non-point pollution sources and moderate erosion. The riparian buffer included oak and ash trees, shrubs, and grasses, with brome and alfalfa dominant. The canopy was partly open canopy and the entire reach vegetated. Of the rooted emergent species present, *Typha sp.* was dominant.

Figure 47. This picture of the SC-1 habitat reach shows what may be a new stream channel (bounded by the fence line) and the old stream channel (oxbow) bounded by the line of trees in the background.

A meander of the stream appeared to have been cut off and excavated to form an impoundment (Figure 48), with a large amount of water held behind the diversion area. Surface water not diverted into the impoundment flowed approximately 70 m to a box culvert. The estimated stream width below the diversion was two to four feet wide. The impoundment appeared to overflow into a lower reach of the segment, approximately 19 meters from the box culvert. Downstream flow through the box culvert appeared to be within the original stream channel and otherwise unimpeded.

Figure 48. View of the upstream flow (lower right) of Spring Creek (site SC-1) and the oxbow impoundment (left rear of photo).

Figure 49 shows a graph of SC-1 habitat assessment scores compared to scores from the ideal habitat score. Site SC-1 scored poorly for a complete lack of available instream cover/substrate. Pool substrate was rated suboptimal, while pool variability and sediment deposition were rated marginal. Channel flow status was rated optimal. Channel alteration and sinuosity were rated marginal, based on the fact that the stream had been diverted from its original course. Bank stability and vegetative protection were rated optimal and the riparian zone width was rated marginal due to frequent cattle access and crossing.

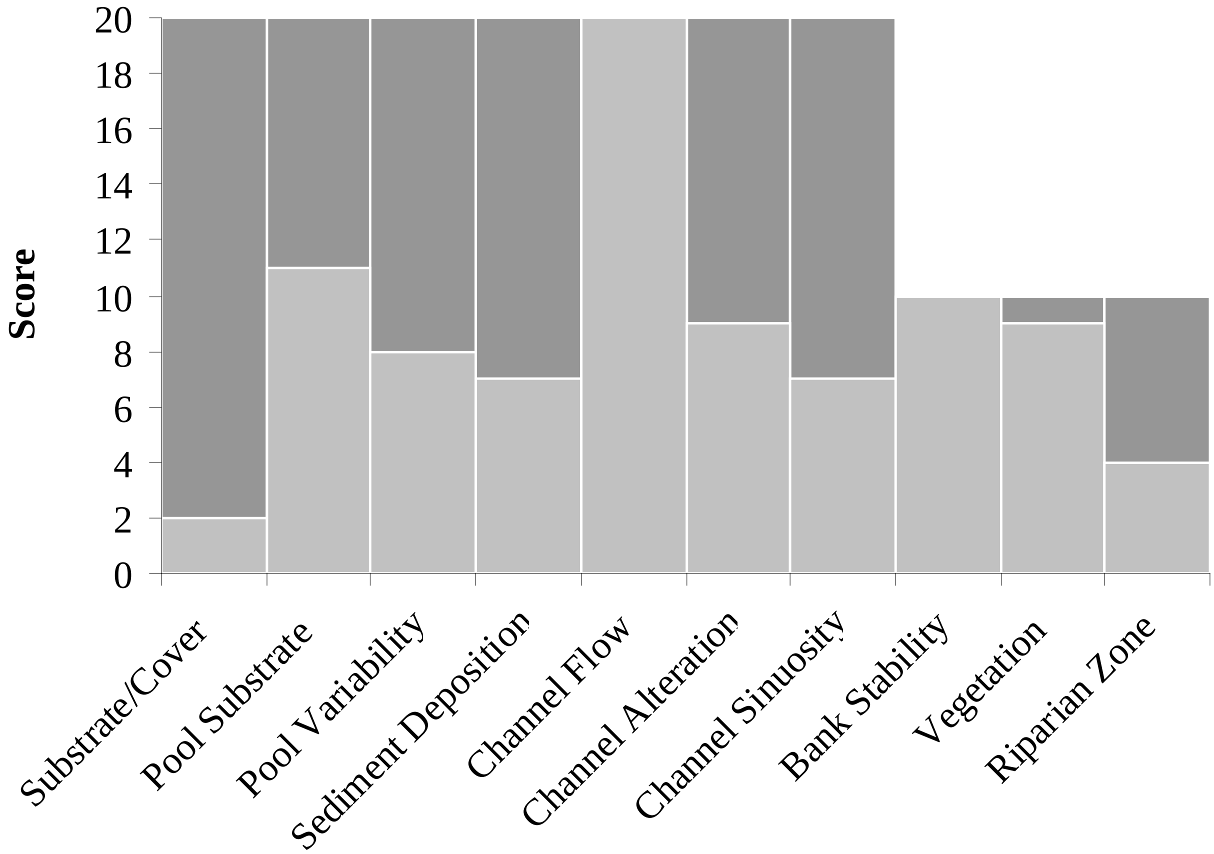


Figure 49. Site SC-1 physical habitat scores; SC-1 was rated lowest for habitat quality due to channel alteration and reduced riparian habitat.

The general characterization of substrate types for SC-1 is shown at Figure 50, with silt (96 %) comprising the bulk of the substrate (highest in the study). Fine gravel (2.0 %), together with sand (1.0 %) and coarse gravel (0.3 %), made up 3 % of the substrate types at this site. No cobble was observed. Fines accounted for over 97 % of the total substrate. The substrate embeddedness rating for SC-1 averaged 1.0, with an average of greater than 75 % of the substrate surface covered with silt. Anaerobic odors were detected and black deposits were seen on the underside of the substrate.

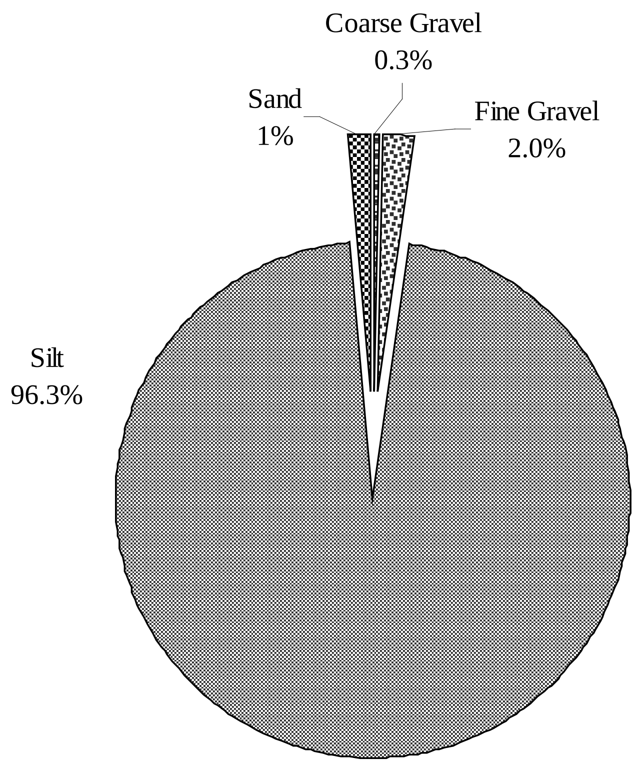


Figure 50. Substrate types at site SC-1 as percentages of total substrate characterized.

Site BB-3

The reach was estimated to be 70 m long. The predominant surrounding land use was field/pasture with potential non-point pollution sources and moderate to heavy erosion. The riparian buffer included willow shrubs and grasses, with brome and sedge dominant. The instream features were not indicated, except the stream channel segment was classified as 60 % riffle and 40 % pool. Types and extent of vegetation were not indicated. No large woody debris was observed.

Figure 51 is a picture of Bear Butte Creek from the road bridge, downstream from the Spring Creek confluence. Both streambeds were dry at the time the photograph was taken. Here, a cattle gate was set up to prevent cattle from becoming stranded in the mud hole below the bridge. An upstream picture of this site was included at Figure 58.

Figure 51. Photograph of site BB-3, looking downstream from the road bridge (27 August 2003).

Figure 52 shows a graph of BB-3 habitat assessment scores compared to an ideal habitat score. Site BB-3 was rated marginal for a lack of available instream cover/substrate. Pool substrate and pool variability were rated optimal, while sediment deposition was rated suboptimal. Channel flow status and alteration were rated suboptimal, while sinuosity was rated marginal. Bank stability, vegetative protection, and riparian width were all rated suboptimal. Site BB-3 was the second-worst habitat among study sites.

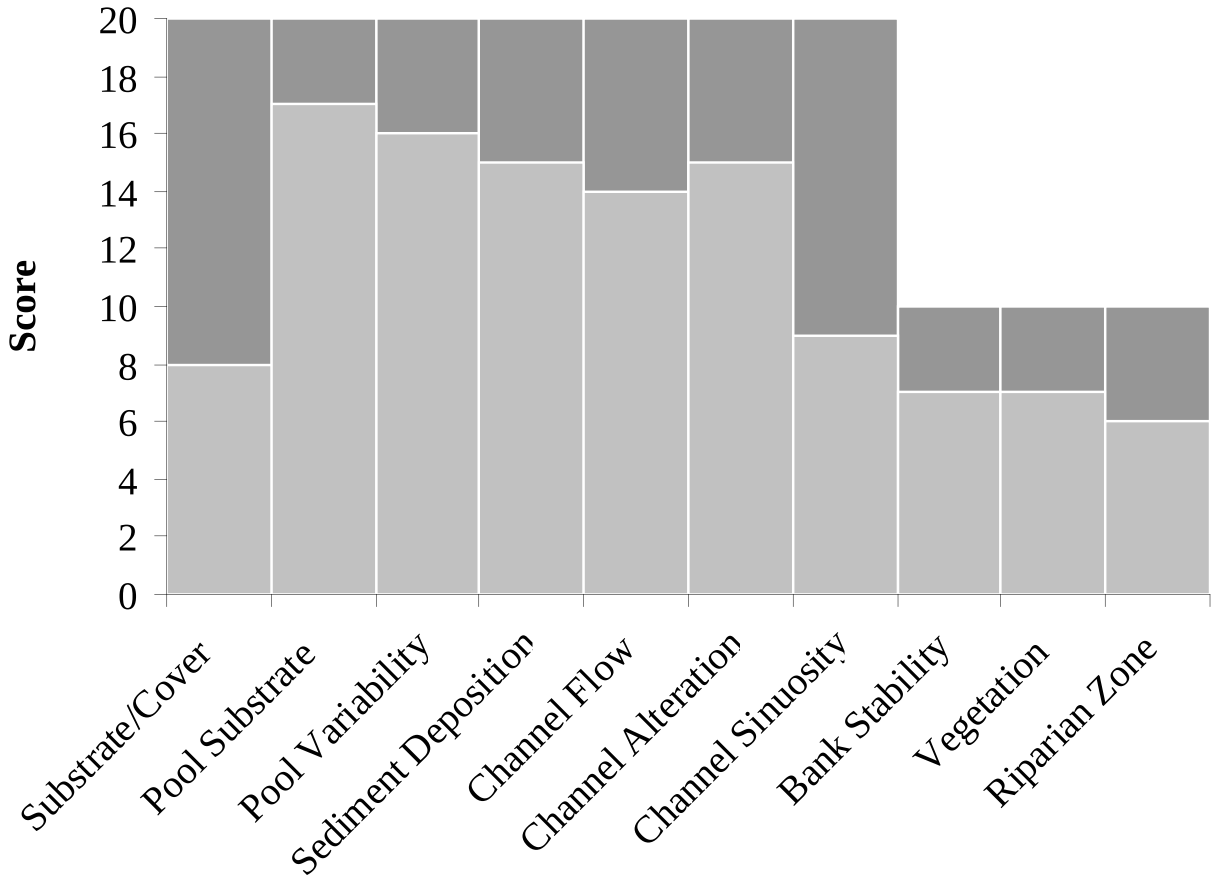


Figure 52. Site BB-3 physical habitat scores; BB-3 was the second-worst habitat in the study due primarily to marginal instream cover, bank stability, vegetative protection, and riparian width.

The general characterization of substrate types for BB-3 is shown at Figure 53, with fine gravel (41 %) comprising the bulk of the substrate (highest in the study). Fine gravel, together with cobble (16 %) and coarse gravel (34 %), made up 91 % of the substrate types at this site. Fines accounted for nine percent of the total substrate. The substrate embeddedness rating for BB-3 averaged 3.7, with an average of 25 to 50 % of the substrate surface covered with silt.

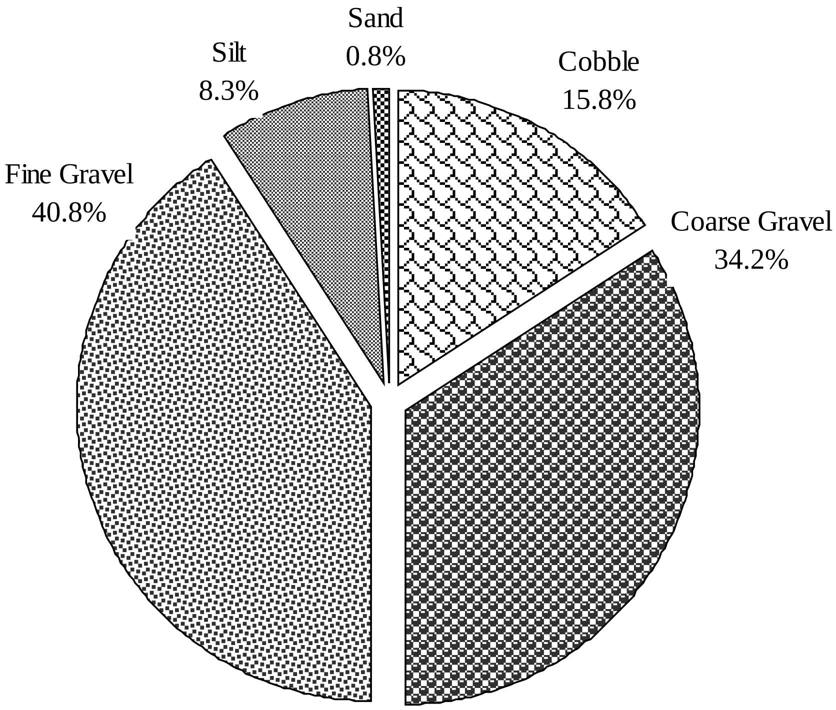


Figure 53. Substrate types at site BB-3 as percentages of total substrate characterized.

Site BB-4

The reach was estimated to be 100 m long. The predominant surrounding land use was field/pasture with potential non-point pollution sources and moderate to heavy erosion. The riparian buffer included honey locust shrubs, and grasses, with brome and sweet clover dominant. The stream channel was nearly ten feet wide, with no canopy. Less than one percent of the reach was vegetated, with a rooted submergent species present (*Potomageton* sp.). The amount of large woody debris was not indicated. Figure 54 is an upstream view of BB-4 at a road crossing. As can be seen in the photograph, the banks of the creek are extremely steep, lacking in vegetation, and easily eroded.

Figure 54. Photograph of site BB-4, where the site had been completely dry for months (27 August 2003).

Figure 55 is a picture of the Bear Butte Creek confluence with the Belle Fourche River. Seen in the center of the picture, a portion of the hillside to the right has slumped down into the creek and narrowed the channel.

Figure 55. Photograph of site BB-4 – confluence of Belle Fourche River; see slumpage of far hill on right (27 August 2003).

Figure 56 shows a graph of BB-4 habitat assessment scores compared to scores from the ideal habitat score. Site BB-4 was rated suboptimal for available instream cover/substrate. Pool substrate and pool variability were rated optimal, while sediment deposition was rated suboptimal. Channel flow status was rated marginal due to very low flow, alteration was rated optimal, and sinuosity was rated suboptimal. Bank stability, vegetative protection, and riparian width were all rated suboptimal. Site BB-4 habitat scores were the third-best among study sites.

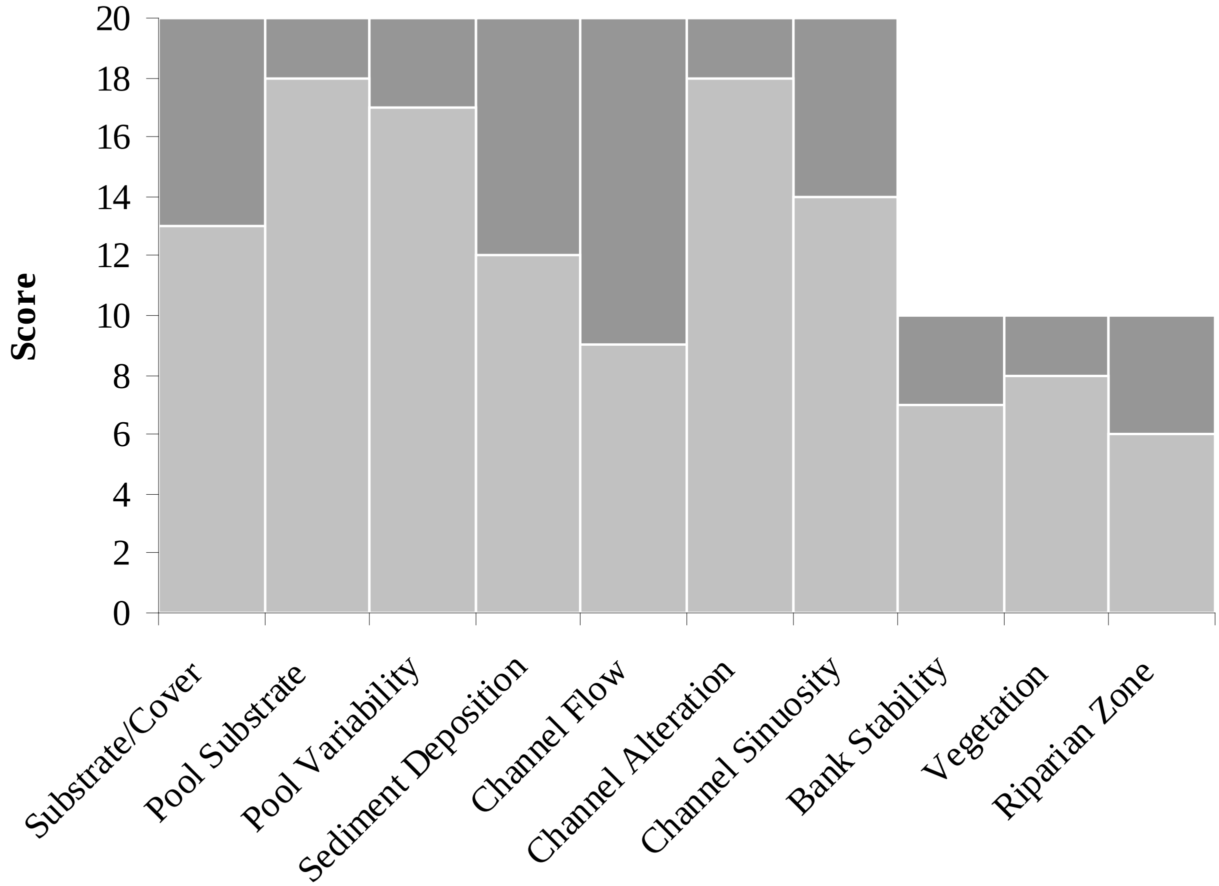


Figure 56. Site BB-4 physical habitat scores; very low flows observed during the assessment at BB-4 contributed to reduced habitat quality.

The general characterization of substrate types for BB-4 is shown at Figure 57, with coarse gravel (32 %) comprising the bulk of the substrate. Coarse gravel, together with cobble (23 %) and fine gravel (26 %), made up 81 % of the substrate types at this site. BB-4 had the highest percentage of sand in the study (5.8 %). Fines accounted for nearly 20 % of the total substrate. The substrate embeddedness rating for BB-4 averaged 2.1, with an average of 50 to 75 % of the substrate surface covered with silt. Black deposits were seen on the underside of the substrate.

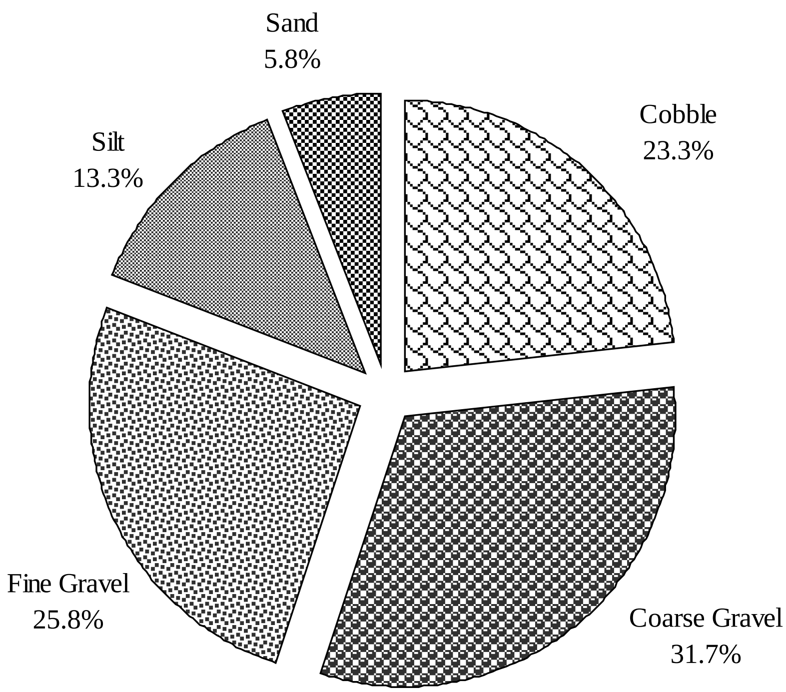


Figure 57. Substrate types at site BB-4 as percentages of total substrate characterized.

Fisheries Data

No fisheries data was collected during this study. However, during a tour of the watershed in August 2003, when the photographs were taken, the studied streams east of Sturgis, SD (except for the dammed portion of Spring Creek) were dry. The aquatic community structure evidently collapsed from the lack of water. Several freshwater clam shells were retrieved from beneath the bridge at BB-3. The clams likely died when the water beneath the bridge dried up (Figure 58) and were estimated to be between 15 and 20 years old. Since clams have limited mobility, these shells provided some evidence as to the number of years the stream segment supported a clam population and since the last dry event. Historic flow records confirmed that previous no-flow events occurred along the lower sections of Bear Butte Creek (zero flow was recorded at site BB-2 from October 1961 to February 1962).

Figure 58. Photograph of site BB-3 looking upstream (27 August 2003); recent remains of freshwater clams found here were estimated to have survived in this segment for 15 to 20 years. A deep pool in the upstream portion of the meander (background) remains.

Endangered Species

The whooping crane (Grus americana) is the only state and federally listed endangered species documented in the Belle Fourche River watershed. The finescale dace (Phoxinus neogaeus) is the only other state listed endangered species documented in the study area.

The bald eagle (Haliaeetus leucocephalus) is the only state and federally listed threatened species documented in the Belle Fourche River watershed. Other state listed threatened species documented in the study area are the American dipper (Cinclus mexicanus) and longnose sucker (Catostomus catostomus).

The activities of this study did not adversely affect any of the above threatened or endangered species.

Quality Assurance Reporting

Quality assurance/quality control (QA/QC) samples were collected, as blank, duplicate, or replicate water quality samples, throughout the project period to validate laboratory and field sampling methods. Of the 122 USGS samples collected, eight (6.6 %) were duplicates or replicates, three (2.5 %) were blanks drawn for metals contamination only and were not included in this report. Nine percent of the USGS samples were for QA/QC purposes.

QA/QC samples were collected on seven of 43 SD DENR WRAP samples (16.3 %). No QA/QC data was reported for the SD DENR WQM sampling efforts. Overall, 18 of 305 samples (6 %) of the sampling performed for the project supported the QA/QC effort. Tables in Appendix E list the routine and QA/QC sample pair and blank sample results.

Replicate and duplicate sample values were compared to the routine sample values using the industrial statistic. The value of the industrial statistic (%I) is given as the absolute difference between the original and the duplicate sample in percent (Smith, 2002). The criterion for compliance was a %I of less than 10 %. The equation used is given as Equation 3:

Equation 3. The industrial statistic equation is given as the absolute difference between the original and the duplicate sample in percent.

$$(\%I) = [\ (A - B) / (A + B)\ ] * 100$$

(%I): the industrial statistic
(A – B): the absolute difference
(A + B): the absolute sum

Ten of the twelve QA/QC samples exceeded the compliance criterion for the following number of the twelve samples: TKN and organic nitrogen (6); Fecal coliform and total phosphorus (5); un-ionized ammonia (4); ammonia and total suspended solids (3); nitrate/nitrite and inorganic nitrogen (2); alkalinity, dissolved phosphorus, total dissolved solids, and total solids (1). The greatest number of exceedances can be attributed to disparities in the ammonia, TKN, and nitrate/nitrite assay results, which also caused problems in the accounting for the other nitrogen groups. Similar compounding problems affected the solids assays, albeit to a lesser extent.

Overall, 77 % (136 of 176) of all industrial statistics values met the QA/QC criterion. Samples with the most exceedances of the QA/QC criterion were collected on 6 October 1998 (BB-1 - eight exceedances and BB-2 - seven exceedances). In the case of fecal coliform samples, the average exceedance of 29 % could have been caused by a combination of variability in sample collection and/or storage, but more likely due to the natural variability of this parameter. Variability in the nitrogen samples may have resulted from sample collection and storage procedures. Because these samples were taken early in the study, the possibility exists that personnel were unfamiliar with QA/QC procedures.

Blank sample values were screened for detectable concentrations. Blank samples were also evaluated by calculating the mean and standard deviation for all samples. The criterion for compliance was that the standard deviation be less than the mean of all blank samples.

All three blank samples collected by WRAP personnel contained detectable levels of fecal coliform bacteria (up to 40 col/100 mL), nitrate/nitrite (up to 0.5 mg/L), and solids (up to 10.5 mg/L TDS). The criterion for compliance was exceeded by the fecal coliform (average of 16.7 mg/L; standard deviation of 20.2 mg/L) and by nitrate/nitrite (average of 0.20 mg/L, standard deviation of 0.26 mg/L). The high reading of nitrate/nitrite concentration in the blank (which also caused the parameter to exceed the criterion) was likely caused by contamination of the blank water or collection bottle.

Future Activity Recommendations

Temperature Monitoring

A system of stream temperature continuous data loggers must be used to increase the reliability of the collected data. Accurate peak and mean temperature results cannot be determined by the current methods. The recommended temperature data loggers offer the most cost-effective approach to determining the extent of the potential heating problem in Bear Butte Creek. Remote sensing data could also be used to determine the length of stream exposed to direct sunlight and the extent of canopy vegetation. Instantaneous or continuous radiance could also be measured at stream sites to determine the amount of direct radiance upon stream segments exposed for extended periods of time.

An increase in the height and density of riparian vegetation, by planting or cultivating vegetation in vulnerable areas, will reduce the extent of stream heating. Channelization of the stream bed exposes the stream to the sun and should be discouraged; instead, meanders should be left in place (or reconstructed) and banks revegetated where possible.

Source Water Study

Flow in the Bear Butte Creek stream channel is lost at Madison and Minnelusa formation sinkholes and reappears from the alluvium near Sturgis, SD (east of Woodle Field). Flow is generally continuous from this reemergence to the Belle Fourche River. The source for the water at the reemergence zone has not been proved, although sampling results indicate a similarity in the upstream and downstream Bear Butte Creek water quality.

A source water study should be undertaken to determine the source(s) of the reemergence flow through the loss areas. This study should include the use of the Efficient Hydrologic Tracer Test Design (USEPA, 2003) to establish the groundwater velocity and residence time of water from the loss zone to the reemergence zone. These results could also be used by the state to support analysis of potential contaminant transport, especially arsenic, from the mining district to the Sturgis drinking water supply.

Management Recommendations

Management practices can control the delivery of nonpoint source pollutants to receiving waters by minimizing pollutants available (i.e. source reduction), retarding the transport and/or delivery of pollutants, or intercepting the pollutant before or after it is delivered to the water through chemical or biological transformation. The recommendations herein are based on known best management practices and professional judgment.

Riparian Zones

Properly functioning riparian areas can significantly reduce nonpoint source pollution by intercepting surface runoff, filtering and storing sediment and associated pollutants, and stabilizing banks. Stream bank stability is directly related to the species composition of the riparian vegetation and the distribution and density of these species. Proposed BMPs to address riparian area degradation include livestock use exclusion, stream bank stabilization and protection, and reseeding or manual planting of native plant species.

Livestock Grazing

Restricting cattle and other livestock access to Bear Butte Creek and its tributaries and establishing buffer zones in the areas immediately adjacent to the stream should result in an appreciable reduction of sediment and nutrient loadings. Management of livestock should include prescribed grazing, constructing fences or other barriers to control concentrated livestock access to riparian areas, livestock crossing structures, and alternative water supply. Other alternatives include seasonal access or rotational grazing to reduce the intensity and duration of access to riparian zones and uplands.

Stream Bank Stabilization

Sloughing banks and eroding areas were observed in the Bear Butte Creek watershed, however, data specific to these areas were not available to estimate reductions. These areas contribute to the overall sediment and nutrient input along the mainstem sites and should be included in an implementation plan. Restoration alternatives could include, but are not limited to, laying back steep banks, replanting barren and susceptible areas with suitable vegetative species, or by stabilizing these areas with non-vegetative structure.

Cropland Conservation

Conservation practices that could be implemented on croplands within the Bear Butte Creek watershed include, but are not limited to, cover crop planting, conservation crop rotation, residue management, and contour farming. These practices can be used to reduce sheet and rill erosion, reduce soil erosion from wind, maintain or improve soil organic matter content, manage the balance of plant nutrients, reduce the transport of sediment and other water-borne contaminants, and improve water use efficiency.

Public Involvement and Coordination

Public involvement and coordination was the responsibility of the Elk Creek County Conservation District. As local sponsor for the project, district personnel were responsible for issuing press releases and/or news bulletins. The project was discussed at monthly meetings of the Elk Creek County Conservation District Board, which was also a setting where the public was invited to attend.

The Elk Creek County Conservation District was the appropriate lead project sponsor for this project. Conservation District personnel were important to the success of this project because of the close working relationship with stakeholders within the watershed.

State Agencies

Because the South Dakota Department of Environment and Natural Resources (SD DENR) is the statewide pollution control agency, it was the appropriate lead state agency for this project. The South Dakota Department of Game, Fish and Parks maintain current and long-term fisheries data. SD GF&P should be contacted and consulted during the planning and implementation phases of this project.

Federal Agencies

Natural Resources Conservation Service (NRCS) provided office space and technical assistance for the project. NRCS is the contact for local landowners involved with conservation plans and practices. NRCS should be involved during all phases of the implementation process.

The United States Environmental Protection Agency will review and approve this assessment and TMDL.

The United States Fish and Wildlife Service should be contacted prior to the implementation project regarding their role in the implementation of the TMDL and the potential impact on any endangered species (consultation process).

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Appendix A

Stream Flow Data

Bear Butte Creek Flow (cfs)

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
01-Oct-98	3.70	7.318	15.276	15.378	1.267	4.170	0.844	5.20
02-Oct-98	4.60	8.584	16.989	18.958	1.373	4.834	0.910	6.70
03-Oct-98	3.60	7.177	15.086	14.980	1.255	4.096	0.836	5.90
04-Oct-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	12.00
05-Oct-98	25.00	37.272	57.745	100.118	3.443	18.853	2.157	11.00
06-Oct-98	7.00	11.959	21.592	28.507	1.644	6.574	1.077	14.00
07-Oct-98	5.20	9.427	48.000	56.400	2.996	5.273	1.893	14.00
08-Oct-98	4.70	8.724	17.179	19.356	1.384	4.908	0.917	21.00
09-Oct-98	4.50	8.443	16.798	18.561	1.361	4.761	0.902	28.00
10-Oct-98	4.40	8.302	16.607	18.163	1.349	4.687	0.895	34.00
11-Oct-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	57.00
12-Oct-98	16.00	24.615	39.309	64.312	2.579	12.835	1.644	43.00
13-Oct-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	39.00
14-Oct-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	38.00
15-Oct-98	12.00	18.990	31.346	48.399	2.175	10.091	1.402	35.00
16-Oct-98	25.00	37.272	57.745	100.118	3.443	18.853	2.157	46.00
17-Oct-98	99.00	141.337	236.562	394.520	9.937	64.845	5.838	62.00
18-Oct-98	51.00	73.835	115.039	203.556	5.780	35.524	3.509	53.00
19-Oct-98	51.00	73.835	115.039	203.556	5.780	35.524	3.509	55.00
20-Oct-98	46.00	66.804	103.555	183.664	5.341	32.377	3.258	54.00
21-Oct-98	40.00	58.366	90.067	159.794	4.809	28.569	2.953	52.00
22-Oct-98	37.00	54.147	83.443	147.859	4.540	26.650	2.798	48.00
23-Oct-98	41.00	59.772	92.293	163.772	4.898	29.206	3.004	57.00
24-Oct-98	41.00	59.772	92.293	163.772	4.898	29.206	3.004	56.00
25-Oct-98	39.00	56.960	87.850	155.815	4.720	27.930	2.901	49.00
26-Oct-98	34.00	49.928	76.899	135.923	4.270	24.720	2.641	49.00
27-Oct-98	29.00	42.897	66.169	116.031	3.814	21.476	2.375	43.00
28-Oct-98	31.00	45.709	70.434	123.988	3.997	22.778	2.482	49.00
29-Oct-98	35.00	51.335	79.071	139.902	4.361	25.364	2.693	56.00
30-Oct-98	25.00	37.272	57.745	100.118	3.443	18.853	2.157	44.00
31-Oct-98	21.00	31.647	49.463	84.204	3.065	16.200	1.934	27.00
01-Nov-98	19.00	28.834	45.375	76.247	2.872	14.861	1.820	28.00
02-Nov-98	18.00	27.428	43.344	72.269	2.775	14.188	1.762	23.00
03-Nov-98	19.00	28.834	45.375	76.247	2.872	14.861	1.820	23.00
04-Nov-98	18.00	27.428	43.344	72.269	2.775	14.188	1.762	22.00
05-Nov-98	17.00	26.021	41.322	68.291	2.677	13.513	1.703	22.00
06-Nov-98	17.00	26.021	41.322	68.291	2.677	13.513	1.703	21.00
07-Nov-98	16.00	24.615	39.309	64.312	2.579	12.835	1.644	20.00
08-Nov-98	16.00	24.615	39.309	64.312	2.579	12.835	1.644	19.00
09-Nov-98	16.00	24.615	39.309	64.312	2.579	12.835	1.644	17.00
10-Nov-98	11.00	17.584	29.378	44.420	2.072	9.397	1.339	15.00
11-Nov-98	10.00	16.177	27.418	40.442	1.967	8.698	1.275	19.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
12-Nov-98	11.00	17.584	29.378	44.420	2.072	9.397	1.339	17.00
13-Nov-98	12.00	18.990	31.346	48.399	2.175	10.091	1.402	14.00
14-Nov-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	17.00
15-Nov-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	14.00
16-Nov-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	14.00
17-Nov-98	14.00	21.803	50.600	62.400	3.118	11.470	1.965	14.00
18-Nov-98	14.00	21.803	35.310	56.355	2.379	11.470	1.524	13.00
19-Nov-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	13.00
20-Nov-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	13.00
21-Nov-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	12.00
22-Nov-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	13.00
23-Nov-98	13.00	20.396	33.324	52.377	2.278	10.782	1.463	13.00
24-Nov-98	12.00	18.990	31.346	48.399	2.175	10.091	1.402	12.00
25-Nov-98	12.00	18.990	31.346	48.399	2.175	10.091	1.402	12.00
26-Nov-98	12.00	18.990	31.346	48.399	2.175	10.091	1.402	12.00
27-Nov-98	11.00	17.584	29.378	44.420	2.072	9.397	1.339	11.00
28-Nov-98	11.00	17.584	29.378	44.420	2.072	9.397	1.339	11.00
29-Nov-98	10.00	16.177	27.418	40.442	1.967	8.698	1.275	11.00
30-Nov-98	10.00	16.177	27.418	40.442	1.967	8.698	1.275	10.00
01-Dec-98	10.00	16.177	27.418	40.442	1.967	8.698	1.275	9.70
02-Dec-98	10.00	16.177	27.418	40.442	1.967	8.698	1.275	9.40
03-Dec-98	9.90	16.037	27.222	40.044	1.956	8.628	1.269	9.10
04-Dec-98	9.60	15.615	26.636	38.850	1.925	8.418	1.249	8.40
05-Dec-98	9.10	14.912	25.662	36.861	1.872	8.066	1.217	7.30
06-Dec-98	8.10	13.506	23.719	32.883	1.764	7.358	1.151	4.50
07-Dec-98	7.80	13.084	23.138	31.689	1.731	7.145	1.131	5.00
08-Dec-98	7.50	12.662	22.557	30.496	1.699	6.931	1.111	5.50
09-Dec-98	7.30	12.381	22.171	29.700	1.677	6.788	1.098	5.50
10-Dec-98	7.20	12.240	21.978	29.302	1.666	6.717	1.091	6.00
11-Dec-98	6.90	11.818	21.399	28.109	1.633	6.502	1.071	6.50
12-Dec-98	6.90	11.818	21.399	28.109	1.633	6.502	1.071	7.00
13-Dec-98	6.60	11.396	20.821	26.915	1.599	6.287	1.050	7.40
14-Dec-98	6.40	11.115	20.436	26.120	1.577	6.143	1.036	6.20
15-Dec-98	6.20	10.834	20.200	22.300	1.563	5.999	1.028	5.70
16-Dec-98	6.30	10.974	20.244	25.722	1.566	6.071	1.029	6.00
17-Dec-98	6.30	10.974	20.244	25.722	1.566	6.071	1.029	6.00
18-Dec-98	6.20	10.834	20.052	25.324	1.555	5.999	1.022	5.00
19-Dec-98	6.20	10.834	20.052	25.324	1.555	5.999	1.022	3.80
20-Dec-98	6.20	10.834	20.052	25.324	1.555	5.999	1.022	4.50
21-Dec-98	6.20	10.834	20.052	25.324	1.555	5.999	1.022	3.50
22-Dec-98	6.20	10.834	20.052	25.324	1.555	5.999	1.022	5.00
23-Dec-98	5.80	10.271	19.284	23.733	1.510	5.709	0.995	6.80
24-Dec-98	5.50	9.849	18.709	22.539	1.476	5.492	0.974	6.10
25-Dec-98	5.50	9.849	18.709	22.539	1.476	5.492	0.974	7.10

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
26-Dec-98	5.50	9.849	18.709	22.539	1.476	5.492	0.974	9.00
27-Dec-98	5.20	9.427	18.135	21.345	1.442	5.273	0.952	8.70
28-Dec-98	5.40	9.709	18.517	22.141	1.465	5.419	0.967	7.60
29-Dec-98	5.20	9.427	18.135	21.345	1.442	5.273	0.952	7.20
30-Dec-98	5.50	9.849	18.709	22.539	1.476	5.492	0.974	6.90
31-Dec-98	5.30	9.568	18.326	21.743	1.453	5.346	0.960	5.90
01-Jan-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	5.90
02-Jan-99	5.40	9.709	18.517	22.141	1.465	5.419	0.967	5.50
03-Jan-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	5.60
04-Jan-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	5.60
05-Jan-99	5.90	10.412	19.476	24.130	1.521	5.782	1.002	6.10
06-Jan-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	4.40
07-Jan-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	2.80
08-Jan-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.30
09-Jan-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.90
10-Jan-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.90
11-Jan-99	7.70	12.943	22.944	31.291	1.721	7.074	1.125	2.90
12-Jan-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.00
13-Jan-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	2.70
14-Jan-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	2.70
15-Jan-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	2.90
16-Jan-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	2.80
17-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.70
18-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.80
19-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.70
20-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.70
21-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.70
22-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.70
23-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.80
24-Jan-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.50
25-Jan-99	4.60	8.584	16.989	18.958	1.373	4.834	0.910	2.50
26-Jan-99	4.50	8.443	14.900	13.800	1.244	4.761	0.829	2.50
27-Jan-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	3.00
28-Jan-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	3.80
29-Jan-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	3.10
30-Jan-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	3.00
31-Jan-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	3.10
01-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	3.10
02-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.70
03-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.50
04-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	1.50
05-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.50
06-Feb-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.60
07-Feb-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.60

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
08-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.60
09-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	3.20
10-Feb-99	4.20	8.021	17.600	20.700	1.410	4.540	0.933	3.00
11-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	1.80
12-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.10
13-Feb-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	3.10
14-Feb-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.80
15-Feb-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.60
16-Feb-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.30
17-Feb-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.00
18-Feb-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.60
19-Feb-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.50
20-Feb-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.50
21-Feb-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	1.90
22-Feb-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	1.40
23-Feb-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	1.90
24-Feb-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	1.90
25-Feb-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	1.90
26-Feb-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.80
27-Feb-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.70
28-Feb-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.30
01-Mar-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	3.00
02-Mar-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	1.70
03-Mar-99	4.60	8.584	16.989	18.958	1.373	4.834	0.910	2.20
04-Mar-99	4.60	8.584	16.989	18.958	1.373	4.834	0.910	2.60
05-Mar-99	4.70	8.724	17.179	19.356	1.384	4.908	0.917	2.60
06-Mar-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	3.50
07-Mar-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	3.10
08-Mar-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	1.80
09-Mar-99	4.10	7.880	17.500	20.000	1.404	4.466	0.929	2.80
10-Mar-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	2.60
11-Mar-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.80
12-Mar-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	1.80
13-Mar-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	3.30
14-Mar-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	5.80
15-Mar-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	8.80
16-Mar-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	9.00
17-Mar-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	6.10
18-Mar-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	6.70
19-Mar-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	7.00
20-Mar-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	7.30
21-Mar-99	4.60	8.584	16.989	18.958	1.373	4.834	0.910	7.50
22-Mar-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	8.60
23-Mar-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	9.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
24-Mar-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	9.70
25-Mar-99	5.40	9.709	18.517	22.141	1.465	5.419	0.967	10.00
26-Mar-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	11.00
27-Mar-99	6.20	10.834	20.052	25.324	1.555	5.999	1.022	11.00
28-Mar-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	10.00
29-Mar-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	10.00
30-Mar-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	11.00
31-Mar-99	5.90	10.412	19.476	24.130	1.521	5.782	1.002	11.00
01-Apr-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	11.00
02-Apr-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	10.00
03-Apr-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	11.00
04-Apr-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	12.00
05-Apr-99	4.60	8.584	16.989	18.958	1.373	4.834	0.910	11.00
06-Apr-99	4.30	8.162	69.200	107.000	3.945	4.614	2.451	13.00
07-Apr-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	19.00
08-Apr-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	24.00
09-Apr-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	27.00
10-Apr-99	9.30	15.193	26.051	37.657	1.893	8.207	1.230	30.00
11-Apr-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	30.00
12-Apr-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	33.00
13-Apr-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	37.00
14-Apr-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	38.00
15-Apr-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	36.00
16-Apr-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	32.00
17-Apr-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	30.00
18-Apr-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	29.00
19-Apr-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	28.00
20-Apr-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	28.00
21-Apr-99	6.70	11.537	29.400	41.700	2.073	6.359	1.340	43.00
22-Apr-99	21.00	31.647	49.463	84.204	3.065	16.200	1.934	40.00
23-Apr-99	13.00	20.396	33.324	52.377	2.278	10.782	1.463	37.00
24-Apr-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	34.00
25-Apr-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	39.00
26-Apr-99	9.60	15.615	26.636	38.850	1.925	8.418	1.249	47.00
27-Apr-99	7.90	13.224	23.331	32.087	1.742	7.216	1.138	40.00
28-Apr-99	6.70	11.537	21.014	27.313	1.611	6.359	1.057	39.00
29-Apr-99	5.90	10.412	19.476	24.130	1.521	5.782	1.002	33.00
30-Apr-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	29.00
01-May-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	27.00
02-May-99	4.70	8.724	17.179	19.356	1.384	4.908	0.917	25.00
03-May-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	26.00
04-May-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	28.00
05-May-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	25.00
06-May-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	24.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
07-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	23.00
08-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	22.00
09-May-99	5.90	10.412	19.476	24.130	1.521	5.782	1.002	23.00
10-May-99	7.80	13.084	32.400	37.200	2.230	7.145	1.435	25.00
11-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	23.00
12-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	21.00
13-May-99	5.70	10.130	19.092	23.335	1.499	5.637	0.988	21.00
14-May-99	5.80	10.271	19.284	23.733	1.510	5.709	0.995	21.00
15-May-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	22.00
16-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	22.00
17-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	18.00
18-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	17.00
19-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	17.00
20-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	16.00
21-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	16.00
22-May-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	17.00
23-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	16.00
24-May-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	15.00
25-May-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	15.00
26-May-99	8.90	14.631	25.272	36.066	1.850	7.925	1.204	18.00
27-May-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	16.00
28-May-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	14.00
29-May-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	13.00
30-May-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	13.00
31-May-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	14.00
01-Jun-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	13.00
02-Jun-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	14.00
03-Jun-99	9.00	14.771	25.467	36.463	1.861	7.995	1.210	24.00
04-Jun-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	17.00
05-Jun-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	19.00
06-Jun-99	15.00	23.209	37.305	60.334	2.479	12.154	1.585	44.00
07-Jun-99	9.10	14.912	25.662	36.861	1.872	8.066	1.217	44.00
08-Jun-99	7.70	12.943	22.944	31.291	1.721	7.074	1.125	40.00
09-Jun-99	6.90	11.818	79.600	119.000	4.382	6.502	2.706	41.00
10-Jun-99	31.00	45.709	70.434	123.988	3.997	22.778	2.482	65.00
11-Jun-99	62.00	89.304	141.083	247.319	6.738	42.373	4.053	80.00
12-Jun-99	99.00	141.337	236.562	394.520	9.937	64.845	5.838	88.00
13-Jun-99	110.00	156.806	267.288	438.282	10.892	71.397	6.363	70.00
14-Jun-99	75.00	107.586	173.246	299.038	7.863	50.356	4.685	65.00
15-Jun-99	86.00	123.055	190.000	265.000	8.427	57.032	5.001	62.00
16-Jun-99	53.00	76.648	119.694	211.513	5.955	36.777	3.609	51.00
17-Jun-99	41.00	59.772	92.293	163.772	4.898	29.206	3.004	47.00
18-Jun-99	35.00	51.335	79.071	139.902	4.361	25.364	2.693	42.00
19-Jun-99	24.00	35.865	55.661	96.139	3.349	18.192	2.102	37.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
20-Jun-99	19.00	28.834	45.375	76.247	2.872	14.861	1.820	33.00
21-Jun-99	18.00	27.428	43.344	72.269	2.775	14.188	1.762	31.00
22-Jun-99	15.00	23.209	37.305	60.334	2.479	12.154	1.585	27.00
23-Jun-99	14.00	21.803	35.310	56.355	2.379	11.470	1.524	25.00
24-Jun-99	13.00	20.396	33.324	52.377	2.278	10.782	1.463	23.00
25-Jun-99	12.00	18.990	31.346	48.399	2.175	10.091	1.402	21.00
26-Jun-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	19.00
27-Jun-99	19.00	28.834	45.375	76.247	2.872	14.861	1.820	19.00
28-Jun-99	14.00	21.803	35.310	56.355	2.379	11.470	1.524	19.00
29-Jun-99	12.00	18.990	31.346	48.399	2.175	10.091	1.402	16.00
30-Jun-99	12.00	18.990	31.346	48.399	2.175	10.091	1.402	15.00
01-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	14.00
02-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	13.00
03-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	12.00
04-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	12.00
05-Jul-99	10.00	16.177	27.418	40.442	1.967	8.698	1.275	11.00
06-Jul-99	10.00	16.177	27.418	40.442	1.967	8.698	1.275	10.00
07-Jul-99	17.00	26.021	41.322	68.291	2.677	13.513	1.703	9.80
08-Jul-99	20.00	30.240	47.414	80.226	2.969	15.532	1.877	9.00
09-Jul-99	14.00	21.803	35.310	56.355	2.379	11.470	1.524	8.40
10-Jul-99	13.00	20.396	33.324	52.377	2.278	10.782	1.463	8.30
11-Jul-99	13.00	20.396	33.324	52.377	2.278	10.782	1.463	7.90
12-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	7.40
13-Jul-99	9.40	15.334	26.246	38.055	1.904	8.277	1.236	7.00
14-Jul-99	9.30	15.193	26.051	37.657	1.893	8.207	1.230	6.70
15-Jul-99	9.70	15.756	26.832	39.248	1.935	8.488	1.256	6.40
16-Jul-99	8.80	14.490	25.078	35.668	1.839	7.854	1.197	6.60
17-Jul-99	12.00	18.990	31.346	48.399	2.175	10.091	1.402	9.70
18-Jul-99	11.00	17.584	29.378	44.420	2.072	9.397	1.339	7.30
19-Jul-99	9.70	15.756	30.600	32.200	2.136	8.488	1.378	6.40
20-Jul-99	9.50	15.474	26.441	38.453	1.914	8.347	1.243	6.40
21-Jul-99	9.30	15.193	26.051	37.657	1.893	8.207	1.230	6.10
22-Jul-99	9.20	15.052	25.856	37.259	1.882	8.136	1.223	5.60
23-Jul-99	8.90	14.631	25.272	36.066	1.850	7.925	1.204	5.30
24-Jul-99	8.80	14.490	25.078	35.668	1.839	7.854	1.197	5.00
25-Jul-99	8.80	14.490	25.078	35.668	1.839	7.854	1.197	4.70
26-Jul-99	8.60	14.209	24.689	34.872	1.818	7.713	1.184	4.70
27-Jul-99	8.50	14.068	24.495	34.474	1.807	7.642	1.178	4.50
28-Jul-99	8.50	14.068	24.495	34.474	1.807	7.642	1.178	4.60
29-Jul-99	8.60	14.209	24.689	34.872	1.818	7.713	1.184	4.50
30-Jul-99	8.90	14.631	25.272	36.066	1.850	7.925	1.204	5.50
31-Jul-99	14.00	21.803	35.310	56.355	2.379	11.470	1.524	7.50
01-Aug-99	9.80	15.896	27.027	39.646	1.946	8.558	1.262	7.60
02-Aug-99	9.00	14.771	25.467	36.463	1.861	7.995	1.210	5.40

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
03-Aug-99	8.80	14.490	25.078	35.668	1.839	7.854	1.197	5.10
04-Aug-99	8.70	14.349	24.883	35.270	1.829	7.783	1.191	4.80
05-Aug-99	8.90	14.631	25.272	36.066	1.850	7.925	1.204	5.30
06-Aug-99	13.00	20.396	33.324	52.377	2.278	10.782	1.463	8.10
07-Aug-99	7.80	13.084	23.138	31.689	1.731	7.145	1.131	8.30
08-Aug-99	7.40	12.521	22.364	30.098	1.688	6.860	1.104	5.40
09-Aug-99	7.20	12.240	21.978	29.302	1.666	6.717	1.091	4.90
10-Aug-99	7.20	12.240	21.978	29.302	1.666	6.717	1.091	4.60
11-Aug-99	7.20	12.240	21.978	29.302	1.666	6.717	1.091	5.70
12-Aug-99	9.40	15.334	26.246	38.055	1.904	8.277	1.236	7.20
13-Aug-99	7.30	12.381	22.171	29.700	1.677	6.788	1.098	6.20
14-Aug-99	7.20	12.240	21.978	29.302	1.666	6.717	1.091	5.10
15-Aug-99	7.00	11.959	21.592	28.507	1.644	6.574	1.077	4.50
16-Aug-99	6.90	11.818	12.400	12.400	1.083	6.502	0.728	4.30
17-Aug-99	6.80	11.677	21.206	27.711	1.622	6.430	1.064	4.20
18-Aug-99	6.80	11.677	21.206	27.711	1.622	6.430	1.064	4.00
19-Aug-99	6.80	11.677	21.206	27.711	1.622	6.430	1.064	3.90
20-Aug-99	6.70	11.537	21.014	27.313	1.611	6.359	1.057	3.80
21-Aug-99	7.10	12.099	21.785	28.904	1.655	6.645	1.084	4.70
22-Aug-99	6.70	11.537	21.014	27.313	1.611	6.359	1.057	4.50
23-Aug-99	6.50	11.255	20.629	26.517	1.588	6.215	1.043	3.80
24-Aug-99	6.50	11.255	20.629	26.517	1.588	6.215	1.043	3.60
25-Aug-99	6.50	11.255	20.629	26.517	1.588	6.215	1.043	3.50
26-Aug-99	6.40	11.115	20.436	26.120	1.577	6.143	1.036	3.50
27-Aug-99	6.80	11.677	21.206	27.711	1.622	6.430	1.064	4.20
28-Aug-99	7.30	12.381	22.171	29.700	1.677	6.788	1.098	12.00
29-Aug-99	12.00	18.990	31.346	48.399	2.175	10.091	1.402	13.00
30-Aug-99	6.80	11.677	21.206	27.711	1.622	6.430	1.064	6.60
31-Aug-99	6.50	11.255	20.629	26.517	1.588	6.215	1.043	5.20
01-Sep-99	6.40	11.115	20.436	26.120	1.577	6.143	1.036	4.80
02-Sep-99	7.10	12.099	21.785	28.904	1.655	6.645	1.084	4.90
03-Sep-99	7.90	13.224	23.331	32.087	1.742	7.216	1.138	5.60
04-Sep-99	7.20	12.240	21.978	29.302	1.666	6.717	1.091	5.70
05-Sep-99	6.40	11.115	20.436	26.120	1.577	6.143	1.036	5.00
06-Sep-99	6.20	10.834	20.052	25.324	1.555	5.999	1.022	4.60
07-Sep-99	6.20	10.834	20.052	25.324	1.555	5.999	1.022	4.30
08-Sep-99	6.20	10.834	20.052	25.324	1.555	5.999	1.022	4.20
09-Sep-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	4.10
10-Sep-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	4.00
11-Sep-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	4.00
12-Sep-99	6.10	10.693	19.860	24.926	1.544	5.926	1.016	3.90
13-Sep-99	6.00	10.552	19.668	24.528	1.532	5.854	1.009	3.60
14-Sep-99	6.20	10.834	9.580	7.910	0.892	5.999	0.607	3.60
15-Sep-99	6.00	10.552	19.668	24.528	1.532	5.854	1.009	3.50

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
16-Sep-99	5.80	10.271	19.284	23.733	1.510	5.709	0.995	3.40
17-Sep-99	5.80	10.271	19.284	23.733	1.510	5.709	0.995	3.30
18-Sep-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	3.30
19-Sep-99	5.60	9.990	18.900	22.937	1.487	5.564	0.981	3.40
20-Sep-99	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.30
21-Sep-99	5.40	9.709	18.517	22.141	1.465	5.419	0.967	3.20
22-Sep-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	3.10
23-Sep-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.00
24-Sep-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	3.00
25-Sep-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.00
26-Sep-99	5.70	10.130	19.092	23.335	1.499	5.637	0.988	3.30
27-Sep-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.20
28-Sep-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.20
29-Sep-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	3.20
30-Sep-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	3.10
01-Oct-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.10
02-Oct-99	5.40	9.709	18.517	22.141	1.465	5.419	0.967	3.20
03-Oct-99	5.30	9.568	18.326	21.743	1.453	5.346	0.960	3.20
04-Oct-99	5.20	9.427	18.135	21.345	1.442	5.273	0.952	3.10
05-Oct-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	3.10
06-Oct-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	3.10
07-Oct-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	3.00
08-Oct-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	3.20
09-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	3.00
10-Oct-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	2.80
11-Oct-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	2.80
12-Oct-99	4.90	9.005	17.561	20.152	1.407	5.054	0.931	2.90
13-Oct-99	5.00	9.146	17.752	20.550	1.419	5.127	0.938	2.90
14-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.90
15-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.90
16-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.90
17-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.80
18-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	3.20
19-Oct-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	3.20
20-Oct-99	4.70	8.724	17.179	19.356	1.384	4.908	0.917	3.10
21-Oct-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.90
22-Oct-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.80
23-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.80
24-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.80
25-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.70
26-Oct-99	4.20	8.021	10.100	11.500	0.929	4.540	0.630	2.70
27-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.80
28-Oct-99	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.70
29-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.70

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
30-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.70
31-Oct-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.70
01-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.60
02-Nov-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.40
03-Nov-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.50
04-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.60
05-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.50
06-Nov-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	2.50
07-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.50
08-Nov-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	2.40
09-Nov-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	2.40
10-Nov-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.40
11-Nov-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.50
12-Nov-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.50
13-Nov-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.40
14-Nov-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.40
15-Nov-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.40
16-Nov-99	3.70	7.318	10.300	10.700	0.942	4.170	0.639	2.30
17-Nov-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.20
18-Nov-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.00
19-Nov-99	5.10	9.287	17.943	20.948	1.430	5.200	0.945	1.80
20-Nov-99	4.50	8.443	16.798	18.561	1.361	4.761	0.902	1.80
21-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	1.70
22-Nov-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	1.60
23-Nov-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	1.50
24-Nov-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	1.60
25-Nov-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	1.80
26-Nov-99	4.80	8.865	17.370	19.754	1.396	4.981	0.924	2.00
27-Nov-99	4.30	8.162	16.417	17.765	1.338	4.614	0.888	2.20
28-Nov-99	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.20
29-Nov-99	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.20
30-Nov-99	4.00	7.740	15.846	16.571	1.303	4.392	0.866	2.40
01-Dec-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.50
02-Dec-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.30
03-Dec-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.20
04-Dec-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.00
05-Dec-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	1.80
06-Dec-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	1.90
07-Dec-99	3.80	7.459	11.500	16.000	1.024	4.244	0.691	2.20
08-Dec-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	1.90
09-Dec-99	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.10
10-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.10
11-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.20
12-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.10

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
13-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.10
14-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.20
15-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.20
16-Dec-99	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.40
17-Dec-99	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.30
18-Dec-99	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.30
19-Dec-99	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.20
20-Dec-99	3.50	7.037	14.896	14.582	1.244	4.021	0.829	2.20
21-Dec-99	3.60	7.177	15.086	14.980	1.255	4.096	0.836	2.30
22-Dec-99	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.40
23-Dec-99	3.60	7.177	15.086	14.980	1.255	4.096	0.836	2.30
24-Dec-99	3.60	7.177	15.086	14.980	1.255	4.096	0.836	2.30
25-Dec-99	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.30
26-Dec-99	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.30
27-Dec-99	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.30
28-Dec-99	3.00	6.333	13.948	12.593	1.184	3.647	0.791	2.40
29-Dec-99	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.40
30-Dec-99	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.30
31-Dec-99	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.30
01-Jan-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.20
02-Jan-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	2.20
03-Jan-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	2.10
04-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.20
05-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.20
06-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.10
07-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.10
08-Jan-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.10
09-Jan-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.10
10-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.00
11-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.00
12-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.10
13-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.00
14-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.00
15-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.10
16-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.10
17-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.20
18-Jan-00	3.20	6.615	9.410	10.800	0.881	3.797	0.599	2.10
19-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.00
20-Jan-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.90
21-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.10
22-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.00
23-Jan-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.90
24-Jan-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.80
25-Jan-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.60

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
26-Jan-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.80
27-Jan-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	1.90
28-Jan-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	1.90
29-Jan-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	1.90
30-Jan-00	3.60	7.177	15.086	14.980	1.255	4.096	0.836	1.90
31-Jan-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	1.90
01-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.90
02-Feb-00	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.00
03-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
04-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.80
05-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.90
06-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.90
07-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
08-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
09-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
10-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
11-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
12-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	2.00
13-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.90
14-Feb-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.90
15-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	2.00
16-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.90
17-Feb-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.90
18-Feb-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	1.80
19-Feb-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	1.90
20-Feb-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	1.80
21-Feb-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	1.80
22-Feb-00	2.90	6.193	9.400	12.700	0.880	3.572	0.599	1.90
23-Feb-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.10
24-Feb-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.10
25-Feb-00	6.30	10.974	20.244	25.722	1.566	6.071	1.029	1.80
26-Feb-00	12.00	18.990	31.346	48.399	2.175	10.091	1.402	1.60
27-Feb-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.60
28-Feb-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	1.70
29-Feb-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.90
01-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.00
02-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.00
03-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.20
04-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.30
05-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.40
06-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.50
07-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.50
08-Mar-00	7.70	12.943	22.944	31.291	1.721	7.074	1.125	2.30
09-Mar-00	2.70	5.912	13.381	11.399	1.147	3.422	0.768	1.90

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
10-Mar-00	2.70	5.912	13.381	11.399	1.147	3.422	0.768	2.00
11-Mar-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	2.20
12-Mar-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.20
13-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	2.30
14-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	2.20
15-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	2.20
16-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	2.30
17-Mar-00	2.70	5.912	13.381	11.399	1.147	3.422	0.768	2.50
18-Mar-00	2.70	5.912	13.381	11.399	1.147	3.422	0.768	2.60
19-Mar-00	2.70	5.912	13.381	11.399	1.147	3.422	0.768	2.70
20-Mar-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	2.80
21-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	3.40
22-Mar-00	2.80	6.052	13.570	11.797	1.159	3.497	0.776	5.10
23-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	5.20
24-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	5.70
25-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	5.60
26-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	5.90
27-Mar-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	6.70
28-Mar-00	3.20	6.615	19.100	13.389	1.499	3.797	0.988	7.70
29-Mar-00	3.20	6.615	14.327	19.500	1.208	3.797	0.806	7.90
30-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	6.70
31-Mar-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	5.90
01-Apr-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	5.90
02-Apr-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	5.50
03-Apr-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	5.30
04-Apr-00	3.10	6.474	14.000	13.000	1.187	3.722	0.793	10.00
05-Apr-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	9.80
06-Apr-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	8.40
07-Apr-00	3.80	7.459	15.466	15.776	1.279	4.244	0.851	8.00
08-Apr-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	9.50
09-Apr-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	9.80
10-Apr-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	10.00
11-Apr-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	9.90
12-Apr-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	11.00
13-Apr-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	13.00
14-Apr-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	12.00
15-Apr-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	11.00
16-Apr-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	12.00
17-Apr-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	12.00
18-Apr-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	12.00
19-Apr-00	7.20	12.240	21.978	29.302	1.666	6.717	1.091	33.00
20-Apr-00	6.40	11.115	20.436	26.120	1.577	6.143	1.036	18.00
21-Apr-00	6.50	11.255	20.629	26.517	1.588	6.215	1.043	18.00
22-Apr-00	5.20	9.427	18.135	21.345	1.442	5.273	0.952	27.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
23-Apr-00	4.90	9.005	17.561	20.152	1.407	5.054	0.931	46.00
24-Apr-00	26.00	38.678	59.838	104.096	3.536	19.511	2.212	79.00
25-Apr-00	94.00	134.305	222.950	374.628	9.504	61.849	5.598	66.00
26-Apr-00	51.00	73.835	115.039	203.556	5.780	35.524	3.509	64.00
27-Apr-00	28.00	41.491	64.050	112.053	3.722	20.823	2.321	54.00
28-Apr-00	14.00	21.803	35.310	56.355	2.379	11.470	1.524	46.00
29-Apr-00	7.00	11.959	21.592	28.507	1.644	6.574	1.077	41.00
30-Apr-00	5.20	9.427	18.135	21.345	1.442	5.273	0.952	35.00
01-May-00	5.00	9.146	17.752	20.550	1.419	5.127	0.938	29.00
02-May-00	4.80	8.865	17.370	19.754	1.396	4.981	0.924	26.00
03-May-00	4.80	8.865	17.370	19.754	1.396	4.981	0.924	24.00
04-May-00	4.80	8.865	17.370	19.754	1.396	4.981	0.924	21.00
05-May-00	4.70	8.724	17.179	19.356	1.384	4.908	0.917	18.00
06-May-00	5.00	9.146	17.752	20.550	1.419	5.127	0.938	17.00
07-May-00	10.00	16.177	27.418	40.442	1.967	8.698	1.275	22.00
08-May-00	4.90	9.005	17.561	20.152	1.407	5.054	0.931	18.00
09-May-00	4.70	8.724	36.400	52.600	2.434	4.908	1.558	15.00
10-May-00	7.80	13.084	23.138	31.689	1.731	7.145	1.131	16.00
11-May-00	12.00	18.990	31.346	48.399	2.175	10.091	1.402	43.00
12-May-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	33.00
13-May-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	30.00
14-May-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	28.00
15-May-00	5.40	9.709	18.517	22.141	1.465	5.419	0.967	25.00
16-May-00	5.90	10.412	19.476	24.130	1.521	5.782	1.002	22.00
17-May-00	10.00	16.177	27.418	40.442	1.967	8.698	1.275	29.00
18-May-00	7.20	12.240	33.400	36.800	2.282	6.717	1.466	26.00
19-May-00	7.20	12.240	21.978	29.302	1.666	6.717	1.091	23.00
20-May-00	7.40	12.521	22.364	30.098	1.688	6.860	1.104	25.00
21-May-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	21.00
22-May-00	6.00	10.552	19.668	24.528	1.532	5.854	1.009	20.00
23-May-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	19.00
24-May-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	18.00
25-May-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	17.00
26-May-00	7.00	11.959	21.592	28.507	1.644	6.574	1.077	29.00
27-May-00	7.40	12.521	22.364	30.098	1.688	6.860	1.104	23.00
28-May-00	5.80	10.271	19.284	23.733	1.510	5.709	0.995	23.00
29-May-00	5.90	10.412	19.476	24.130	1.521	5.782	1.002	22.00
30-May-00	7.40	12.521	22.364	30.098	1.688	6.860	1.104	21.00
31-May-00	6.10	10.693	19.860	24.926	1.544	5.926	1.016	19.00
01-Jun-00	6.00	10.552	19.668	24.528	1.532	5.854	1.009	18.00
02-Jun-00	6.10	10.693	19.860	24.926	1.544	5.926	1.016	16.00
03-Jun-00	6.40	11.115	20.436	26.120	1.577	6.143	1.036	15.00
04-Jun-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	14.00
05-Jun-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	13.00

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
06-Jun-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	12.00
07-Jun-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	11.00
08-Jun-00	6.50	11.255	20.629	26.517	1.588	6.215	1.043	10.00
09-Jun-00	6.90	11.818	21.399	28.109	1.633	6.502	1.071	9.60
10-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	8.90
11-Jun-00	6.70	11.537	21.014	27.313	1.611	6.359	1.057	8.50
12-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	8.20
13-Jun-00	7.00	11.959	21.592	28.507	1.644	6.574	1.077	8.70
14-Jun-00	7.40	12.521	22.364	30.098	1.688	6.860	1.104	9.50
15-Jun-00	9.00	14.771	25.467	36.463	1.861	7.995	1.210	11.00
16-Jun-00	7.30	12.381	22.171	29.700	1.677	6.788	1.098	9.40
17-Jun-00	6.90	11.818	21.399	28.109	1.633	6.502	1.071	8.50
18-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	7.40
19-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	6.80
20-Jun-00	6.70	11.537	21.014	27.313	1.611	6.359	1.057	7.20
21-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	6.60
22-Jun-00	6.60	11.396	20.821	26.915	1.599	6.287	1.050	5.80
23-Jun-00	11.00	17.584	29.378	44.420	2.072	9.397	1.339	5.60
24-Jun-00	8.20	13.646	23.913	33.281	1.775	7.429	1.158	8.00
25-Jun-00	11.00	17.584	29.378	44.420	2.072	9.397	1.339	9.20
26-Jun-00	6.50	11.255	20.629	26.517	1.588	6.215	1.043	6.60
27-Jun-00	9.00	14.771	25.467	36.463	1.861	7.995	1.210	8.00
28-Jun-00	6.50	11.255	20.629	26.517	1.588	6.215	1.043	7.00
29-Jun-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	5.70
30-Jun-00	6.10	10.693	19.860	24.926	1.544	5.926	1.016	5.20
01-Jul-00	6.00	10.552	19.668	24.528	1.532	5.854	1.009	5.00
02-Jul-00	6.00	10.552	19.668	24.528	1.532	5.854	1.009	4.90
03-Jul-00	5.60	9.990	18.900	22.937	1.487	5.564	0.981	4.70
04-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	4.20
05-Jul-00	5.60	9.990	18.900	22.937	1.487	5.564	0.981	4.20
06-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	4.20
07-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	4.00
08-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	3.90
09-Jul-00	5.90	10.412	19.476	24.130	1.521	5.782	1.002	4.00
10-Jul-00	7.20	12.240	21.978	29.302	1.666	6.717	1.091	4.70
11-Jul-00	6.80	11.677	21.206	27.711	1.622	6.430	1.064	4.60
12-Jul-00	5.60	9.990	18.900	22.937	1.487	5.564	0.981	3.60
13-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.50
14-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.50
15-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.60
16-Jul-00	7.40	12.521	22.364	30.098	1.688	6.860	1.104	8.50
17-Jul-00	6.10	10.693	19.860	24.926	1.544	5.926	1.016	5.50
18-Jul-00	5.80	10.271	19.284	23.733	1.510	5.709	0.995	4.60
19-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	4.10

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
20-Jul-00	5.80	10.271	19.284	23.733	1.510	5.709	0.995	4.00
21-Jul-00	7.10	12.099	21.785	28.904	1.655	6.645	1.084	4.40
22-Jul-00	5.90	10.412	19.476	24.130	1.521	5.782	1.002	5.50
23-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	3.80
24-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.40
25-Jul-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	3.20
26-Jul-00	5.40	9.709	18.517	22.141	1.465	5.419	0.967	3.00
27-Jul-00	5.40	9.709	18.517	22.141	1.465	5.419	0.967	2.70
28-Jul-00	5.70	10.130	19.092	23.335	1.499	5.637	0.988	2.80
29-Jul-00	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.60
30-Jul-00	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.50
31-Jul-00	5.00	9.146	17.752	20.550	1.419	5.127	0.938	2.40
01-Aug-00	14.00	21.803	35.310	56.355	2.379	11.470	1.524	2.50
02-Aug-00	19.00	28.834	45.375	76.247	2.872	14.861	1.820	3.30
03-Aug-00	5.50	9.849	18.709	22.539	1.476	5.492	0.974	2.70
04-Aug-00	5.10	9.287	17.943	20.948	1.430	5.200	0.945	2.60
05-Aug-00	5.00	9.146	17.752	20.550	1.419	5.127	0.938	2.80
06-Aug-00	4.70	8.724	17.179	19.356	1.384	4.908	0.917	2.50
07-Aug-00	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.50
08-Aug-00	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.40
09-Aug-00	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.40
10-Aug-00	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.30
11-Aug-00	4.40	8.302	16.607	18.163	1.349	4.687	0.895	2.30
12-Aug-00	4.20	8.021	16.226	17.367	1.326	4.540	0.881	2.30
13-Aug-00	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.20
14-Aug-00	4.10	7.880	16.036	16.969	1.314	4.466	0.873	2.10
15-Aug-00	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.10
16-Aug-00	3.90	7.599	15.656	16.174	1.291	4.318	0.859	2.20
17-Aug-00	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.10
18-Aug-00	3.80	7.459	15.466	15.776	1.279	4.244	0.851	2.10
19-Aug-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.00
20-Aug-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.00
21-Aug-00	3.60	7.177	15.086	14.980	1.255	4.096	0.836	1.90
22-Aug-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.00
23-Aug-00	3.50	7.037	14.896	14.582	1.244	4.021	0.829	2.00
24-Aug-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.90
25-Aug-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.90
26-Aug-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.80
27-Aug-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.80
28-Aug-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.80
29-Aug-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.80
30-Aug-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	1.80
31-Aug-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.00
01-Sep-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.80

Date	BB1	BB2	BB3	BB4	SC1	SC2	CC3	W125
02-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.70
03-Sep-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	1.70
04-Sep-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	1.70
05-Sep-00	2.90	6.193	13.759	12.195	1.172	3.572	0.784	1.70
06-Sep-00	3.00	6.333	13.948	12.593	1.184	3.647	0.791	1.70
07-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.70
08-Sep-00	3.10	6.474	0.750	12.991	0.132	3.722	0.101	1.70
09-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.70
10-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.70
11-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.70
12-Sep-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	1.60
13-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.70
14-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.60
15-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.70
16-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.60
17-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	1.70
18-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	1.70
19-Sep-00	3.60	7.177	15.086	14.980	1.255	4.096	0.836	2.00
20-Sep-00	3.70	7.318	15.276	15.378	1.267	4.170	0.844	2.20
21-Sep-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	2.00
22-Sep-00	6.20	10.834	20.052	25.324	1.555	5.999	1.022	2.50
23-Sep-00	4.50	8.443	16.798	18.561	1.361	4.761	0.902	2.40
24-Sep-00	3.60	7.177	15.086	14.980	1.255	4.096	0.836	2.50
25-Sep-00	3.40	6.896	14.706	14.184	1.232	3.947	0.821	2.60
26-Sep-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	2.50
27-Sep-00	3.30	6.755	14.516	13.787	1.220	3.872	0.814	2.30
28-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.20
29-Sep-00	3.20	6.615	14.327	13.389	1.208	3.797	0.806	2.10
30-Sep-00	3.10	6.474	14.137	12.991	1.196	3.722	0.799	2.10

Appendix B

Water Quality Sampling Data for Study Period
October 1998 – September 2000

Parameter abbreviations and units:

Abbreviation	Parameter	Units
Alka	Alkalinity	mg/L
DO	Dissolved Oxygen	mg/L
Flow	Streamflow	cfs
Fecal	Fecal Coliform	Colony Forming Units (CFU)/100 mL
Hard	Hardness	mg/L
ION	Inorganic Nitrogen	mg/L
NH4	Ammonia	mg/L
Nit	Nitrite + Nitrate	mg/L
N/P Ratio	Nitrogen/Phosphorous Ratio	
ON	Organic Nitrogen	mg/L
pH	pH	Standard Units
pka	pka	Standard Units
Sp Cond	Specific Conductivity	µmhos/cm
TDP	Total Dissolved Phosphorous	mg/L
TDS	Total Dissolved Solids	mg/L
TKN	Total Kjeldahl Nitrogen	mg/L
Tot N	Total Nitrogen	mg/L
Tot P	Total Phosphorous	mg/L
Tot S	Total Solids	mg/L
TSS	Total Suspended Solids	mg/L
Un-ion'd NH4	Unionized Ammonia	mg/L
% Un-Ion'd NH4	Percent Unionized Ammonia	percent
Water T	Water Temperature	°C

Water Quality Sampling Data for Water Year 1999

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
BB-1	6-Oct-98	10:40	7.3	196	250	1090	10.1	528	9.73	0.73	0.0001	0.0100	0.26	0.25	2.40	2.41	2.66	7.6		0.097	690	2	692	10.0	27
BB-2	6-Oct-98	13:46	17.0	151	3200	751	11.2	355	9.83	1.15	0.0001	0.0100	0.63	0.62	0.60	0.61	1.23	7.9		0.108	490	52	542	7.0	11
BB-3	7-Oct-98	10:35	48.0	105	2300	1040	12.4	450	9.89	0.51	0.0001	0.0100	1.38	1.37	0.30	0.31	1.68	7.6		0.358	753	200	953	5.5	5
BB-4	7-Oct-98	13:30	56.0	193	2000	1980	12.3	970	9.80	0.63	0.0001	0.0100	1.35	1.34	0.30	0.31	1.65	7.6		0.554	1589	384	1973	8.0	3
460-116	13-Oct-98			57		970	10.0	361	9.82	7.72	0.0154	0.2000	0.11	0.00	3.40	3.60	3.60	8.7		0.030	773	27	800	7.5	120
460-125	13-Oct-98			63		300	11.8	112	9.93	0.86	0.0001	0.0100	0.11	0.10	0.35	0.36	0.46	7.9		0.040	225	5	230	4.2	12
460-126	13-Oct-98			50		170	11.8	72	9.93	0.86	0.0001	0.0100	0.11	0.10	0.06	0.07	0.17	7.9		0.050	171	9	180	4.2	3
BB-1	17-Nov-98	9:30	14.0	209	20	941	11.9	473	9.85	0.35	0.0000	0.0100	0.26	0.25	2.10	2.11	2.36	7.4		0.013	632	2	634	6.5	182
BB-2	17-Nov-98	11:30	22.0	231	170	1250	13.3	629	9.89	1.02	0.0001	0.0100	0.38	0.37	0.70	0.71	1.08	7.9		0.023	874	10	884	5.5	47
BB-3	17-Nov-98	12:50	51.0	203	50	1710	14.1	784	9.94	0.90	0.0001	0.0100	0.67	0.66	0.50	0.51	1.17	7.9		0.058	1284	24	1308	4.0	20
BB-4	17-Nov-98	14:20	62.0	207	110	1890	13.6	809	9.94	1.13	0.0001	0.0100	0.73	0.72	0.50	0.51	1.23	8.0		0.086	1423	40	1463	4.0	14
460-116	19-Nov-98						12.1	269	9.85	0.44	0.0000	0.0100	0.11	0.10	0.10	0.11	0.21	7.5			666	1	667	6.6	
460-125	19-Nov-98						12.5	129	10.07	0.22	0.0000	0.0100	0.11	0.10	0.06	0.07	0.17	7.4			312	1	313	0.4	
460-126	19-Nov-98						13.2	91	10.07	0.66	0.0001	0.0100	0.11	0.10	0.06	0.07	0.17	7.9			86	7	93	0.4	
460-116	15-Dec-98						11.8	609	9.81	0.92	0.0001	0.0100	0.11	0.10	0.10	0.11	0.21	7.8			3600	1	3601	7.6	
460-125	15-Dec-98						13.2	155	10.08	0.22	0.0000	0.0100	0.11	0.10	0.06	0.07	0.17	7.4			530	1	531	0.1	
460-126	15-Dec-98						13.9	101	10.08	0.66	0.0001	0.0100	0.11	0.10	0.06	0.07	0.17	7.9			216	1	217	0.1	
BB-1	15-Dec-98	9:30	6.5	260	5	1120	12.3	601	9.87	0.27	0.0000	0.0100	0.37	0.36	3.10	3.11	3.47	7.3		0.007	772	4	776	6.0	496
BB-2	15-Dec-98	11:15	10.0	249	40	1360	15.2	679	10.01	0.39	0.0000	0.0100	0.38	0.37	0.90	0.91	1.28	7.6		0.009	970	5	975	2.0	142
BB-3	15-Dec-98	12:50	20.0	251	60	2000	16.4	1002	10.03	0.47	0.0000	0.0100	0.56	0.55	1.10	1.11	1.66	7.7		0.024	1565	10	1575	1.5	69
BB-4	15-Dec-98	14:30	22.0	244	5	2080	16.5	990	10.08	0.52	0.0001	0.0100	0.53	0.52	1.00	1.01	1.53	7.8		0.021	1608	14	1622	0.0	73
460-116	19-Jan-99			56		1210	11.5	313	10.08	0.05	0.0002	0.4000	0.11	0.00	1.26	1.66	1.66	6.8	0.002	0.002	849	15	864	0.0	830
460-125	19-Jan-99			96		314	12.6	142	10.08	0.93	0.0001	0.0100	0.11	0.10	0.23	0.24	0.34	8.1		0.010	204	1	205	0.2	34
460-126	19-Jan-99			100		248	12.7	123	10.06	0.72	0.0001	0.0100	0.11	0.10	0.15	0.16	0.26	7.9		0.020	153	5	158	0.6	13
BB-1	25-Jan-99	11:25	4.8	245	5	1160	12.5	605	9.92	0.75	0.0001	0.0100	0.11	0.10	3.00	3.01	3.11	7.8		0.012	772	2	774	4.5	259
BB-2	25-Jan-99	13:00	8.4	279	30	1580	12.4	800	10.08	0.52	0.0001	0.0100	0.12	0.11	0.90	0.91	1.02	7.8		0.015	1091	3	1094	0.0	68
BB-3	26-Jan-99	8:55	15.0	283	230	2160	12.1	1100	10.08	0.41	0.0000	0.0100	0.34	0.33	1.30	1.31	1.64	7.7		0.018	1659	4	1663	0.0	91
BB-4	26-Jan-99	11:25	14.0	279	5	2360	13.5	1122	10.08	0.82	0.0001	0.0100	0.48	0.47	1.20	1.21	1.68	8.0		0.025	1824	12	1836	0.0	67
BB-1	10-Feb-99	9:15	4.3	262	5	1160	13.7		9.89	0.81	0.0001	0.0100	0.28	0.27	2.90	2.91	3.18	7.8		0.007	791	1	792	5.5	454
BB-2	10-Feb-99	10:55	6.6	269	40	1490	14.5	728	9.98	0.83	0.0001	0.0100	0.41	0.40	0.70	0.71	1.11	7.9		0.019	1057	6	1063	3.0	58
BB-3	10-Feb-99	12:30	18.0	214	100	2090	13.8	991	9.99	1.00	0.0001	0.0100	0.46	0.45	1.00	1.01	1.46	8.0		0.024	1574	9	1583	2.5	61
BB-4	10-Feb-99	14:05	21.0	216	40	2220	12.4	942	10.08	1.03	0.0001	0.0100	0.50	0.49	0.80	0.81	1.30	8.1		0.057	1624	30	1654	0.0	23
460-116	23-Feb-99						10.6	310	10.08	0.03	0.0001	0.3000	1.10	0.80	1.82	2.12	2.92	6.5	0.010	0.010	586	14	600	0.1	292
460-125	23-Feb-99						13.1	132	10.08	0.75	0.0001	0.0100	0.50	0.49	0.22	0.23	0.72	8.0	0.002	0.010	202	1	203	0.1	72
460-126	23-Feb-99						12.5	122	10.08	0.73	0.0001	0.0100	0.50	0.49	0.14	0.15	0.64	8.0	0.002	0.020	162	1	163	0.0	32
BB-1	9-Mar-99	9:15	3.8	221	5	1150	13.3	580	9.96	0.55	0.0001	0.0100	0.18	0.17	2.80	2.81	2.98	7.7		0.005	740	2	742	3.5	596
BB-2	9-Mar-99	11:05	6.3	247	10	1530	16.3	750	10.03	0.47	0.0000	0.0100	0.39	0.38	0.70	0.71	1.09	7.7		0.017	1068	3	1071	1.5	64
BB-3	9-Mar-99	12:45	18.0	238	10	2200	14.3	1070	10.01	0.77	0.0001	0.0100	0.48	0.47	0.80	0.81	1.28	7.9		0.026	1683	8	1691	2.0	49
BB-4	9-Mar-99	14:35	20.0	218	5	2310	14.2	1000	9.98	1.05	0.0001	0.0100	0.56	0.55	0.60	0.61	1.16	8.0		0.029	1727	15	1742	3.0	40
460-116	23-Mar-99						11.2	220	9.92	0.52	0.0001	0.0100	0.11	0.10	0.18	0.19	0.29	7.6	0.050	0.290	324	6	330	4.6	1
460-125	23-Mar-99						12.3	82	10.04	0.35	0.0000	0.0100	0.11	0.10	0.18	0.19	0.29	7.6	0.080	0.100	118	7	125	1.2	3

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
460-126	23-Mar-99						12.4	71	10.02	0.29	0.0000	0.0100	0.11	0.10	0.16	0.17	0.27	7.5	0.080	0.100	108	6	114	1.8	3
BB-1	6-Apr-99	9:00	4.3	236	5	1130	12.3	596	9.89	0.81	0.0001	0.0100	0.24	0.23	2.60	2.61	2.84	7.8		0.004	746	2	748	5.5	710
BB-2	6-Apr-99	10:55	20.0	278	540	1730	11.2	881	9.89	1.28	0.0001	0.0100	0.48	0.47	0.40	0.41	0.88	8.0		0.045	1663	32	1695	5.5	20
BB-3	6-Apr-99	12:20	69.0	219	660	2110	10.7	914	9.85	1.39	0.0001	0.0100	1.05	1.04	0.20	0.21	1.25	8.0		0.174	1589	130	1719	6.5	7
BB-4	6-Apr-99	14:00	107.0	212	780	2150	9.6	786	9.78	2.03	0.0002	0.0100	0.96	0.95	0.30	0.31	1.26	8.1		0.317	1321	416	1737	8.5	4
BB-1	21-Apr-99	10:40	4.7	219	5	1010	11.0	511	9.77	1.34	0.0001	0.0100	0.34	0.33	2.20	2.21	2.54	7.9		0.010	657	7	664	9.0	254
BB-2	21-Apr-99	11:44	15.0	252	5	1530	10.1	748	9.73	1.16	0.0001	0.0100	0.47	0.46	0.60	0.61	1.07	7.8		0.021	1067	17	1084	10.0	51
BB-3	21-Apr-99	12:35	29.0	238	5	2140	10.6	1011	9.70	2.46	0.0002	0.0100	0.67	0.66	0.40	0.41	1.07	8.1		0.049	1598	25	1623	11.0	22
BB-4	21-Apr-99	13:33	42.0	248	5	2620	10.8	1024	9.70	2.46	0.0002	0.0100	0.66	0.65	0.40	0.41	1.06	8.1		0.069	1945	54	1999	11.0	15
460-116	28-Apr-99			54		653	10.2	285	9.83	1.02	0.0001	0.0100	0.11	0.10	0.31	0.32	0.42	7.8	0.030	0.070	475	21	496	7.2	6
460-125	28-Apr-99			53		153	11.3	82	9.88	1.19	0.0001	0.0100	0.11	0.10	0.06	0.07	0.17	8.0	0.030	0.260	115	9	124	5.7	1
460-126	28-Apr-99			53		129	10.9	66	9.87	1.75	0.0002	0.0100	0.11	0.10	0.06	0.07	0.17	8.1	0.040	0.150	101	13	114	6.0	1
BB-1	10-May-99	9:00	6.6	188	90	843	7.9	435	9.80	0.32	0.0000	0.0100	0.26	0.25	2.10	2.11	2.36	7.3		0.072	559	7	566	8.0	33
BB-2	10-May-99	11:30	16.0	254	1400	1470	5.4	732	9.78	1.29	0.0001	0.0100	0.44	0.43	0.80	0.81	1.24	7.9		0.031	1044	17	1061	8.5	40
BB-3	10-May-99	13:10	32.0	243	1100	2020	4.9	976	9.77	1.69	0.0002	0.0100	0.55	0.54	0.70	0.71	1.25	8.0		0.014	1525	28	1553	9.0	89
BB-4	10-May-99	14:45	37.0	244	220	2410	5.3	1004	9.77	2.11	0.0002	0.0100	0.59	0.58	0.60	0.61	1.19	8.1		0.051	1851	52	1903	9.0	23
460-116	26-May-99				1		9.1	331	9.67	0.55	0.0001	0.0100	0.60	0.59	3.64	3.65	4.24	7.4	0.002	0.050	1100	1	1101	11.8	85
460-125	26-May-99				1		10.3	120	9.77	1.89	0.0002	0.0100	0.11	0.10	0.45	0.46	0.56	8.1	0.020	0.040	330	1	331	9.0	14
460-126	26-May-99				10		10.2	79	9.76	2.21	0.0002	0.0100	0.11	0.10	0.46	0.47	0.57	8.1	0.030	0.030	126	14	140	9.3	19
BB-1	9-Jun-99	9:15	7.4	235	2100	1090	9.3	580	9.66	2.12	0.0002	0.0100	0.19	0.18	2.70	2.71	2.89	8.0		0.018	741	4	745	12.0	161
BB-2	9-Jun-99	11:00	17.0	274	4300	1730	8.2	801	9.52	3.70	0.0004	0.0100	0.71	0.70	0.80	0.81	1.51	8.1		0.080	1259	46	1305	16.5	19
BB-3	9-Jun-99	12:45	80.0	214	1200	1870	7.5	811	9.45	4.27	0.0004	0.0100	1.10	1.09	0.30	0.31	1.40	8.1		0.424	1400	256	1656	18.5	3
BB-4	9-Jun-99	14:30	119.0	215	400	1930	8.2	754	9.37	6.32	0.0006	0.0100	1.17	1.16	0.20	0.21	1.37	8.2		0.576	1426	440	1866	21.0	2
BB-1	15-Jun-99	7:55	92.0	118	1900	438	6.4	189	9.66	1.35	0.0001	0.0100	0.56	0.55	0.60	0.61	1.16	7.8		0.154	236	51	287	12.0	8
BB-2	15-Jun-99	9:40	123.0	179	2100	755	7.8	349	9.61	2.38	0.0002	0.0100	0.83	0.82	0.60	0.61	1.43	8.0		0.200	478	148	626	13.5	7
BB-3	15-Jun-99	11:05	193.0	203	900	1240	7.3	556	9.53	1.95	0.0002	0.0100	1.31	1.30	0.50	0.51	1.81	7.8		0.372	840	274	1114	16.0	5
BB-4	15-Jun-99	13:50	265.0	211	1100	1410	5.1	570	9.47	6.81	0.0007	0.0100	1.25	1.24	0.60	0.61	1.85	8.3		0.676	985	552	1537	18.0	3
460-116	22-Jun-99				1		9.2	341	9.66	0.70	0.0001	0.0100	0.11	0.10	1.90	1.91	2.01	7.5	0.020	0.090	543	7	550	12.0	22
460-125	22-Jun-99				135		9.2	93	9.67	1.49	0.0001	0.0100	4.10	4.09	0.05	0.06	4.15	7.9	0.040	0.040	110	12	122	11.8	104
460-126	22-Jun-99				160		9.3	82	9.68	1.13	0.0001	0.0100	1.30	1.29	0.05	0.06	1.35	7.7	0.040	0.050	103	15	118	11.5	27
BB-1	19-Jul-99	7:03	9.9	267	110	1200	8.5	640	9.60	0.50	0.0001	0.0100	0.19	0.18	3.90	3.91	4.09	7.3		0.013	835	2	837	14.0	315
BB-2	19-Jul-99	9:25	14.0	263	430	1380	6.9	694	9.42	1.88	0.0002	0.0100	0.37	0.36	1.30	1.31	1.67	7.7		0.042	991	21	1012	19.5	40
BB-3	19-Jul-99	10:50	30.0	213	460	2000	6.0	1007	9.36	2.71	0.0003	0.0100	0.75	0.74	0.90	0.91	1.65	7.8		0.062	1507	34	1541	21.5	27
BB-4	19-Jul-99	12:10	3.2	204	150	2070	6.1	955	9.29	3.89	0.0004	0.0100	0.40	0.39	0.70	0.71	1.10	7.9		0.059	1571	42	1613	23.5	19
460-116	20-Jul-99			95	1	462	9.3	196	9.60	0.72	0.0007	0.1000	0.11	0.01	0.23	0.33	0.34	7.5	0.020	0.040	404	1	405	13.9	9
460-125	20-Jul-99			102	115	290	9.2	122	9.63	2.27	0.0002	0.0100	0.11	0.10	0.06	0.07	0.17	8.0	0.050	0.060	234	1	235	12.9	3
460-126	20-Jul-99			98	130	253	9.5	111	9.62	2.86	0.0003	0.0100	0.11	0.10	0.06	0.07	0.17	8.1	0.030	0.120	177	5	182	13.3	1
460-116	3-Aug-99				6		7.5	944	9.43	0.49	0.0141	2.9000	3.20	0.30	33.00	35.90	36.20	7.1	0.002	0.002	6145	5	6150	19.1	18100
460-125	3-Aug-99				55		8.3	200	9.41	7.17	0.0007	0.0100	0.11	0.10	3.25	3.26	3.36	8.3	0.030	0.040	566	1	567	19.7	84
460-126	3-Aug-99				60		9.2	116	9.41	8.68	0.0009	0.0100	0.11	0.10	0.67	0.68	0.78	8.4	0.020	0.050	132	1	133	19.7	16
BB-1	16-Aug-99	8:40	7.4	272	220	1210	9.0	690	9.60	0.79	0.0001	0.0100	0.25	0.24	3.60	3.61	3.85	7.5		0.006	838	4	842	14.0	642

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
BB-2	16-Aug-99	10:25	6.8	247	380	1430	8.2	742	9.45	1.75	0.0002	0.0100	0.50	0.49	0.90	0.91	1.40	7.7		0.037	1026	25	1051	18.5	38
BB-3	16-Aug-99	11:45	12.0	216	260	2090	8.7	1080	9.40	3.05	0.0003	0.0100	0.65	0.64	0.80	0.81	1.45	7.9		0.048	1625	31	1656	20.0	30
BB-4	16-Aug-99	12:55	12.0	192	40	2090	8.9	1040	9.31	4.69	0.0005	0.0100	0.54	0.53	0.50	0.51	1.04	8.0		0.052	1650	36	1686	23.0	20
BB-1	14-Sep-99	9:10	6.2	250	80	1230	8.9	670	9.68	0.52	0.0001	0.0100	0.18	0.17	3.40	3.41	3.58	7.4		0.005	838	1	839	11.5	716
BB-2	14-Sep-99	11:00	5.2	231	190	1470	11.3	744	9.70	0.63	0.0001	0.0100	0.29	0.28	0.80	0.81	1.09	7.5		0.020	1046	16	1062	11.0	55
BB-3	14-Sep-99	12:45	9.6	225	70	2170	10.7	1056	9.66	1.35	0.0001	0.0100	0.51	0.50	1.00	1.01	1.51	7.8		0.026	1717	21	1738	12.0	58
BB-4	14-Sep-99	14:30	7.9	199	60	2250	9.0	1052	9.55	1.40	0.0001	0.0100	0.41	0.40	0.60	0.61	1.01	7.7		0.028	1766	24	1790	15.5	36
460-116	20-Sep-99				4		8.0	946	9.62	0.13	0.0021	1.6000	1.50	0.00	28.10	29.70	29.70	6.7	0.002	0.002	8022	8	8030	13.3	14850
460-125	20-Sep-99				30		10.9	206	9.99	0.47	0.0000	0.0100	0.11	0.10	1.40	1.41	1.51	7.7	0.010	0.010	910	1	911	2.5	151
460-126	20-Sep-99				66		10.7	101	9.98	0.52	0.0001	0.0100	0.11	0.10	0.06	0.07	0.17	7.7	0.002	0.060	143	5	148	2.8	3

Water Quality Sampling Data for Water Year 2000

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
460-116	25-Oct-99						8.6		9.67									7.0						11.8	
460-125	25-Oct-99						11.2		9.81									8.6						7.6	
460-126	25-Oct-99						10.9		9.80									8.3						8.1	
BB-1	26-Oct-99	9:10	4.2	248	5	1220	9.7	658	9.75	0.71	0.0001	0.0100	0.11	0.10	3.30	3.31	3.41	7.6		0.002	814	1	815	9.5	1705
BB-2	26-Oct-99	10:50	5.6	252	10	1530	10.9	772	9.80	0.79	0.0001	0.0100	0.27	0.26	0.60	0.61	0.87	7.7		0.021	1081	11	1092	8.0	41
BB-3	26-Oct-99	12:20	10.0	237	30	2240	11.7	1100	9.80	1.56	0.0002	0.0100	0.36	0.35	0.70	0.71	1.06	8.0		0.020	1745	9	1754	8.0	53
BB-4	26-Oct-99	13:45	12.0	214	5	2350	11.6	1079	9.77	2.11	0.0002	0.0100	0.38	0.37	0.50	0.51	0.88	8.1		0.011	1843	6	1849	9.0	80
BB-1	16-Nov-99	8:50	3.8	281	10	1200	11.2	653	9.78	0.82	0.0001	0.0100	0.15	0.14	3.40	3.41	3.55	7.7		0.002	830	2	832	8.5	1775
BB-2	16-Nov-99	10:25	5.7	266	50	1510	11.7	775	9.89	0.65	0.0001	0.0100	0.26	0.25	0.70	0.71	0.96	7.7		0.014	1105	7	1112	5.5	69
BB-3	16-Nov-99	11:55	10.0	257	280	2180	13.5	1091	9.90	0.98	0.0001	0.0100	0.45	0.44	0.80	0.81	1.25	7.9		0.014	1727	9	1736	5.0	89
BB-4	16-Nov-99	13:25	11.0	235	5	2300	11.9	1090	9.89	1.61	0.0002	0.0100	0.39	0.38	0.60	0.61	0.99	8.1		0.009	1835	4	1839	5.5	110
460-116	17-Nov-99						9.0	1200	9.77	0.10	0.0011	1.1000	0.11	0.00	21.80	22.90	22.90	6.8	0.002	0.002	8955	15	8970	9.0	11450
460-125	17-Nov-99						12.3	350	10.05	1.07	0.0001	0.0100	0.11	0.10	3.90	3.91	4.01	8.1	0.002	0.002	1790	1	1791	1.0	2005
460-126	17-Nov-99						12.3	133	10.04	1.27	0.0001	0.0100	0.11	0.10	0.11	0.12	0.22	8.2	0.010	0.020	196	1	197	1.2	11
BB-1	7-Dec-99	9:00	3.9	248	12	1210	11.8	641	9.85	0.18	0.0000	0.0100	0.20	0.19	3.40	3.41	3.60	7.1		0.008	805	3	808	6.5	450
BB-2	7-Dec-99	10:50	5.5	249	100	1570	14.0	778	10.05	0.22	0.0000	0.0100	0.24	0.23	0.90	0.91	1.14	7.4		0.009	1091	6	1097	1.0	127
BB-3	7-Dec-99	12:05	12.0	243	270	2220	14.5	1059	10.08	0.33	0.0000	0.0100	0.39	0.38	1.10	1.11	1.49	7.6		0.018	1635	14	1649	0.0	83
BB-4	7-Dec-99	13:40	16.0	236	26	2400	13.2	1092	10.07	0.43	0.0000	0.0100	0.41	0.40	0.80	0.81	1.21	7.7		0.020	1829	14	1843	0.5	61
460-116	15-Dec-99						10.1	1240	10.08	0.04	0.0005	1.2900	0.11	0.00	21.60	22.89	22.89	6.7	0.002	0.002	8916	14	8930		11445
460-125	15-Dec-99						12.0	299	10.06	0.59	0.0001	0.0100	0.11	0.10	3.34	3.35	3.45	7.8	0.002	0.020	1470	1	1471	0.7	173
460-126	15-Dec-99						12.1	113	10.05	0.60	0.0001	0.0100	0.11	0.10	0.13	0.14	0.24	7.8	0.030	0.030	189	3	192	0.9	8
460-116	18-Jan-00			10		6790	10.5	1370	9.94	0.09	0.0011	1.2000	1.50	0.30	15.20	16.40	16.70	6.9	0.002	0.020	6691	9	6700	3.9	835
460-125	18-Jan-00			92		1830	12.2	355	10.06	0.88	0.0001	0.0100	0.60	0.59	3.18	3.19	3.78	8.0	0.020	0.020	1350	1	1351	0.6	189
460-126	18-Jan-00			120		289	12.3	132	10.06	1.54	0.0002	0.0100	0.11	0.10	0.15	0.16	0.26	8.3	0.030	0.050	172	1	173	0.8	5
BB-1	18-Jan-00	9:05	3.5	268	1	1200	10.0	644	9.94	0.90	0.0001	0.0100	0.11	0.10	3.20	3.21	3.31	7.9		0.006	820	2	822	4.0	552
BB-2	18-Jan-00	11:05	4.6	275	4	1660	12.1	822	10.08	0.65	0.0001	0.0100	0.32	0.31	0.90	0.91	1.22	7.9		0.006	1153	1	1154	0.0	203

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
BB-3	18-Jan-00	12:55	9.4	295	36	2400	13.0	1163	10.08	0.82	0.0001	0.0100	0.44	0.43	1.30	1.31	1.74	8.0		0.016	1829	12	1841	0.0	109
BB-4	18-Jan-00	14:25	11.0	281	12	2540	14.2	1166	10.08	1.03	0.0001	0.0100	0.45	0.44	1.10	1.11	1.55	8.1		0.005	1943	6	1949	0.0	310
460-116	9-Feb-00						10.4	400	9.91	0.05	0.0000	0.0100	1.20	1.19	4.03	4.04	5.23	6.7	0.060	0.480	720	156	876	4.8	11
460-125	9-Feb-00						12.5	450	10.06	0.69	0.0001	0.0100	0.11	0.10	5.30	5.31	5.41	7.9	0.050	0.050	837	9	846	0.8	108
460-126	9-Feb-00						12.2	460	10.05	1.07	0.0001	0.0100	0.11	0.10	6.25	6.26	6.36	8.1	0.050	0.080	838	1	839	1.0	80
BB-1	22-Feb-00	8:45	2.9	230	2	1200	11.0	624	9.89	0.81	0.0001	0.0100	0.11	0.10	2.90	2.91	3.01	7.8		0.008	791	3	794	5.5	376
BB-2	22-Feb-00	10:30	4.5	234	10	1610	12.7	774	10.03	0.74	0.0001	0.0100	0.33	0.32	0.70	0.71	1.03	7.9		0.010	1103	5	1108	1.5	103
BB-3	22-Feb-00	12:00	9.4	225	1	2210	13.6	1030	10.01	1.21	0.0001	0.0100	0.44	0.43	1.10	1.11	1.54	8.1		0.024	1638	16	1654	2.0	64
BB-4	22-Feb-00	13:30	13.0	211	1	2280	14.5	971	10.07	1.34	0.0001	0.0100	0.33	0.32	0.90	0.91	1.23	8.2		0.022	1669	18	1687	0.5	56
460-116	6-Mar-00						10.0	930	9.87	0.09	0.0007	0.8000	1.50	0.70	14.50	15.30	16.00	6.8	0.010	0.010	6620	10	6630	5.9	1600
460-125	6-Mar-00						12.1	190	10.04	0.72	0.0001	0.0100	0.60	0.59	1.45	1.46	2.05	7.9	0.030	0.050	727	5	732	1.3	41
460-126	6-Mar-00						11.9	96	10.04	0.56	0.0001	0.0100	0.11	0.10	0.14	0.15	0.25	7.8	0.030	0.050	144	1	145	1.2	5
CC-3	13-Mar-00	11:30	1.4	290	5		11.8		9.89	0.11	0.0000	0.0100	0.36	0.35	0.10	0.11	0.46	6.9	0.008	0.023	1806	3	1809	5.3	20
SC-1	13-Mar-00	14:45	1.1	242	5		13.8		9.84	0.08	0.0000	0.0100	0.51	0.50	1.00	1.01	1.51	6.8	0.008	0.025	2504	10	2514	6.8	60
SC-2	13-Mar-00	10:00		188	40				10.08	0.00	0.0000	0.0100	0.86	0.85	0.50	0.51	1.36		0.016	0.115	2164	39	2203		12
CC-3	21-Mar-00	10:55	1.5	308	5		13.2		9.90	0.13	0.0000	0.0100	0.37	0.36	0.10	0.11	0.47	7.0	0.008	0.022	1880	10	1890	5.0	21
SC-1	21-Mar-00	12:05	0.7	252	5		13.8		9.87	0.00	0.0000	0.0100	0.53	0.52	0.80	0.81	1.33	5.1	0.014	0.017	2487	9	2496	6.0	78
SC-2	21-Mar-00	9:00	3.9	182	190		12.7		9.94	0.88	0.0001	0.0100	0.66	0.65	0.30	0.31	0.96	7.9	0.008	0.039	2247	48	2295	4.0	25
BB-1	28-Mar-00	9:00	3.2	232	5	1190	12.2	645	9.87	0.67	0.0001	0.0100	0.11	0.10	2.80	2.81	2.91	7.7		0.005	795	1	796	6.0	582
BB-2	28-Mar-00	11:30	7.5	235	240	1650	10.6	839	9.85	1.10	0.0001	0.0100	0.45	0.44	0.50	0.51	0.95	7.9		0.032	1190	14	1204	6.5	30
BB-3	28-Mar-00	14:00	19.0	232	5	2130	10.8	998	9.78	2.55	0.0003	0.0100	0.58	0.57	0.30	0.31	0.88	8.2		0.074	1666	39	1705	8.5	12
BB-4	29-Mar-00	10:00	20.0	221	5	2240	11.2	1010	9.82	2.36	0.0002	0.0100	0.66	0.65	0.10	0.11	0.76	8.2		0.042	1717	31	1748	7.5	18
BB-1	4-Apr-00	8:55	3.0	251	10	1190	10.7	649	9.90	0.49	0.0000	0.0100	0.27	0.26	2.90	2.91	3.17	7.6		0.001	807	3	810	5.0	3170
BB-2	4-Apr-00	10:35	6.3	256	1100	1620	11.0	811	9.92	0.94	0.0001	0.0100	0.44	0.43	0.50	0.51	0.94	7.9		0.020	1165	9	1174	4.5	47
BB-3	4-Apr-00	12:00	14.0	242	30	2200	12.2	1070	9.89	1.28	0.0001	0.0100	0.58	0.57	0.50	0.51	1.08	8.0		0.041	1679	23	1702	5.5	26
BB-4	4-Apr-00	13:30	13.0	220	5	2300	11.4	1060	9.80	1.96	0.0002	0.0100	0.52	0.51	0.20	0.21	0.72	8.1		0.022	1806	12	1818	8.0	33
CC-3	17-Apr-00	13:30	1.0		10		9.2		9.82	0.09	0.0000	0.0100	0.40	0.39	0.10	0.11	0.50	6.8	0.001	0.025				7.5	20
SC-1	17-Apr-00	13:30	0.8		5		10.7		9.73	0.09	0.0000	0.0100	0.66	0.65	0.70	0.71	1.36	6.7	0.001	0.021				10.0	65
SC-2	17-Apr-00	13:30	2.4		380		11.9		9.87	0.15	0.0000	0.0100	0.54	0.53	0.50	0.51	1.04	7.1	0.001	0.040				6.0	26
CC-3	21-Apr-00	10:10	2.1	239			10.1		9.83	0.04	0.0000	0.0100	0.81	0.80	0.10	0.11	0.91	6.5	0.024	0.115	1798	44	1842	7.3	8
SC-1	21-Apr-00	11:40	1.0	241			10.1		9.73	0.10	0.0000	0.0300	0.73	0.70	0.80	0.83	1.53	6.7	0.013	0.047	2281	17	2298	10.0	33
SC-2	21-Apr-00	9:15		232			10.1		9.83	0.02	0.0000	0.0100	0.86	0.85	0.20	0.21	1.06	6.1	0.019	0.742	2213	584	2797	7.0	1
460-116	25-Apr-00			29		760	10.3	310	9.89	1.19	0.0001	0.0100	0.11	0.10	2.01	2.02	2.12	8.0	0.020	0.050	563	37	600	5.4	42
460-125	25-Apr-00			37		218	11.1	70	9.99	1.02	0.0001	0.0100	0.11	0.10	0.56	0.57	0.67	8.0	0.070	0.170	162	68	230	2.7	4
460-126	25-Apr-00			33		101	11.1	42	9.99	2.34	0.0002	0.0100	0.11	0.10	0.14	0.15	0.25	8.4	0.050	0.190	98	72	170	2.6	1
BB-1	9-May-00	9:00	4.6	220	120	1120	12.2	611	9.78	1.48	0.0001	0.0100	0.29	0.28	2.80	2.81	3.09	8.0		0.009	737	5	742	8.5	343
BB-2	9-May-00	10:30	16.0	236	250	1460	11.3	743	9.70	3.08	0.0003	0.0100	0.48	0.47	0.70	0.71	1.18	8.2		0.031	1061	15	1076	11.0	38
BB-3	9-May-00	12:15	36.0	236	470	2020	10.4	954	9.61	4.63	0.0005	0.0100	0.74	0.73	0.40	0.41	1.14	8.3		0.133	1541	102	1643	13.5	9
BB-4	9-May-00	13:45	53.0	234	600	2120	10.4	879	9.58	6.19	0.0006	0.0100	0.94	0.93	0.30	0.31	1.24	8.4		0.187	1588	118	1706	14.5	7
460-116	15-May-00				1		9.2	520	9.73	0.96	0.0038	0.4000	1.20	0.80	26.70	27.10	27.90	7.7	0.002	0.030	2584	16	2600	9.9	930
460-125	15-May-00				1		10.7	84	9.82	3.13	0.0003	0.0100	0.11	0.10	0.94	0.95	1.05	8.3	0.030	0.060	216	6	222	7.4	18
460-126	15-May-00				10		10.4	56	9.83	2.35	0.0002	0.0100	0.11	0.10	0.06	0.07	0.17	8.2	0.030	0.070	121	5	126	7.2	2
BB-1	18-May-00	9:00	7.7	215	540	885	12.8	468	9.80	1.56	0.0002	0.0100	0.30	0.29	2.10	2.11	2.40	8.0		0.015	588	3	591	8.0	160

Station	Date	Time	Flow	Alka	Fecal	Sp Cond	DO	Hard	pka	% Un-ion'd NH4	Un-ion'd NH4	NH4	TKN	ON	Nit	ION	Tot N	pH	TDP	Tot P	TDS	TSS	Tot S	Water T	N/P Ratio
BB-2	18-May-00	11:00	19.0	255	650	1440	10.5	733	9.73	3.57	0.0004	0.0100	0.54	0.53	0.70	0.71	1.24	8.3		0.037	1047	33	1080	10.0	34
BB-3	18-May-00	12:30	33.0	236	380	2010	10.4	944	9.66	4.15	0.0004	0.0100	0.93	0.92	0.50	0.51	1.43	8.3		0.104	1538	63	1601	12.0	14
BB-4	18-May-00	14:00	37.0	237	160	2220	10.6	950	9.58	7.67	0.0008	0.0100	0.90	0.89	0.40	0.41	1.30	8.5		0.109	1710	70	1780	14.5	12
CC-3	18-May-00	9:30	1.8	325	720		10.2		9.75	0.08	0.0000	0.0100	0.54	0.53	0.10	0.11	0.64	6.7	0.010	0.037	1827	22	1849	9.5	17
SC-1	18-May-00	11:05	1.0	260	2500		10.5		9.70	0.28	0.0000	0.0100	0.85	0.84	0.70	0.71	1.55	7.2	0.007	0.027	2455	21	2476	11.0	57
SC-2	18-May-00	8:45	3.4	223	250		9.6		9.66	0.16	0.0000	0.0100	1.06	1.05	0.50	0.51	1.56	6.9	0.020	0.074	2405	60	2465	12.0	21
CC-3	30-May-00	10:45	1.2	310	190		8.3		9.60	0.79	0.0001	0.0100	0.21	0.20	0.10	0.11	0.31	7.5	0.001	0.020	1844	14	1858	14.0	16
SC-1	30-May-00	12:00	1.2	261	800		8.9		9.63	0.77	0.0005	0.0600	0.45	0.39	0.60	0.66	1.05	7.5	0.001	0.050	2333	22	2355	13.0	21
SC-2	30-May-00	9:15	3.0	195	850		8.3		9.53	2.23	0.0002	0.0100	0.60	0.59	0.60	0.61	1.20	7.9	0.001	0.141	2365	70	2435	16.0	9
460-116	6-Jun-00				2		8.0	670	9.51	0.78	0.0039	0.5000	0.60	0.10	38.30	38.80	38.90	7.4	0.010	0.020	3556	14	3570	16.6	1945
460-125	6-Jun-00				1		9.5	120	9.47	23.75	0.0024	0.0100	0.60	0.59	2.25	2.26	2.85	9.0	0.030	0.040	332	1	333	18.0	71
460-126	6-Jun-00				1		8.9	71	9.44	14.21	0.0014	0.0100	0.11	0.10	0.06	0.07	0.17	8.7	0.040	0.060	110	1	111	18.8	3
CC-3	13-Jun-00	11:15	1.0	310	230		7.4		9.45	1.56	0.0002	0.0100	0.56	0.55	0.10	0.11	0.66	7.7	0.010	0.052	1914	20	1934	18.5	13
SC-1	13-Jun-00	12:15	1.1	229	510		8.7		9.45	2.29	0.0002	0.0100	0.64	0.63	0.60	0.61	1.24	7.8	0.006	0.050	2427	33	2460	18.5	25
SC-2	13-Jun-00	10:15	1.9	226	210		8.7		9.42	3.01	0.0003	0.0100	0.78	0.77	0.90	0.91	1.68	7.9	0.008	0.070	2667	36	2703	19.5	24
CC-3	26-Jun-00	10:00	1.3				8.0		9.55	2.06	0.0002	0.0100	0.11	0.10	0.06	0.07	0.17	7.9						15.5	
SC-1	26-Jun-00	11:15	1.3	239	760		9.9		9.53	1.63	0.0002	0.0100	0.53	0.52	0.70	0.71	1.23	7.8	0.008	0.026	2318	19	2337	16.0	47
SC-2	26-Jun-00	8:45	2.4	209	200		8.2		9.50	2.69	0.0003	0.0100	0.61	0.60	0.70	0.71	1.31	7.9	0.057	0.108	2574	58	2632	17.0	12
460-116	11-Jul-00			22	4	6810	8.3	1080	9.65	0.23	0.0016	0.7000	1.20	0.50	19.90	20.60	21.10	7.0	0.020	0.020	6655	15	6670	12.4	1055
460-125	11-Jul-00			94	600	1100	8.4	250	9.59	1.57	0.0002	0.0100	0.60	0.59	1.90	1.91	2.50	7.8	0.020	0.040	763	11	774	14.3	63
460-126	11-Jul-00			106	810	324	8.8	150	9.58	3.11	0.0003	0.0100	0.11	0.10	0.06	0.07	0.17	8.1	0.020	0.050	195	7	202	14.4	3
BB-1	16-Aug-00	12:30				1132			9.52	1.32	0.0017	0.1300	0.77	0.64	0.10	0.23	0.87	7.7	0.020	0.054	73	1	74	16.3	16
BB-1	16-Aug-00	12:00		235	280	1132			9.52	1.32	0.0001	0.0100	0.11	0.10	2.90	2.91	3.01	7.7	0.002	0.009	1012	3	1015	16.3	334
BB-2	16-Aug-00	14:30		253	230	1659	12.1		9.43	3.71	0.0004	0.0100	0.11	0.10	0.06	0.07	0.17	8.0	0.005	0.066	1481	30	1511	19.0	3
BB-3	16-Aug-00	16:00		236	100	2233	14.6		9.39	3.79	0.0004	0.0100	0.11	0.10	0.30	0.31	0.41	8.0	0.006	0.124	2079	63	2142	20.3	3
CC-3	16-Aug-00	13:30		295	140	2059	9.9		9.44	2.05	0.0002	0.0100	0.11	0.10	0.06	0.07	0.17	7.8	0.074	0.044	1927	13	1940	18.8	4
SC-1	16-Aug-00	9:30		182	280	2171	12.8		9.45	1.49	0.0001	0.0100	0.11	0.10	0.40	0.41	0.51	7.6	0.010	0.045	2312	32	2344	18.5	11
BB-4	17-Aug-00	8:00		167	40	2342	12.9		9.49	5.33	0.0011	0.0200	0.11	0.09	0.06	0.08	0.17	8.2	0.004	0.073	2355	45	2400	17.3	2
460-116	19-Sep-00				2		7.7	1150	9.55	0.53	0.0042	0.8000	0.11	0.00	34.30	35.10	35.10	7.3	0.030	0.040	7372	18	7390	15.3	878
460-125	19-Sep-00				2000		8.9	338	9.68	1.37	0.0001	0.0100	0.11	0.10	5.93	5.94	6.04	7.8	0.060	0.060	1670	1	1671	11.6	101
460-126	19-Sep-00				390		9.1	119	9.71	2.61	0.0003	0.0100	0.11	0.10	0.06	0.07	0.17	8.1	0.040	0.070	168	1	169	10.6	2

Appendix C

Quality Assurance Data

Bear Butte Creek Quality Assurance/Quality Control Data (Replicates and Duplicates).

Station	Sample Type	Comments	Date	Time	Alk (mg/L $CaCO_3$)	Fecal (Col / 100mL)	SpCond (µmhos/ cm)	DO (mg/L)	Hardness (mg/L)	Un-ionized NH3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Org N (mg/L)	NO2, 3 (mg/L)	Inorg N (mg/L)	pH	DP (mg/L)	Total Dis'd Solids (mg/L)	Tot. Solids (mg/L)	TSS (mg/L)	TP (mg/L)
BB-4D	Duplicate	SHL	17-Aug-00	8:45	164	20.0				0.0002	0.03	0.11	0.08	0.05	0.08		0.00	2,348	2,375	27.0	0.053
BB-4	Routine	SD WRAP	17-Aug-00	8:00	167	40.0				0.0011	0.02	0.11	0.09	0.06	0.08		0.00	2,355	2,400	45.0	0.073
					1%	**33%**				**70%**	**20%**	0%	6%	9%	0%		0%	0%	1%	**25%**	**16%**
BB-3D	Duplicate	SHL	4-Oct-00	10:45	282	650				0.0002	0.01	0.11	0.10	0.30	0.31		0.00	2,035	2,059	24.0	0.03
BB-3	Routine	SD WRAP	4-Oct-00	10:45	280	610				0.0004	0.01	0.11	0.10	3.00	3.01		0.00	2,079	2,101	22.0	0.02
					0%	3%				**38%**	0%	0%	0%	**82%**	**81%**		0%	1%	1%	4%	4%
SC-1D	Duplicate	SHL	17-Apr-00	13:30		5.0		10.7		0.00001	0.01	0.65	0.64	0.70	0.71	6.69	0.00				0.02
SC-1	Routine	SD WRAP	17-Apr-00	13:30		5.0		10.7		0.00001	0.01	0.66	0.65	0.70	0.71	6.69	0.00				0.02
						0%		0%		0%	0%	1%	1%	0%	0%	0%	0%				2%
SC-2D	Duplicate	SHL	13-Jun-00	10:15	227	230		8.90		0.0003	0.01	1.02	1.01	0.80	0.81	7.91	0.01	2,662	2,697	35.0	0.07
SC-2	Routine	SD WRAP	13-Jun-00	10:15	226	210		8.70		0.0003	0.01	0.78	0.77	0.90	0.91	7.91	0.01	2,667	2,703	36.0	0.07
					0%	5%		1%		0%	0%	**13%**	**13%**	6%	6%	0%	**14%**	0%	0%	1%	2%
BB-1	Replicate	split to NWQL	6-Oct-98	10:48	253	111	1,090	10.1		0.0002	0.021	0.12	0.10	2.74	2.76	7.60		581	582	0.50	0.025
BB-1	Routine	USGS	6-Oct-98	10:40	196	250	1,090	10.1		0.0001	0.01	0.26	0.25	2.40	2.41	7.60		690	692	2.00	0.097
					13%	**39%**	0%	0%		**35%**	**35%**	**37%**	**43%**	7%	7%	0%		9%	9%	**60%**	**59%**
BB-1	Duplicate	qa	18-May-00	9:05	213	360	885	12.8	475	0.00	0.01	0.28	0.27	2.20	2.21	8.00		593	597	4.00	0.01
BB-1	Routine	USGS	18-May-00	9:00	215	540	885	12.8	468	0.00	0.01	0.30	0.29	2.10	2.11	8.00		588	591	3.00	0.02
					0%	**20%**	0%	0%	1%	0%	0%	3%	4%	2%	2%	0%		0%	1%	**14%**	3%
BB-2	Replicate	split to NWQL	6-Oct-98	13:50	146.0	2,840	751	11.2		0.0003	0.03	0.18	0.16	0.60	0.63	7.90		383	430	47.0	0.07
BB-2	Routine	USGS	6-Oct-98	13:46	151.0	3,200	751	11.2		0.0001	0.01	0.63	0.62	0.60	0.61	7.90		490	592	52.0	0.11
					2%	6%	0%	0%		**43%**	**43%**	**56%**	**60%**	0%	1%	0%		**12%**	**16%**	5%	**23%**
BB-2	Duplicate	qa duplicate NWQL	28-Mar-00	11:35	259	N/A	1,650	10.6	800	0.00	0.01	0.30	0.29	0.49	0.50	7.90		1,207	1,220	13.0	0.05
BB-2	Routine	USGS	28-Mar-00	11:30	235	240	1,650	10.6	839	0.00	0.01	0.45	0.44	0.50	0.51	7.90		1,190	1,204	14.0	0.03
					5%		0%	0%	2%	0%	0%	**20%**	**21%**	1%	1%	0%		1%	1%	4%	**22%**
BB-3	Replicate	qa/qc split	7-Oct-98	10:36	105	3,600	1,040	12.4	450	0.00	0.01	1.09	1.08	0.40	0.41	7.60		753	949	196	0.35
BB-3	Routine	USGS	7-Oct-98	10:35	105	2,300	1,040	12.4	450	0.00	0.01	1.38	1.37	0.30	0.31	7.60		753	953	200	0.36
					0%	**22%**	0%	0%	0%	0%	0%	**12%**	**12%**	**14%**	**14%**	0%		0%	0%	1%	1%
BB-3	Duplicate	qa duplicate SHL	28-Mar-00	14:02	227	10.0	2,130	10.8	989	0.00	0.01	0.50	0.49	0.30	0.31	8.20		1,610	1,650	40.0	0.07
BB-3	Routine	USGS	28-Mar-00	14:00	232	5.0	2,130	10.8	998	0.00	0.01	0.58	0.57	0.30	0.31	8.20		1,610	1,650	41.0	0.07
					1%	**33%**	0%	0%	0%	0%	0%	7%	8%	0%	0%	0%		0%	0%	1%	3%
BB-3	Duplicate	qa duplicate NWQL	28-Mar-00	14:05	234	N/A	2,130	10.8	980	0.00	0.01	0.41	0.40	0.31	0.32	8.20		1,666	1,705	39.0	0.06
BB-3	Routine	USGS	28-Mar-00	14:00	232	5.0	2,130	10.8	998	0.00	0.01	0.58	0.57	0.30	0.31	8.20		1,610	1,650	41.0	0.07
					0%		0%	0%	1%	0%	0%	17%	17%	1%	1%	0%		2%	2%	3%	12%
BB-4	Replicate	qa/qc split	7-Oct-98	13:31	192	2,000	1,980	12.3	968	0.00	0.01	1.40	1.39	0.30	0.31	7.60		1,586	1,978	392	0.56
BB-4	Routine	USGS	7-Oct-98	13:30	193	2,000	1,980	12.3	970	0.00	0.01	1.35	1.34	0.30	0.31	7.60		1,589	1,973	384	0.55
					0%	0%	0%	0%	0%	0%	0%	2%	2%	0%	0%	0%		0%	0%	1%	0%

Note: Bold lettering indicates an exceedance of the QA/QC criterion.

Bear Butte Creek Quality Assurance/Quality Control Data (Blank Samples).

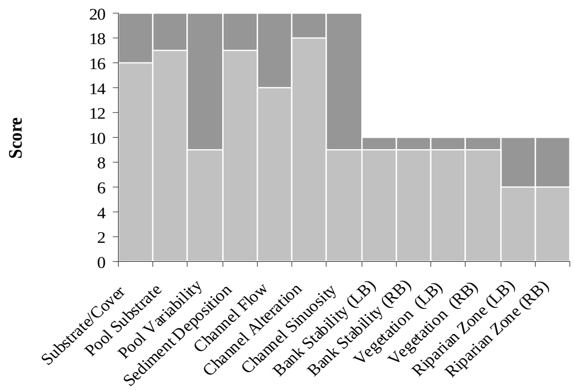
Station	Sample Type	Comments	Date	Time	Alk (mg/L $CaCO_3$)	Fecal (Col/100mL)	SpCond (mmS/ cm)	DO (mg/L)	Hardness (mg/L)	Un-ionized NH3 (mg/L)	NH3 (mg/L)	TKN (mg/L)	Org N (mg/L)	NO2, 3 (mg/L)	Inorg N (mg/L)	pH	DP (mg/L)	Total Dis'd Solids (mg/L)	Tot. Solids (mg/L)	TSS (mg/L)	TP (mg/L)
BB-4B	B	SD WRAP	17-Aug-00	10:00	3	5				0.00000	0.010	0.11	0.10	0.05	0.06		0.001	11	11	0.5	0.001
SC-1B	B	SD WRAP	17-Apr-00	13:20		5		10.7		0.00001	0.010	0.11	0.10	0.5	0.51	6.69	0.001				0.001
SC-2B	B	SD WRAP	13-Jun-00	10:15	3	40		8.7		0.00030	0.010	0.11	0.10	0.05	0.06	7.91	0.001	3	4	0.5	0.001
Mean					3.00	16.7		9.7		0.0	0.01	0.11	0.10	0.20	0.21	7.3	0.0	6.8	7.3	0.5	0.0
Standard Deviation					0	**20.2**		1.4		0.0	0.0	0.0	0.0	**0.26**	**0.26**	0.9	0.0	5.3	5.3	0.0	0.0

Note: Bold lettering indicates an exceedance of the QA/QC criterion. Shaded values indicate concentrations in the blank specimen above the minimum detection limit.

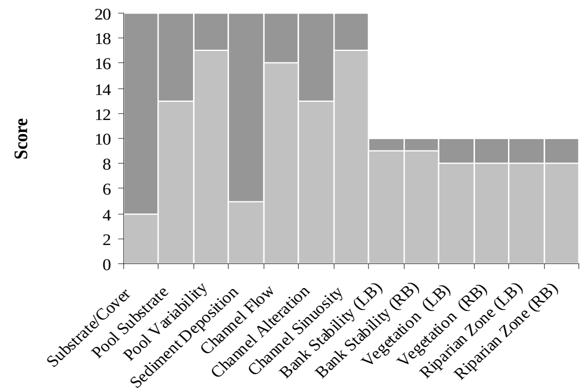
Appendix D

Bear Butte Creek Habitat Analysis Results.

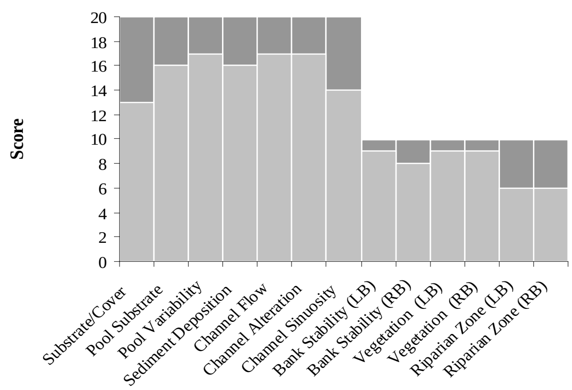
Bear Butte Creek 2000 Habitat Assessment Scoring by Site (page 1 of 1)



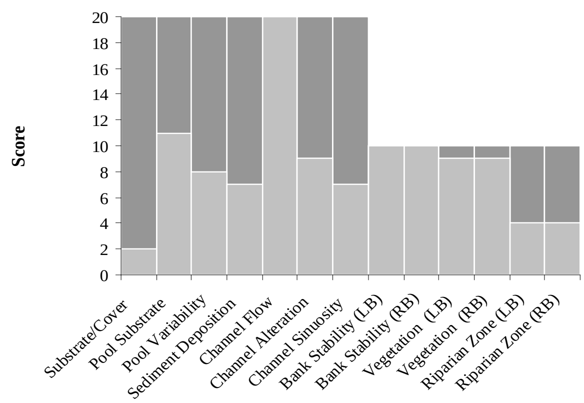
Site BB-1 Compared to Ideal Habitat



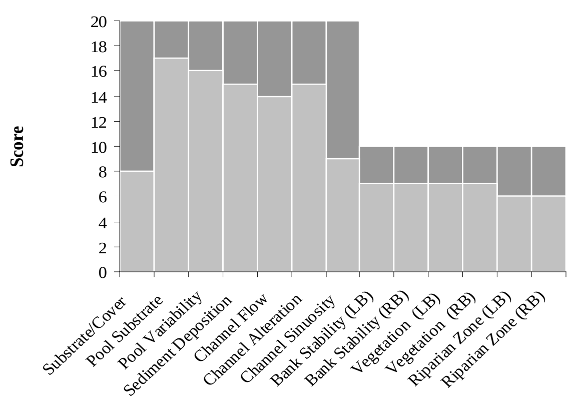
Site CC-3 Compared to Ideal Habitat



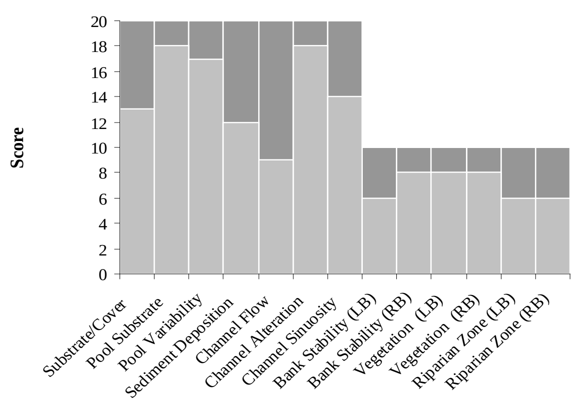
Site BB-2 Compared to Ideal Habitat



Site SC-1 Compared to Ideal Habitat



Site BB-3 Compared to Ideal Habitat

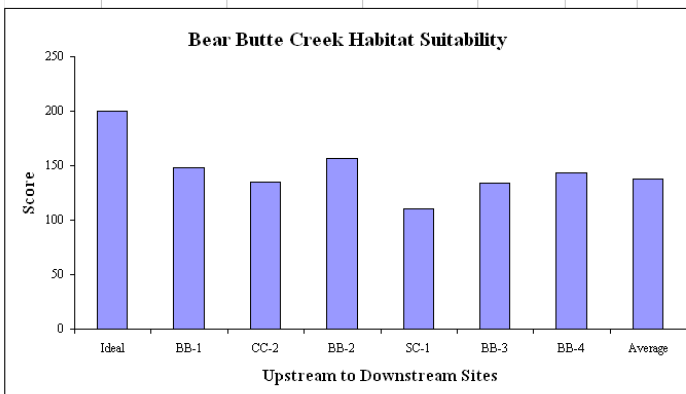


Site BB-4 Compared to Ideal Habitat

Bear Butte Creek 2000 Habitat Assessment Statistics (page 1 of 1)

Bear Butte Creek Habitat Parameter Scores

	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability (LB)	Bank Stability (RB)	Vegetative Cover (LB)	Vegetative Cover (RB)	Riparian Vegetative Zone Width (LB)	Riparian Vegetative Zone Width (RB)	Total Score
Ideal	20	20	20	20	20	20	20	10	10	10	10	10	10	**200**
BB-1	16	17	9	17	14	18	9	9	9	9	9	6	6	**148**
CC-2	4	13	17	5	16	13	17	9	9	8	8	8	8	**135**
BB-2	13	16	17	16	17	17	14	9	8	9	9	6	6	**157**
SC-1	2	11	8	7	20	9	7	10	10	9	9	4	4	**110**
BB-3	8	17	16	15	14	15	9	7	7	7	7	6	6	**134**
BB-4	13	18	17	12	9	18	14	6	8	8	8	6	6	**143**
Average	9	15	14	12	15	15	12	8	9	8	8	6	6	**138**



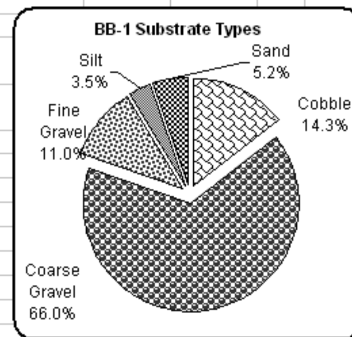
Descriptive statistics	
Mean	138
Standard Error	6.6
Median	139
Mode	
Standard Deviation	16.1
Sample Variance	259
Kurtosis	1.5
Skewness	(1.0)
Range	47.0
Minimum	110
Maximum	157
Count	6.0
Largest(1)	157
Smallest(1)	110
Confidence Level (95.0%)	16.9

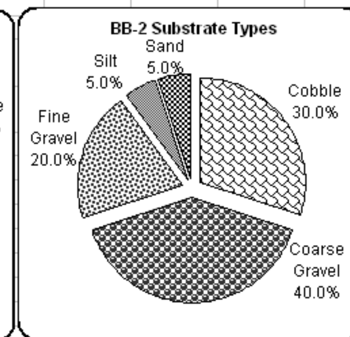
	Epifaunal Substrate/ Available Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability (LB)	Bank Stability (RB)	Vegetative Cover (LB)	Vegetative Cover (RB)	Riparian Vegetative Zone Width (LB)	Riparian Vegetative Zone Width (RB)	Total Score (Ideal Reference)	Total Score (Relative Reference)
Ideal	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	**100%**	
BB-1	80%	85%	45%	85%	70%	90%	45%	90%	90%	90%	90%	60%	60%	**74%**	**94%**
CC-2	20%	65%	85%	25%	80%	65%	85%	90%	90%	80%	80%	80%	80%	**68%**	**86%**
BB-2	65%	80%	85%	80%	85%	85%	70%	90%	80%	90%	90%	60%	60%	**79%**	**100%**
SC-1	10%	55%	40%	35%	100%	45%	35%	100%	100%	90%	90%	40%	40%	**55%**	**70%**
BB-3	40%	85%	80%	75%	70%	75%	45%	70%	70%	70%	70%	60%	60%	**67%**	**85%**
BB-4	65%	90%	85%	60%	45%	90%	70%	60%	80%	80%	80%	60%	60%	**72%**	**91%**
Average	47%	77%	70%	60%	75%	75%	58%	83%	85%	83%	83%	60%	60%	**69%**	**88%**

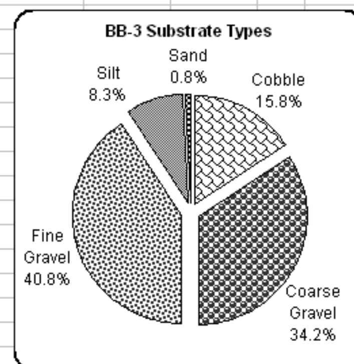
Bear Butte Creek 2000 Habitat Assessment Substrate Analysis (page 1 of 1)

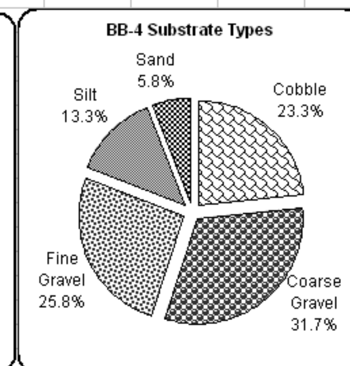
Bear Butte Creek Habitat Substrate Characterization

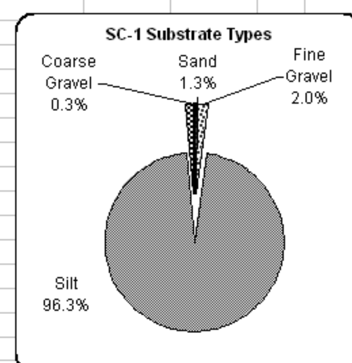
Site ID	Sub-Location	Cobble	Coarse Gravel	Fine Gravel	Silt	Sand	Clay	Organic	Precip.	Total		5	4	3	2	1	Total	Mean
		Substrate Types by Percent:										Embeddedness Rating						
BB-1												Percents						
	B1	14	69	9	4	4	0	0	0	100		61	26	6	6	0	100	25
	B2	14	69	9	4	4	0	0	0	100		61	26	6	6	0	100	25
	B3	15	60	15	3	8	0	0	0	100		61	26	6	6	0	100	25
	Ave	14.3	66.0	11.0	3.5	5.2	0.0	0.0	0.0		Ave	61	26	6	6	0		
												306	105	19	13	0		4.4
BB-2																		
	B1	30	40	20	5	5	0	0	0	100		5	90	5	0	0	100	33
	B2	30	40	20	5	5	0	0	0	100		5	90	5	0	0	100	33
	B3	30	40	20	5	5	0	0	0	100		5	90	5	0	0	100	33
	Ave	30.0	40.0	20.0	5.0	5.0	0.0	0.0	0.0		Ave	5	90	5	0	0		
												25	360	15	0	0		4.0
BB-3																		
	B1	5	50	40	3	3	0	0	0	100		10	30	40	20	0	100	25
	B2	20	30	40	10	0	0	0	0	100		20	40	30	10	0	100	25
	B3	23	23	43	13	0	0	0	0	100		40	30	20	10	0	100	25
	Ave	15.8	34.2	40.8	8.3	0.8	0.0	0.0	0.0		Ave	23	33	30	13	0		
												117	133	90	27	0		3.7
BB-4																		
	B1	20	30	35	5	10	0	0	0	100		6	46	31	11	6	100	20
	B2	30	40	10	20	0	0	0	0	100		0	0	30	30	40	100	33
	B3	25	25	30	10	10	0	0	0	100		0	0	20	40	40	100	33
	B4	30	30	20	20	0	0	0	0	100		0	0	30	30	40	100	33
	B5	5	25	50	10	10	0	0	0	100		0	0	10	40	50	100	33
	B6	30	40	10	15	5	0	0	0	100		0	0	40	30	30	100	33
	Ave	23.3	31.7	25.8	13.3	5.8	0.0	0.0	0.0		Ave	1	8	27	30	34		
												5	31	81	60	34		2.1
SC-1																		
	B1	0	0	0	100	0	0	0	0	100		0	0	0	0	100	100	100
	B2	0	0	2	96	2	0	0	0	100		0	0	0	0	100	100	100
	B3	0	1	4	93	2	0	0	0	100		0	0	0	10	90	100	50
	Ave	0.0	0.3	2.0	96.3	1.3	0.0	0.0	0.0		Ave	0	0	0	3	97		
												0	0	0	7	97		1.0
CC-3																		
	B1	0	40	15	40	4	0	1	0	100		0	0	0	10	90	100	50
	B2	0	2	3	90	4	0	1	0	100		0	0	0	5	95	100	50
	B3	0	2	3	90	4	0	1	0	100		0	0	0	5	95	100	50
	Ave	0.0	14.7	7.0	73.3	4.0	0.0	1.0	0.0		Ave	0	0	0	7	93		
												0	0	0	13	93		1.1

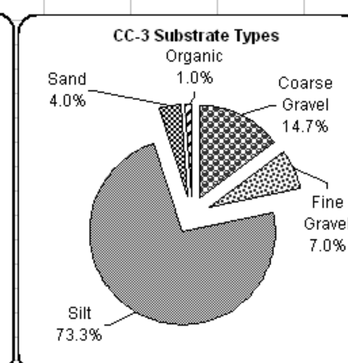












Appendix E

Project Funding Summary

Project Funding Summary

Project Title: Bear Butte Creek Watershed Assessment Project

Project Start Date: November 15, 1999	**Project Completion Date:** January 1, 2001
Funding:	**Total Budget:** $ 17,573
Total EPA Budget:	$ 15,500
Total Expenditures of EPA Funds:	$ 12,655.99
Total Match Accrued:	$ 1,149.06
Budget Revisions:	No Revisions
Total Expenditures:	$ 13,805.05

Appendix F

Bear Butte Creek Total Maximum Daily Load Summary

TOTAL MAXIMUM DAILY LOAD EVALUATION

of

TOTAL SUSPENDED SOLIDS

for

BEAR BUTTE CREEK

(Hydrologic Unit Code 10120202)

MEADE AND LAWRENCE COUNTIES, SOUTH DAKOTA

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

October 2018

Bear Butte Creek Total Maximum Daily Load

Waterbody Type: Stream

303(d) Listing Parameter: Total suspended solids (TSS)

Designated Uses:

- Coldwater permanent fish life propagation water
- Coldwater marginal fish life propagation water
- Limited contact recreation
- Fish and wildlife propagation and stock watering
- Recreation

Size of Impaired Waterbody: Approximately 24 stream miles

Size of Watershed: 57,110 hectare (141,000 acres)

Water Quality Standards: Narrative and numeric

Indicators: TSS concentrations

Analytical Approach: FLUX and Annualized AGNPS models

Location: Hydrologic Unit Code 10120202

Goal: 61% reduction in TSS load (2,177,370 kg/yr)

Target: TSS concentration ≤158 mg/L

Objective

The intent of this summary is to clearly identify the components of the TMDL submittal to support adequate public participation and facilitate the US Environmental Protection Agency (EPA) review and approval. The TMDL development was developed in accordance with Section 303(d) of the federal Clean Water Act and guidance developed by EPA.

Introduction

The Bear Butte Creek watershed is located in Lawrence and Meade counties in South Dakota (Figure F1). Bear Butte Creek, which is 97.1 km in length (60.4 mi) drains approximately 57,000 ha (141,000 acres) into the Belle Fourche River (HUC 10120202). Streams in this drainage network are typically 4 m wide or less. Approximately two-thirds of the landuse in the watershed is agricultural and one-third is forested. Major landuse categories found in this watershed include rangeland (54%), forest (30%), and cropland (14%). Other landuse in the watershed includes mining, industrial/commercial services, and urban/residential areas (2%). Crops grown in this area include wheat, oats, alfalfa, sorghum, barley and rye.

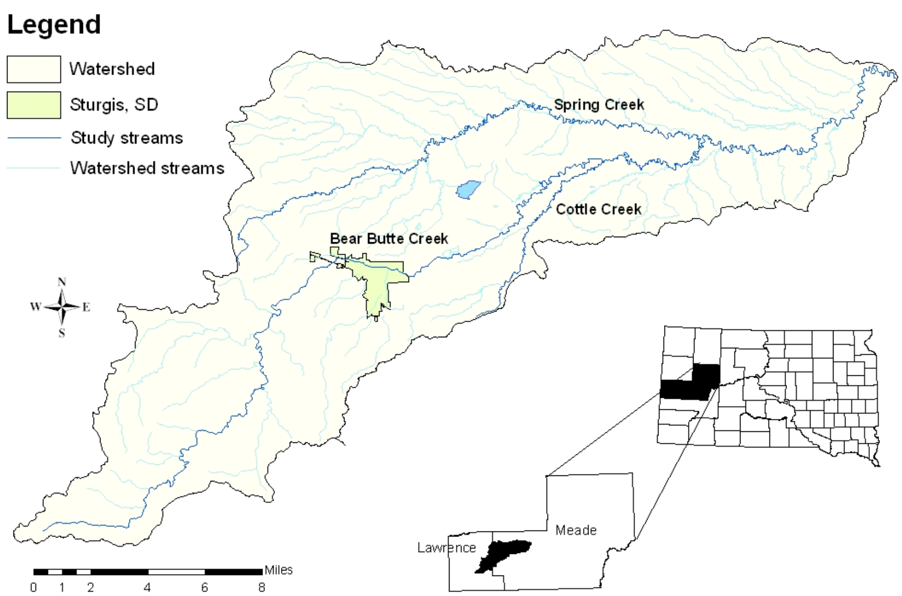


Figure F1. The Bear Butte Creek watershed in Meade and Lawrence Counties in South Dakota.

Bear Butte Creek, from the headwaters to the Lawrence County line, was included in the 1998 South Dakota Department of Environment and Natural Resources (SD DENR) 303(d) impaired waterbodies list (SD DENR, 1998) for total suspended solids (TSS), cadmium, copper, and zinc. Subsequent monitoring efforts within the watershed resulted in a delisting for metals but revealed exceedance of the TSS standard.

Problem Identification

The Bear Butte Creek study began with an examination of the water quality impairments documented in the 2002 SD DENR Impaired Waterbodies (303d) List and Waterbodies Assessment (305b) Report. Water quality sampling results, land-use activities, and the regional geology of these areas were also considered when determining impairment sources. Agriculture (cropland and pasture) was the dominant landuse category of the Bear Butte Creek watershed. Several campgrounds and parks are also located alongside the creek. Additionally, several abandoned mines are located in the watershed at the historic Galena mining district.

Along with landuse activities, the geology, physiography, climate, soils, vegetation, and hydrology of the Bear Butte Creek watershed was considered in order to compare habitat and water quality along the length of the creek. As shown in Figure F2, the creek flowed across four

Class IV ecoregions. The headwaters of the creek flowed from the Black Hills Core Highlands (granitic and metamorphic rock) and then across the Black Hills Plateau (metamorphic and sedimentary rock), where flows of less than 12 cfs were lost for much of the year. Stream flow typically reemerged on the outer edge of the Black Hills Foothills ecoregion, an area of sandstone and shale formations. From this area, the creek flowed through the Semiarid Pierre Shale Plains before meeting the Belle Fourche River.

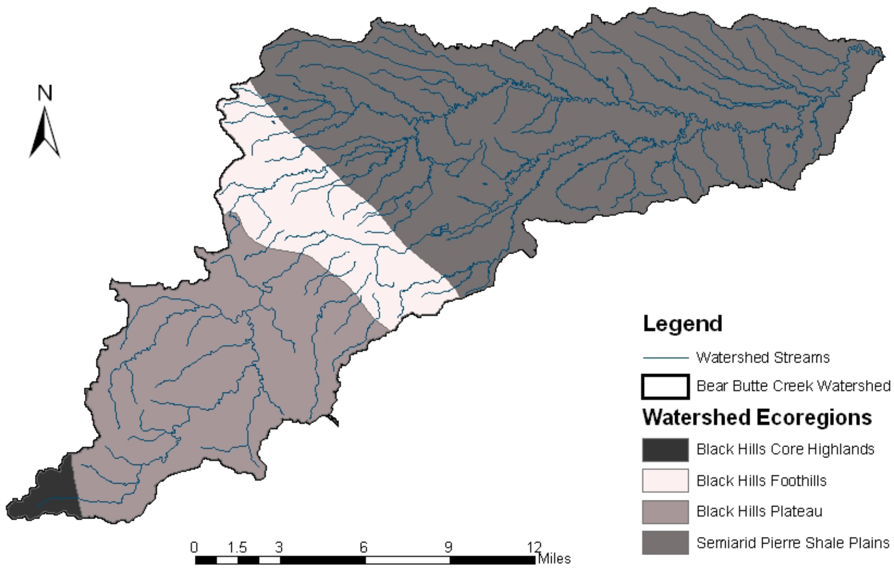


Figure F2. The Bear Butte Creek watershed crosses portions of four Level IV ecoregions.

The major portion of the suspended solids load originates from erosion of the Pierre Shale Plains. These erosional sources include the uplands (croplands and pasture) and the stream channel. A noticeable lack of wooded riparian areas was observed in the lower reaches of Bear Butte Creek and tributaries to the lower reaches. Additionally, lower reaches of Bear Butte Creek have unstable stream banks and channel substrate composed chiefly of clay and silt, which are easily eroded. These particles, due to their physical characteristics, have a very low settling velocity and tend to remain in suspension.

Crop and livestock production in the Bear Butte Creek watershed has altered drainage and channel characteristics, decreased riparian cover and stream habitat, and served as a conduit for increased sediment, nutrient, and other contaminant loading. Grazing livestock can contribute to the removal of most vegetative cover, soil compaction, exposure of the soil, degradation of the soil structure, and loss of soil infiltration capacity. In the Bear Butte Creek watershed, higher rates of sediment delivery from rangeland can be attributed to steep slopes, highly erodible soils, and storm events.

Applicable Water Quality Standards and Numeric Water Quality Targets

Bear Butte Creek has been assigned beneficial uses by the State of South Dakota Surface Water Quality Standards regulations. Along with these assigned uses are narrative and numeric criteria that define the desired water quality for the assigned beneficial use. These criteria must be maintained for the waterbody to satisfy its assigned beneficial uses, which are listed below:

- Coldwater *permanent* fish life propagation water
- Coldwater *marginal* fish life propagation water
- Limited-contact recreation
- Fish and wildlife propagation, recreation and stock watering
- Irrigation

From SD State Highway 79 to Dead Man Creek and from the boundary of S2, T4N, R4E to the boundary of S22, T4N, R3E, Bear Butte Creek is designated a category 2 beneficial use, or coldwater *permanent* fish life propagation water. All other portions of Bear Butte Creek and most of the named tributaries are designated as a category 3 beneficial use, or coldwater *marginal* fish life propagation water. Figure F3 shows the designated fisheries as thick gray (coldwater marginal) or black (coldwater permanent) lines.

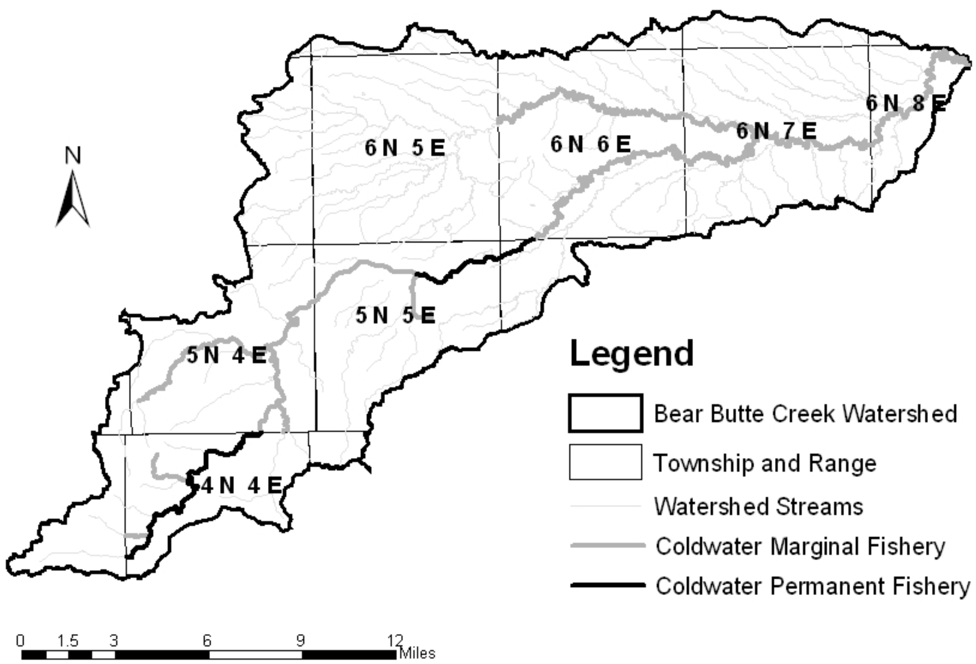


Figure F3. Stream segments with designated beneficial uses of coldwater permanent and marginal fisheries for the Bear Butte Creek watershed.

Additional beneficial uses for Bear Butte Creek include limited-contact recreation (category 8), fish and wildlife propagation, recreation and stock watering (category 9), and irrigation (category 10). Unless specified, the beneficial-use classifications (other than categories 9 and 10) do not apply to Bear Butte Creek tributaries. The following table (Table F1) lists the assigned beneficial uses for all segments of Bear Butte Creek and the named tributaries and the counties in which they are located. Cottle Creek is not listed in Table F1 because it is not classified as a fish life propagation water.

Table F1. Assigned beneficial uses for Bear Butte Creek and named tributaries designated as fisheries in the Bear Butte Creek watershed.

Water Body	From	To	Beneficial Uses	County
Bear Butte Creek	Belle Fourche River	Route 79	3, 8, 9, and 10	Meade
Bear Butte Creek	Route 79	Dead Man Creek	2, 8, 9, and 10	Meade
Spring Creek	Bear Butte Creek	S14, T6N, R5E	3, 8, 9, and 10	Lawrence
Bear Butte Creek	Dead Man Creek	S2, T4N, R4E	3, 8, 9, and 10	Meade
Bear Butte Creek and south fork	S2, T4N, R4E	S22, T4N, R3E	2, 8, 9, and 10	Lawrence
Boulder Creek	Bear Butte Creek	Two Bit Creek	3, 8, 9, and 10	Lawrence
Two Bit Creek	Boulder Creek	S30, T5N, R4E	3, 8, 9, and 10	Lawrence
Bear Butte Creek (north fork)	Bear Butte Creek	S14, T4N, R3E	3, 8, 9, and 10	Lawrence
Park Creek	Bear Butte Creek	S11, T4N, R4E	3, 8, 9, and 10	Lawrence
Strawberry Creek	Bear Butte Creek	S5, T4N, R4E	3, 8, 9, and 10	Lawrence
Vanocker Creek	Bear Butte Creek	S32, T5N, R5E	3, 8, 9, and 10	Lawrence

South Dakota has several applicable narrative standards that may be applied to the undesired eutrophication of lakes and streams. Administrative Rules of South Dakota Article 74:51 contains language that prohibits the existence of materials causing pollutants to form, visible pollutants, taste and odor producing materials, and nuisance aquatic life.

The numeric criteria were used to assess the impairment and determine a numeric target for Bear Butte Creek. Bear Butte Creek is currently considered partially supporting of its beneficial uses with TSS concentrations in excess of the 158 mg/L compliance criterion for coldwater marginal fish life propagation water. The TMDL numeric target is established at 158 mg/L.

<u>Pollutant Assessment</u>

Linkage Analysis

Water quality data was collected from ten stream sites. Samples were collected according to South Dakota's EPA approved Standard Operating Procedures for Field Samplers. Water samples were sent to the state Health Laboratory in Pierre, SD for analysis. Quality Assurance/Quality Control samples were collected for 10% of the samples according to South Dakota's Nonpoint Source Quality Assurance/Quality Control Plan. Details concerning water sampling techniques, analysis, and quality control are addressed in the assessment final report.

FLUX, a program developed by the US Army Corps of Enignеers, was used to calculate the current TSS load at eight monitoring sites (WQM-125, BB-1, BB-2, BB-3, BB-4, SC-1, SC-2, CC-3) for water years 1999 and 2000. See pages 17-18 and 54-60 of the assessment report for details concerning the FLUX analysis.

The Annualized Agricultural Nonpoint Source Model (AnnAGNPS) was used to define critical areas within the watershed (i.e. those with high sediment export potential) and identify the most effective management practices. The sediment loads estimated using this model may not accurately represent the total load that was calculated from sample concentrations and stream flow, since the model does not account for streambed and bank erosion. However, the model identifies upland erosional problem areas and shows the importance of well-managed grazing systems within this watershed. Results indicate that improving the pasture condition from poor to good would reduce the annual sediment load by approximately 70%. See page 65-68 of the assessment report for AnnAGNPS model analysis results.

Point Sources

There are no point sources of pollutants of concern in this watershed.

Nonpoint Sources

The impacts of grazing livestock and crop production on the TSS load in the Bear Butte Creek were observed during this study. Generally, TSS concentrations increased in a downstream direction. Most of the agricultural landuse also occurs at the lower end of the watershed. Several extreme TSS concentrations were observed during event-based flows. The TSS water quality standard (158 mg/L) was exceeded at sites BB-3 and BB-4. At site BB-3, three out of 24 (13%) samples exceeded the TSS standard (158 mg/L). At site BB-4, four out of 24 (17%) samples exceeded the standard.

TMDL and Allocations

A TMDL was calculated for the impaired reach of Bear Butte Creek (from site BB-2 to the mouth) shown in Figure 25 of the assessment report. A goal of 61% reduction of current TSS load was set for the impaired reach. The goal is derived from the daily maximum water quality standard and will meet or exceed the required reductions for the impaired segment.

To determine the amount of TSS load reduction required to meet water quality standards, the FLUX model was executed for each assessment site requiring TSS reductions (sites BB-3 and BB-4), replacing TSS concentrations exceeding the 158 mg/L daily maximum standard with the actual daily maximum standard value. FLUX model results from site BB-4 were used to set the TMDL goal because this site receives runoff from the entire watershed, required the greatest level of TSS load reduction, and provides a conservative TMDL goal. Currently, the TSS load at site BB-4 is 5,611,373 kg/yr (6,185 ton/yr). TSS loads need to be reduced by 3,434,003 kg/yr (3,785 ton/yr) to reach the TMDL goal of 2,177,370 kg/yr (2,400 ton/yr).

Wasteload Allocations (WLAs)

The wasteload allocation (WLA) portion of the TMDL identifies the portion of the loading capacity allocated to existing and future point sources. There are no point sources of pollutants of concern in this watershed. Therefore, the WLA component of this TMDL is considered a zero value.

Load Allocations (LAs)

The load allocation (LA) portion of the TMDL identifies the portion of the loading capacity allocated to existing and future non-point sources. Natural background sources are included in the nonpoint source load allocation to represent the portion of the loading capacity attributed to natural geologic processes.

The required reductions of TSS concentrations may be achieved through the implementation of BMPs primarily including grazing management systems, livestock exclusion, enhanced buffer zones, and stream bank stabilization. Model results demonstrate the importance of well-managed grazing systems in this watershed. Implementation of cropland management practices including, but not limited to, cover crop planting, conservation crop rotation, residue management, and contour farming may also be needed to meet the TMDL goal. The recommended BMPs should bring the mean TSS concentrations below the standard of 158 mg/L.

The load analysis was performed on monthly data from a two-year period, predicting changes to average annual loads. Daily fluctuations may result in TSS loads that are greater in the spring and summer months or less in the winter months. Still, the suggested BMPs and resulting reduction in TSS loads should bring Bear Butte Creek into compliance for TSS concentrations.

Seasonal Variation

Different seasons of the year can yield differences in water quality due in part to changes in precipitation and landuse practices. The monthly TSS load contributions from each subwatershed were grouped into seasons as follows:

Winter – December, January, February
Spring – March, April, May
Summer – June, July, August
Fall – September, October, November

TSS loads peak during summer months when most sites experience maximum stream flow rates and receive runoff from areas experiencing greater landuse activity. However, TSS loadings were highest during spring months at site WQM-125, possibly due to snowmelt runoff from areas of higher elevation (Figure F4).

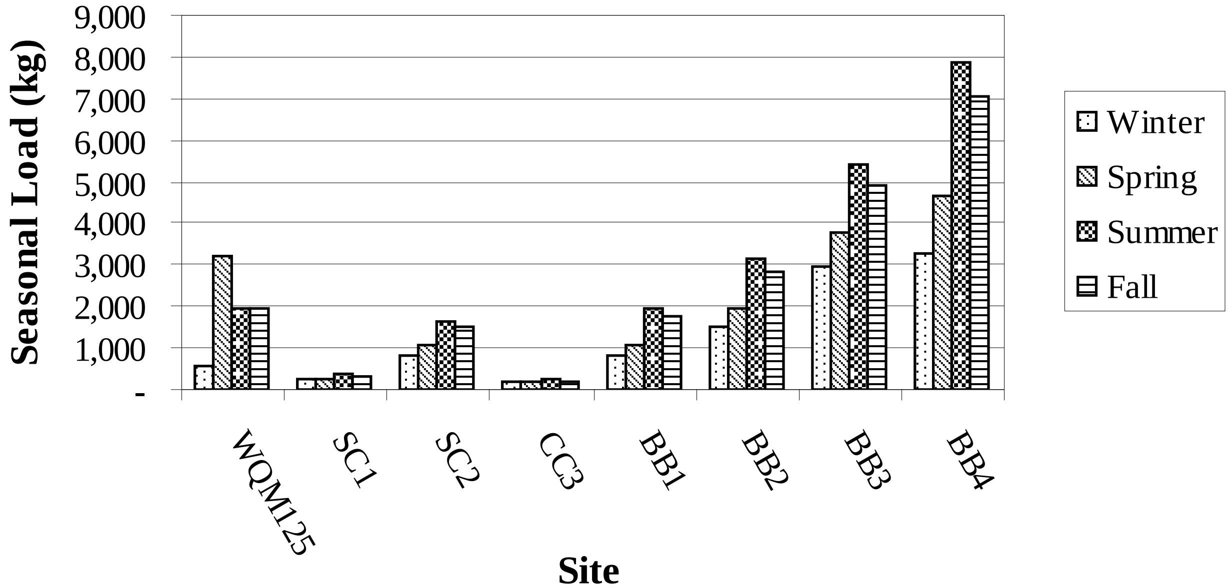


Figure F4. Seasonal TSS loads (kg) by site for water years 1999-2000.

Margin of Safety

Substantial uncertainty is often inherent in estimating TSS loads from nonpoint sources. To account for uncertainty, a margin of safety is incorporated in the TMDL calculations. The margin of safety for this TMDL is implicit, in that conservative modeling coefficients were used in predicting the achievable TSS reductions. In addition, the site requiring the largest reduction of TSS load was used to set the TMDL goal for the entire impaired reach of Bear Butte Creek.

Critical Conditions

Critical conditions associated with TSS loading seem to be driven by seasonal differences in landuse and hydrologic conditions. The impairments to Bear Butte Creek are most severe during the summer months (i.e. June, July, and August), when erosional forces are exacerbated by greater amounts of precipitation, increased livestock grazing intensity and duration, and cropping practices.

Follow-Up Monitoring

Water quality monitoring will be necessary to determine whether or not the proposed implementation actions have had an impact on water quality in the Bear Butte Creek watershed. Once the implementation of management practices is completed, post-implementation monitoring will be needed to ensure that the TMDL is attained.

Monitoring will continue at all SDDENR ambient monitoring sites in this watershed (sites WQM-125, WQM- 126, and WQM-116). However, additional monitoring sites should be positioned in the lower, impaired reach of Bear Butte Creek. At a minimum, site BB-4 should be sampled quarterly following the implementation of BMPs. Measurements should include stream flow, turbidity, specific conductance, temperature, pH, total solids concentrations, and TSS concentrations. Continuous flow data should also be collected at monitoring sites in order to develop loading estimates.

Public Participation

Efforts were taken to gain public education, review, and comment during development of the TMDL, including local newspaper articles, general public meetings, Technical Group meetings, and the Belle Fourche River Watershed Partnership (BFRWP) meetings (the Bear Butte Creek watershed is a portion of the Belle Fourche River watershed). General public meetings provided an opportunity to present assessment results and to receive input from the stakeholders.

Implementation Plan

The BFRWP was awarded a 319 implementation grant to support a one-year project. The goals of this first project segment were to begin initial implementation of BMPs in this watershed, which includes the Bear Butte Creek watershed, to reduce TSS loads, develop a 10-year watershed strategic implementation plan to guide the long-term implementation process, and conduct public education and outreach to stakeholders within the Belle Fourche River watershed.

The BFRWP was recently awarded another 319 grant to complete the second implementation project segment. This project segment will continue implementation of BMPs to reduce TSS loads in the Belle Fourche River Watershed. BMPs will consist primarily of grazing management systems and irrigation efficiency improvements.

Results of this study will assist the BFRWP in making implementation decisions related to the Bear Butte Creek watershed. Priority areas within the Bear Butte Creek watershed to be targeted for management practices have been identified. Recommended BMPs installed in these areas will reduce TSS loads in a cost effective manner.