Water Quality Conditions of Antelope Creek, Black Thunder Creek and the Cheyenne River *2002-2006*

Wyoming Department of Environmental Quality
Water Quality Division

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CONTENTS

FIGURES

TABLES

LIST OF ACRONYMS

EPT	Ephemeroptera, Plecoptera and Trichoptera
HUC	Hydrologic Unit Code
NGP	Northwestern Great Plains Ecoregion
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WDEQ/WQD	Wyoming Department of Environmental Quality/Water Quality Division
WGFD	Wyoming Game and Fish Department
WSII	Wyoming Stream Integrity Index
WY RIVPACS	Wyoming River Invertebrate Prediction and Classification System
WYPDES	Wyoming Pollutant Discharge Elimination System

This document was peer reviewed by Lanny Goyn (WDEQ/WQD) and Jeremy Zumberge (WDEQ/WQD).

Cover photos (clockwise from top left): Black Thunder Creek above Little Thunder Creek, Antelope Creek below Porcupine Creek, Cheyenne River near Dull Center, and Cheyenne River near Wyoming/South Dakota stateline.

1.0 EXECUTIVE SUMMARY

Stream assessments are performed under Section 305(b) of the Clean Water Act to evaluate the extent to which Wyoming waterbodies meet the goals of the Clean Water Act and support designated uses established under Chapter 1 of the Wyoming Department of Environmental Quality-Water Quality Division (WDEQ/WQD) Water Quality Rules and Regulations. Water quality in Wyoming is protected for designated uses such as fisheries, aquatic life other than fish, drinking water, fish consumption, recreation, agriculture, industry and scenic value. Stream assessments are performed by the WDEQ/WQD Watershed Management Section's Monitoring Program. Representative and valid data collected by other federal, state and local entities are also used in stream assessments where appropriate.

Data and reports from stream assessments are later combined with information gathered by the WDEQ/WQD and other federal, state and local entities to make designated use support determinations which are summarized in the biennial Wyoming 305(b) State Water Quality Assessment Report and 303(d) List of Waters Requiring TMDLs.

During 2003 and 2004, the WDEQ/WQD Monitoring Program conducted stream assessments on the Cheyenne River, Antelope Creek and Black Thunder Creek where chemical, physical and biological information were collected. The objectives of these assessments were to 1) document baseline conditions and 2) evaluate water quality conditions to determine whether designated uses were supported on their dates of sampling. Additional data collected by the United States Geological Survey (USGS) from 2002 to 2006 and the Wyoming Game and Fish Department (WGFD) in 2004 and 2005 were also used to characterize baseline conditions and evaluate designated use support of these waters. This report contains a summary of the analysis performed on the 2002-2006 dataset and conclusions on designated use support for the Cheyenne River, Antelope Creek and Black Thunder Creek.

Several exceedences of the chronic aquatic life criterion for dissolved iron were present along lower Antelope Creek (below Porcupine Creek) and the Cheyenne River at Dull Center from 2002-2006. Dissolved iron in the Cheyenne River at Dull Center also exceeded the respective human health criterion during 2004-2006. The predominant source of dissolved iron at these locations appeared to be from natural groundwater contributions. Drought conditions in the basin since 2000 have likely resulted in elevated dissolved iron concentrations in groundwater. Effluent from permitted facilities in the area was considered a negligible contributor to the dissolved iron exceedences. There were no numeric criteria exceedences for other water chemistry parameters. Parameters without numeric criteria were within the expected range of conditions for streams in the Cheyenne River Basin. Data were insufficient to conclude whether fish consumption and recreational uses on the Cheyenne River, Antelope Creek and Black Thunder Creek were supported.

Available information indicated the channel and riparian zones of the Cheyenne River and its tributaries have undergone significant changes during the last century as evidenced by multiple episodes of historical downcutting, widening and lateral migration at several stations. Changes in the flow and sediment regimes, land use changes and modifications associated with climatic cycles and intense flood-events are likely reasons for the channel changes. Channel reaches of the Cheyenne River and its tributaries continue to adjust their dimensions in response to these factors though evidence suggests the channels are progressing towards a more stable form. Though the upward trend shows promise, it may take a long period of time for the channels to reach a stable form given the present climate, current hydrologic regime and assuming no major change in land management. In light of these circumstances, channels were generally characterized by stable banks, sufficient riparian vegetative cover and adequate in-stream habitat for aquatic life which were conducive to supporting designated uses.

Collections of warm-water game and non-game fishes on the Cheyenne River indicated this waterbody is correctly classified as a Class 2AB water-water fishery. Antelope Creek and Black Thunder Creek are currently classified as 3B waters which are not known to support game or non-game fisheries. However, collections by the WGFD indicated these streams can support both non-game and game warm-water fishes at least seasonally. Evaluation of all biological data indicates the biological condition of the Cheyenne River, Antelope Creek and Black Thunder Creek was comparable to expected conditions determined to be representative of the basin. Therefore, these streams were considered supportive of their aquatic life uses.

2.0 INTRODUCTION

The Monitoring and Assessment Program of the Wyoming Department of Environmental Quality-Water Quality Division (WDEQ/WQD) assesses the water quality and makes use-support determinations for streams and rivers in Wyoming. In 2003 and 2004, WDEQ/WQD performed complete and partial bioassessments at eight stations located on Antelope Creek, Black Thunder Creek and the Cheyenne River. The purpose of this monitoring was to establish biological, chemical and physical baseline conditions on the Cheyenne River and selected tributaries. Additional information used to characterize baseline conditions in the Cheyenne River basin were instantaneous stream discharge measurements and water quality samples gathered from 2002 to 2005 at seven United States Geological Survey (USGS) stations located on Antelope Creek, Black Thunder Creek, Cheyenne River, Little Thunder Creek and Porcupine Creek. Provisional water chemistry and biological data collected in 2005 and 2006 at selected USGS stations were also used where applicable. Supplemental mean daily stream discharge information collected at one USGS gage station on the Cheyenne River from 1976 to 2005 was also used to characterize a typical flow regime of a perennial segment in the Cheyenne River basin. Fish survey information collected by the Wyoming Game and Fish Department (WGFD) in 2004 and 2005 were included in this report.

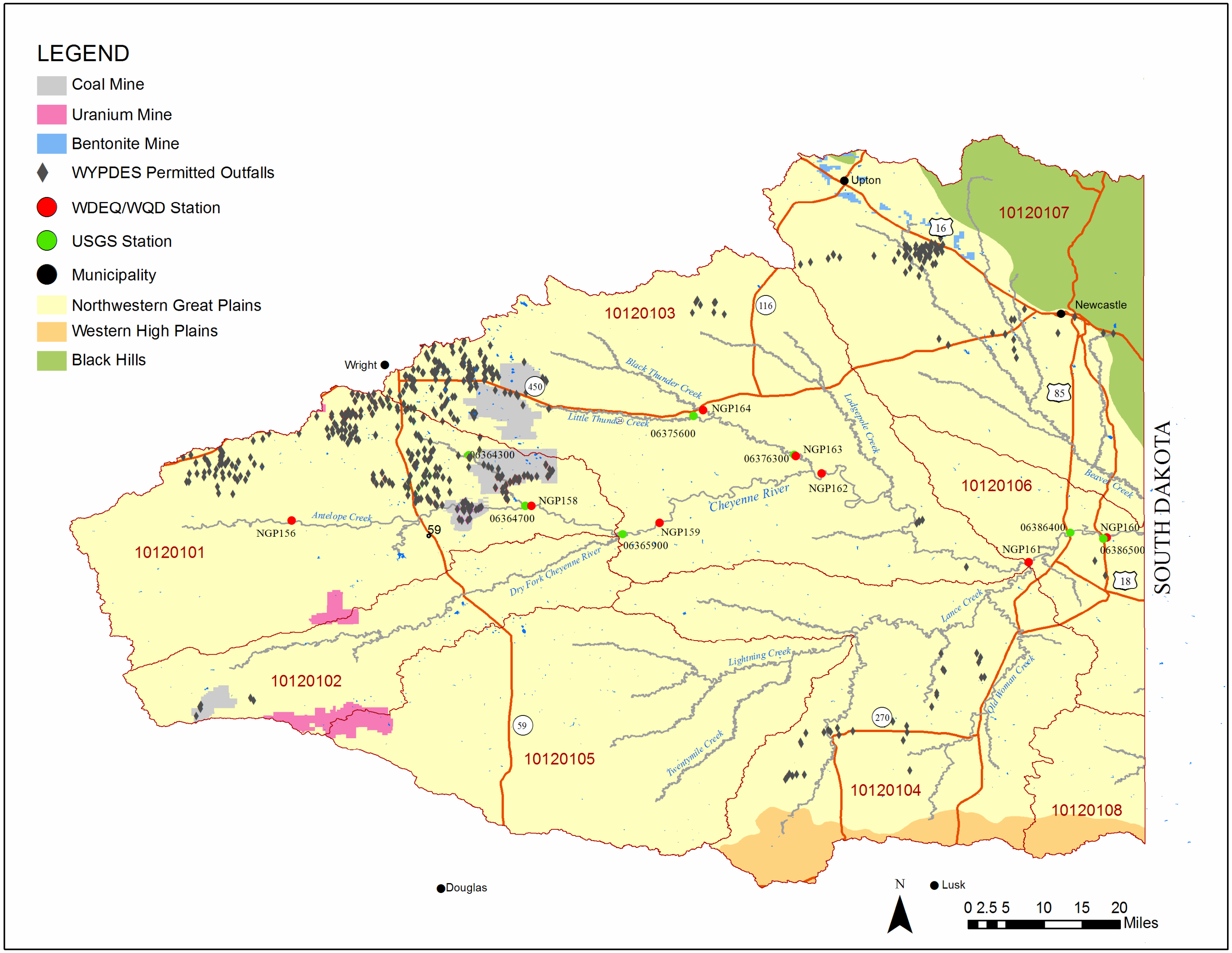
The objectives of this report are 1) to document the baseline conditions in Antelope Creek, Black Thunder Creek and the Cheyenne River from 2002 to 2006 and 2) to evaluate water quality conditions of these waters with respect to Wyoming water quality standards to determine whether designated uses along these waters were supported during their dates of sampling.

3.0 DESCRIPTION OF ASSESSMENT AREA

3.1 Environmental Setting

The Cheyenne River and the majority of its tributaries have their origins in the Northwestern Great Plains ecoregion (Omernik and Gallant 1987) (Figure 1). The Northwestern Great Plains are semiarid rolling plains of shale and sandstone derived soils with granitic and sedimentary escarpments (Chapman et al. 2003). The bedrock geology of the basin is composed of sedimentary formations such as the Fort Union, Fox Hills, Lance and Wasatch that contain varying thicknesses of coal beds. Marine deposits of the Carlile and Pierre Shales are located along the Cheyenne River near the stateline with South Dakota. One tributary to the Cheyenne River, Beaver Creek, partially originates in the granitic and sedimentary geology of the Black Hills foothills ecoregion in the northeastern portion of the basin. These foothills are a mixture of ponderosa pine and juniper woodlands interspersed with grasslands (Chapman et al. 2003). The Cheyenne River at the Wyoming/South Dakota stateline drains an almost 6,000 mi^2 watershed comprised of the Antelope (HUC 10120101), Dry Fork Cheyenne (HUC 10120102), Upper

Figure 1 – The Cheyenne River basin and associated ecoregions, mines, WYPDES permitted discharges, municipalities and WDEQ/WQD and USGS monitoring stations.



Cheyenne (HUC 10120103), Lance (HUC 10120104), Lightning (HUC 10120105), and Angostura Reservoir (HUC 10120106) sub-basins (Figure 1). Streams in the Beaver (HUC 10120107) and Hat (HUC 10120108) sub-basins confluence the Cheyenne River in South Dakota. Land ownership in the basin is primarily private with small areas managed by Wyoming State Lands, Bureau of Land Management and the U.S. Forest Service. Primary land uses in the watershed are livestock grazing, irrigated agriculture and mineral development. Irrigated agriculture is practiced predominantly along stream corridors and valleys via surface water diversions and groundwater wells. Coal, uranium, bentonite, oil and coal-bed natural gas make up the majority of mineral development in the watershed. Most coal and coal-bed natural gas development occurs in the northeastern areas of the watershed along the headwater regions of Antelope Creek, Little Thunder Creek and Porcupine Creek (Figure 1). Uranium mining occurs along the upper Dry Fork Cheyenne River sub-basin while bentonite mining is confined to the upper Beaver Creek sub-basin (Figure 1). The Lance Creek and Beaver Creek sub-basins contain most of the oil development in the basin. Mineral development in the Cheyenne basin has occurred since the early to mid-20th century while coal-bed natural gas is a relative newcomer to the basin with the earliest development occurring in the late 1990's followed by a peak around 2004-2005 (personnel communications, WDEQ/WQD Wyoming Pollutant Discharge Elimination System (WYPDES) Program). Since 2004-2005, new coal-bed natural gas development in the Cheyenne basin has been minimal.

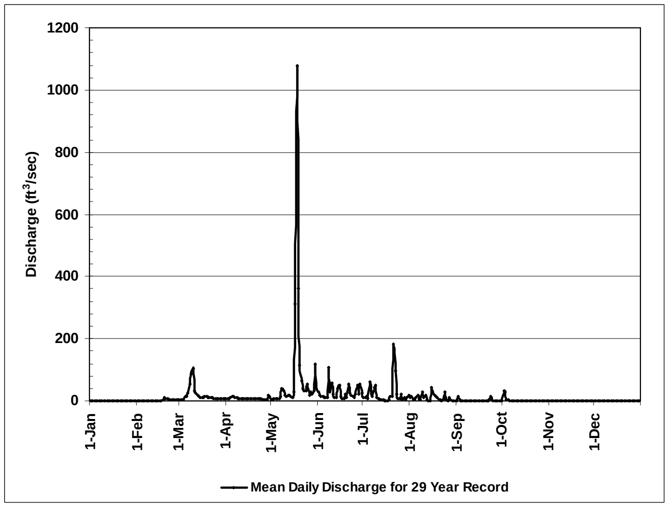
3.2 Stream Classification and Designated Uses

According to WDEQ/WQD (2001c, 2007), Antelope Creek, Black Thunder Creek, Little Thunder Creek above the North Prong and Porcupine Creek are classified as 3B waters. Designated uses protected on Class 3B waters include aquatic life other than fish, recreation, wildlife, agriculture, industry and scenic value. All of the Cheyenne River and Little Thunder Creek below the North Prong are categorized as Class 2ABww waters (WDEQ/WQD 2001c, 2007). Designated uses protected on Class 2ABww waters include drinking water, warm-water game fisheries, non-game fisheries, fish consumption and all uses protected for Class 3B waters.

3.3 Surface Water Hydrology

Most streams in the Cheyenne basin including the Cheyenne River are ephemeral or intermittent. The flow regime of these streams is flashy in response to temporary runoff events caused by snowmelt and precipitation events. Streams in the basin typically respond to snowmelt/spring thaw from March to April with a peak in stream discharge generally in early summer corresponding with the peak rain season (Figure 2). For most streams, flows normally cease around mid to late-summer of each year. Perennial stream segments in the basin, such as the Cheyenne River near Dull Center (USGS station 06365900), either continue to flow throughout the year (albeit minimally) or standing water is maintained due to groundwater discharge from local springs and/or seepage from upstream beaver dams with occasional peaks in flow due to intense thunderstorms (Figure 2). Additionally, stream flows in some segments of the Cheyenne River and other tributaries are influenced by numerous on-channel impoundments in the basin, surface water diversions and groundwater withdrawal. Some perennial stream segments in the basin are fed primarily by effluent discharges from WYPDES permitted facilities. For example, segments of Little Thunder Creek and Porcupine Creek are fed by effluent discharges from nearby coal mines, oil treaters and/or coal-bed natural gas facilities.

Figure 2 – Annual hydrograph (1976-2005) of mean daily discharge at USGS station 06365900 (Cheyenne River at Dull Center)



4.0 DATA COLLECTION

All WDEQ/WQD data collection, analysis, and models used in the evaluation of data collected on the Cheyenne River and selected tributaries were conducted in accordance with approved procedures (Hargett et al. *In Press*; Hargett and Zumberge 2006; Hargett et al. 2005 and WDEQ/WQD 1998, 2001a, 2001b, and 2004). A list of all monitoring stations and associated data types used in this report can be found in Table 1.

Table 1 - Descriptive information on WDEQ/WQD and USGS stations on the Cheyenne River and selected tributaries (Figure 1).

Station ID	Entire Record	*Data	Entity	Legal	Latitude	Longitude
NGP156	2003	P	WDEQ/WQD	SWNW of Sec. 7, T40N, R73W	43.453208°	-105.677169°
06364300	2003-05	C	USGS	SW of Sec. 25, T42N, R71W	43.578056°	-105.338611°
06364700	1977-81, 2000-06	C B	USGS	NE of Sec. 35, T41N, R70W	43.485556°	-105.227500°
NGP158	2003	C B P	WDEQ/WQD	SWNE of Sec. 35, T41N, R70W	43.484733°	-105.231764°
06365900	1976-2006	C B	USGS	NE of Sec. 20, T40N, R68W	43.429167°	-105.045278°
NGP159	2003-04	C B P	WDEQ/WQD	SWSW of Sec. 12, T40N, R68W	43.451769°	-104.976283°
NGP164	2003	C B P	WDEQ/WQD	NWNW of Sec. 34, T43N, R67W	43.666253°	-104.895758°
06375600	1977-81, 1988-97 2004-05	C	USGS	SW of Sec. 33, T43N, R67W	43.655000°	-104.909167°
06376300	1980-81, 1986-89 2000-05	C B	USGS	NW of Sec. 31, T42N, R65W	43.581667°	-104.719222°
NGP163	2003	P	WDEQ/WQD	NWNE of Sec. 31, T42N, R65W	43.578836°	-104.718297°
NGP162	2003-04	C B P	WDEQ/WQD	SWNE of Sec. 9, T41N, R65W	43.546086°	-104.667386°
NGP161	2003	C P	WDEQ/WQD	NWNE of Sec. 11, T39N, R62W	43.375031°	-104.270492°
06386400	1980-92, 2001-05	C	USGS	SW of Sec. 21, T40N, R61W	43.428056°	-104.195833°
06386500	1969-79, 2003-05	C B	USGS	NE of Sec. 25, T40N, R61W	43.421111°	-104.131111°
NGP160	2003	C B P	WDEQ/WQD	NENE of Sec. 25, T40N, R61W	43.422211°	-104.126697°

*Data Type: C = Chemical, B = Biological, P = Physical

5.0 ENVIRONMENTAL CONDITIONS

5.1 Streamflow Conditions

(See Appendix 1 for dataset) Instantaneous streamflow information gathered at USGS stations from 2002 to 2005 indicate that daily streamflow in selected tributaries and the Cheyenne River can vary considerably. Drought conditions were prevalent in the basin during this time period and likely had an effect on streamflows. During this period, median daily flows in Porcupine and Antelope Creeks were generally less than 0.50 cfs. Most flows in Porcupine Creek during this time period were suspected to be effluent discharges from coal mines and/or coal-bed natural gas facilities. Much of these effluent flows may be lost to infiltration/evaporation or captured and stored in a large on-channel impoundment located on Porcupine Creek a few miles upstream from its confluence with Antelope Creek. Field observations in 2003 at the mouth of Porcupine Creek verified that indeed the channel had been dry for a long period of time. Antelope Creek is generally intermittent though perennial pool-dominated segments occur in the lower reaches of this stream. Flows in these perennial segments are minimal to imperceptible and originate from local springs though effluent discharged from the upstream facilities has the potential to contribute. Beaver dam complexes are prevalent throughout the lower reaches of Antelope Creek, storing flows prior to reaching the Cheyenne River. Little Thunder and Black Thunder Creeks were generally ephemeral to intermittent with flashy occurrences of stream flow from 2002 to 2005. Effluent from coal mines, oil treaters and coal-bed natural gas facilities are discharged to Little Thunder Creek, though are generally lost to infiltration/evaporation or stored behind large beaver dam complexes prior to entry into Black Thunder Creek. According to data gathered in 2003 and other available information such as the national wetland inventory database, perennial segments exist but are infrequent throughout much of Black Thunder Creek. Those perennial segments that do exist appear to be maintained by local springs. Perennial segments of flowing water or persistent pools are scattered throughout the Cheyenne River, particularly downstream of Antelope Creek to the Wyoming/South Dakota stateline. These perennial segments appear to be fed by local springs and when present, facilitated by surface and sub-surface seepage from large beaver dam complexes. When flowing water is present, the median stream flows on these perennial Cheyenne River segments generally increase with distance downstream.

5.2 Chemical Quality

(See Appendices 1 and 2 for dataset) All water samples collected at USGS stations from 2002 to 2005 were conducted when flows were present rather than from standing pools. Water samples gathered by WDEQ/WQD in 2003 and 2004 were collected from pools, representing water quality conditions when flowing water is absent. Water temperatures in the Class 2ABww Cheyenne River (both in flowing water and pools) were below the WDEQ/WQD (2001c and 2007) maximum criteria of 30˚C for a warm-water fishery. Only once was the 30˚C water temperature criteria exceeded on the lower Class 2ABww Cheyenne River. However, this one exceedence represented less than 10% of the total number of samples gathered during a three-year period. There are no applicable numeric water temperature criteria for Class 3B waters, though most temperatures on these systems in flowing and standing water were below 30˚C. Dissolved oxygen concentrations in both flowing water and pools from the Class 2ABww streams were generally above the acceptable one-day minimum criterion of 5 mg/L that is considered protective of early aquatic life stages in 2ABww waters (WDEQ/WQD 2001c and 2007). Though no numeric dissolved oxygen criteria exist for Class 3B waters, most dissolved oxygen concentrations on these waters were above 5 mg/L. Instantaneous dissolved oxygen concentrations in these Class 3B systems can fall below 5 mg/L during the summer months due to low flows, shallow depth, warmer water temperatures and high rates of organic decomposition in pools. All pH values were ≥ 7.0 but within the limit of 6.0-9.0 (WDEQ/WQD 2001c and 2007).

Though WDEQ/WQD currently has no numeric water quality criteria for total phosphorous and nitrate-nitrogen, recent guidance by the USEPA (2001) recommends that total phosphorous and nitrate-nitrogen concentrations less than 0.029 mg/L and 0.030 mg/L, respectively, may be protective of aquatic life uses for streams in the Northwestern Great Plains ecoregion. It's important to note that USEPA's recommended nutrient criteria were developed for a broad ecoregion and may not be representative of the maximum nutrient concentrations protective of designated uses in the Cheyenne River and its tributaries. Nutrient samples for the period of record were only collected at WDEQ/WQD stations from standing pools. Nitrate-nitrogen and total phosphorous concentrations at WDEQ/WQD stations were generally at or below detection (<0.1 mg/L). Black Thunder Creek station NGP164 exhibited the highest total phosphorous concentration at 0.3 mg/L, the cause of which is unknown. However, the nutrient results from the WDEQ/WQD samples are not particularly informative since the detection limit was greater than the recommended concentrations and more importantly, USEPAs recommended criteria are for perennial streams with flowing water, not pool-dominated intermittent stream segments. Elevated total nutrient concentrations in pools can be expected since they may have high organic decomposition rates, function as nutrient sinks that may lead to algal blooms or dense growth of aquatic macrophytes. Filamentous algae and macrophytes were present in pools at most WDEQ/WQD stations, though only station NGP158 on Antelope Creek exhibited dense macrophyte growth. It is unknown whether nutrient concentrations during periods of flow exceeded the federally recommended criteria.

Where sufficient data was available, conductivity, sulfate, and in some cases alkalinity were elevated in non-flowing pools and generally increased in flowing water with distance downstream due to elevated concentrations of dissolved solids in streams draining sedimentary materials of the Northwestern Great Plains. Elevated conductivity (range: 1000 to >5000 uS/cm) and sulfate (range: 185 to >4000 mg/L) is expected in the Cheyenne River, its tributaries and throughout many plains streams due to the alkaline sedimentary geology and soils coupled with evapo-concentration of dissolved solids during low flows and leaching of soil salts during runoff. As the Cheyenne River comes in contact with marine shales near the Wyoming/South Dakota stateline (Figure 3), chloride concentrations increased, although remained below the 230 mg/L criterion protective of aquatic life uses (WDEQ/WQD 2001c and 2007).

Concentrations of dissolved calcium, magnesium and sodium were elevated when flowing water was present and in pools, however, sodium represented the largest fraction of the three constituents at most sites. Dissolved calcium was the predominant cation in Antelope Creek relative to sodium and magnesium in flowing water. Concentrations and ratios of these constituents are driven by the watersheds' sedimentary geology, variation in streamflow, and quality of groundwater from springs.

Where applicable, dissolved concentrations of iron in flowing water were all below the numeric human health criterion of 300 ug/L and chronic aquatic life criterion of 1000 ug/L (WDEQ/WQD 2001c and 2007) at USGS stations on Porcupine Creek, Black Thunder Creek and stations on the lower Cheyenne River. Dissolved iron in flowing water at USGS station 06364700 (Antelope Creek nr. Teckla) was greater than the aquatic life criterion of 1000 ug/L (2 instances or 6% of total samples) during the 2002-2005 sampling period (Table 2). Though the data is provisional, two additional exceedences of the chronic aquatic life criteria occurred in 2006. All dissolved iron exceedences on Antelope Creek occurred during low flow conditions in December, January or February. During 2004 and 2005, the Cheyenne River at Dull Center (USGS station 06365900), was characterized by ten exceedences (83% of total samples) of the 300 ug/L human health criterion and three exceedences (25% of total samples) of the 1000 ug/L chronic aquatic life criterion for dissolved iron. Though the data is provisional, two and four additional exceedences of the numeric chronic aquatic life and human health criterion, respectively, occurred in 2006. These exceedences occurred throughout most of the year except around May where spring flows substantially reduced instream dissolved iron concentrations.


Cheyenne River at Dull Center USGS Station 06365900 (2004)

Figure 3 – Bedrock geology of the Cheyenne River Basin. (Source: Bedrock Geology of Wyoming, 1994, U.S. Geological Survey, Denver, Colorado).

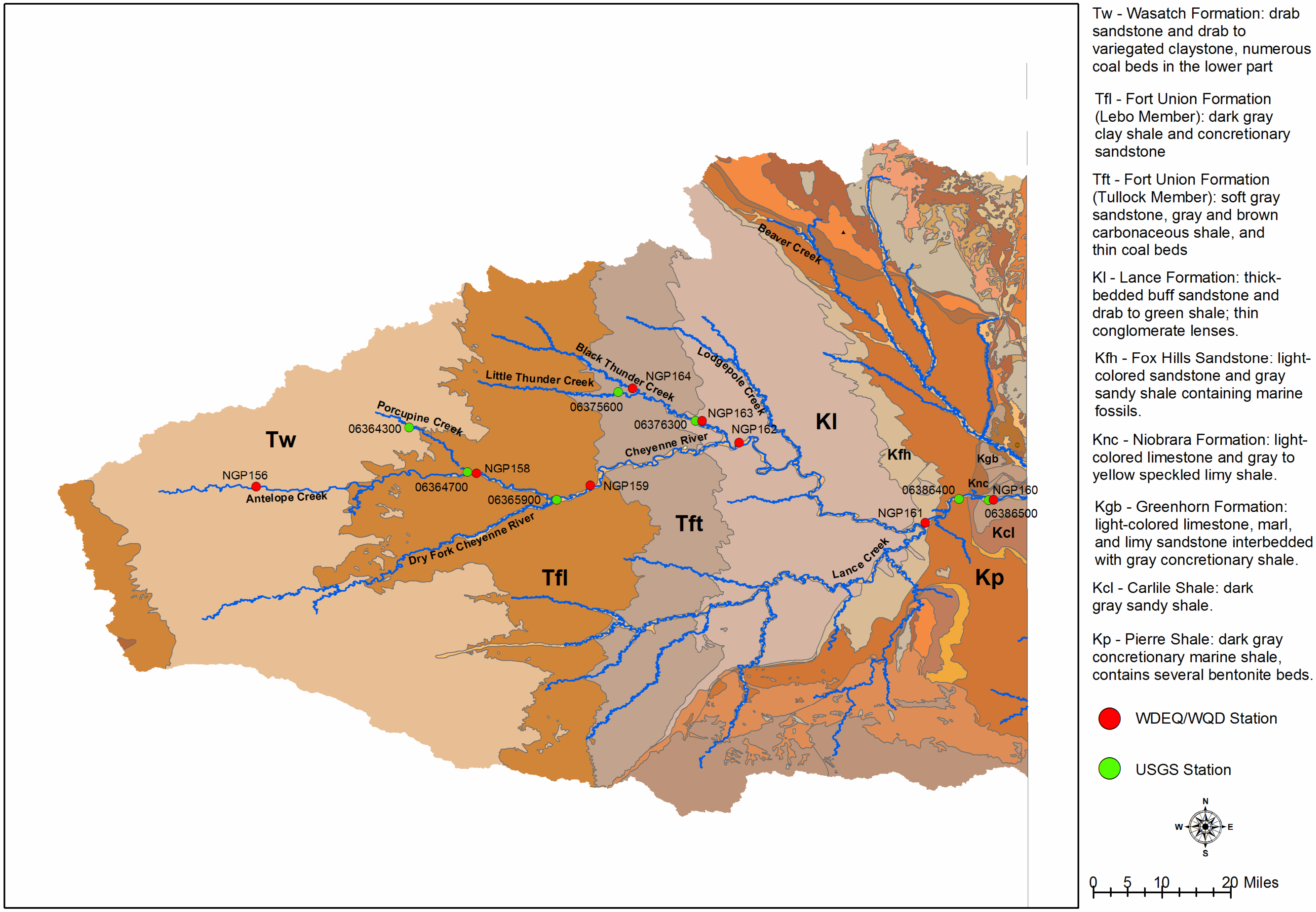


Table 2 – Dissolved iron concentrations and associated pH and discharge collected at USGS stations on Antelope Creek, Black Thunder Creek, Porcupine Creek and the Cheyenne River (2002-2006). No dissolved iron data was collected at USGS station 06375600 on Little Thunder Creek.

	Porcupine Ck. nr. Teckla 06364300			Antelope Ck. nr. Teckla 06364700			Cheyenne R. nr. Dull Center 06365900			Black Thunder Ck. Nr. Hampshire 06376300			Cheyenne R. nr. Riverview 06386400			Cheyenne R. nr. Spencer 06386500		
Collection Date	Discharge (cfs)	pH	D. Iron ug/L	Discharge (cfs)	pH	D. Iron ug/L	Discharge (cfs)	pH	D. Iron ug/L	Discharge (cfs)	pH	D. Iron ug/L	Discharge (cfs)	pH	D. Iron ug/L	Discharge (cfs)	pH	D. Iron ug/L
1/7/2002				0.16	7	531				0	NC	NC	0.18	7.2	<50			
2/11/2002				0.15	7.4	297				0	NC	NC	0.63	7.4	<30			
3/11/2002				0.11	7.3	8 est.				0.06	8.1	25	1.4	8.2	<10			
4/8/2002				0.17	7.5	12				0.62	8.1	8 est.	7.1	8.2	19			
5/6/2002				0.3	7.7	<30				0.04	8.4	<10	3.9	8.2	<30			
6/10/2002				0.16	7.7	<30				0.01	8.4	<30	0.48	8.2	<30			
7/10/2002				0	NC	NC				0	NC	NC	0.03	8.2	<50			
8/12/2002				0	NC	NC				0.12	7.8	17	0.03	8.4	<50			
9/9/2002				0	NC	NC				0.22	7.8	10	6.8	8.1	<10			
10/9/2002				0	NC	NC				0	NC	NC	0.59	8	<30			
11/4/2002				0.07	7.6	28 est.				0	NC	NC	0.63	8.2	<30			
12/10/2002				0.04	7.2	119				0	NC	NC	0.62	7.9	15			
1/15/2003				0.11	7.2	414				0	NC	NC	0.55	8	<30			
2/11/2003				0.12	7.3	414				0	NC	NC	0.97	8	<30			
3/6/2003				0.08	7.4	255				0	NC	NC	1.1	7.8	<30			
4/7/2003				0.06	7.8	22 est.				0.73	8.6	<10	6.1	8.7	<30			
5/5/2003	1.8	8.2	38	0.4	7.6	35				2.6	8.5	<10	6.2	8.5	<10			
6/4/2003	1.3	8.2	111	0.19	7.4	22				0	NC	NC	23	7.9	9			
7/15/2003	0	NC	NC	0.01	7.6	56				0.02	8.4	<8	2.9	8.1	<24			
8/11/2003	0	NC	NC	0	NC	NC				0	NC	NC	0.63	8.3	<24			
9/8/2003	0	NC	NC	0	NC	NC				0	NC	NC	0.01	8.3	46			
10/6/2003	0.27	8.6	32	0	NC	NC				0	NC	NC	0.07	8.1	13 est.			
11/5/2003	1.2	8.5	19	0.06	8.4	109				0	NC	NC	0.51	8	<19			
12/3/2003	1.1	8.4	9	0.14	7.3	486				0	NC	NC	0.63	8	<64			
1/7/2004	0.3	7.8	29	0.1	7.2	1510				0	NC	NC	0.26	7.7	63			
2/4/2004	0.69	8.2	8	0.1	7.2	1030				0	NC	NC	0.34	7.7	38			
3/9/2004	1.1	8.1	11	0.12	7.5	109				0.02	8	21	2.1	8.1	8			
4/5/2004	0.22	8	16 est.	0.14	7.6	22				0	NC	NC	0.57	8.1	13 est.			
5/3/2004	0.21	8.2	24	0.16	8.2	17 est.				0	NC	NC	0.06	8.2	10 est.			
6/8/2004	0.01	8.5	44	0.05	7.2	180				0	NC	NC	0.02	8	40			
7/13/2004	0	NC	NC	0.02	7.4	19 est.	0.01	7.1	3080	0	NC	NC	0	NC	NC			
8/9/2004	0	NC	NC	0	NC	NC	0.01	7.3	613	0	NC	NC	0	NC	NC			
9/7/2004	0	NC	NC	0	NC	NC	0.03	7.4	416	0	NC	NC	0	NC	NC			
10/5/2004	0	NC	NC	0	NC	NC	0.01	7.3	2540	0	NC	NC	0	NC	NC			
11/3/2004	0	NC	NC	0.04	7.6	14 est.	0.05	7.5	698	0	NC	NC	0.05	7.9	19 est.			
12/7/2004	0.16	8.1	9 est.	0.04	7.3	541	0.03	7.5	606	0	NC	NC	0	NC	NC			
1/11/2005				0.05	7.3	604	0.04	7.4	533	0	NC	NC	0.2	8.1	26			
2/8/2005	0.11	8.2	28	0.11	7.6	374	0.05	7.7	780	0	NC	NC	19	8	19			
3/7/2005	0.13	8.4	12 est.	0.08	8.1	17 est.	0.02	7.9	509	0	NC	NC	0.25	8.2	11			
4/13/2005	0.16	8.2	32	0.1	7.8	21	0.04	7.6	1190	0	NC	NC	0.2	8.1	26			
5/17/2005	1.1	8.3	29	0.11	7.9	22	0.05	8	51	15	7.9	23	19	8	19			
6/6/2005	0.28	8.3	49	0.1	7.6	28	0.03	7.7	82	0	NC	NC	0.25	8.2	11 est.			
6/7/2005	0.33	8.1	NC	0.09	7.8	NC	0.04	8.1	NC	0	8.1	NC						
7/12/2005	0.04	8	117	0	NC	NC	0	NC	NC	0	NC	NC						
8/9/2005	0	NC	NC	0	NC	NC	0	NC	NC	0	NC	NC						
9/7/2005	0	NC	NC	0	NC	NC	0	NC	NC	0	NC	NC						
10/11/2005	0.12	8.3	13 est.	0	NC	NC	0	NC	NC	0.65	8	18				0.14	8.2	15
11/7/2005	0.19	8.2	<18	0	NC	NC	0	NC	NC	0	NC	NC				0.05 est.	8.1	<18
12/7/2005	0.02	7.8	30	0	NC	NC	0.02	7.5	1080	0	NC	NC				0	NC	NC
1/10/2006	0.09	8.1	12	0.01	7.5	1330	0.04	7.8	613	0	NC	NC				0.38	7.6	23
2/7/2006	0.07	8.2	<18	0.02	7.3	1010	0.4	7.6	394	0	NC	NC				0.47	8	<18
3/7/2006	0.38	8.2	19	0.07	7.5	412	0.01	7.5	1550	0	NC	NC				0.6	8.1	<18
4/11/2006	0.16	8.2	31	0.09	7.6	206	0.01	8.5	42	0	NC	NC				0.36	8.1	15 est.
5/9/2006	0.12	8.5	29	0.07	7.7	61	0.05	8	27	0	NC	NC				0.11	8.3	17 est.
6/5/2006				0	NC	NC	0	NC	NC	0	NC	NC				0.03	7.7	<30
7/12/2006				0	NC	NC	0	NC	NC	0	NC	NC				0	NC	NC
8/8/2006				0	NC	NC	0	NC	NC	0	NC	NC				38	8	18
9/6/2006				0	NC	NC	0	NC	NC	0	NC	NC				0.01	8.3	<18

NOTE: According to the USGS, all data collected from 10/11/2005 to 9/6/2006 is PROVISIONAL AND SUBJECT TO REVISION

NC = No collection due to non-flowing water

Green highlighted cells indicate no dissolved iron data was collected

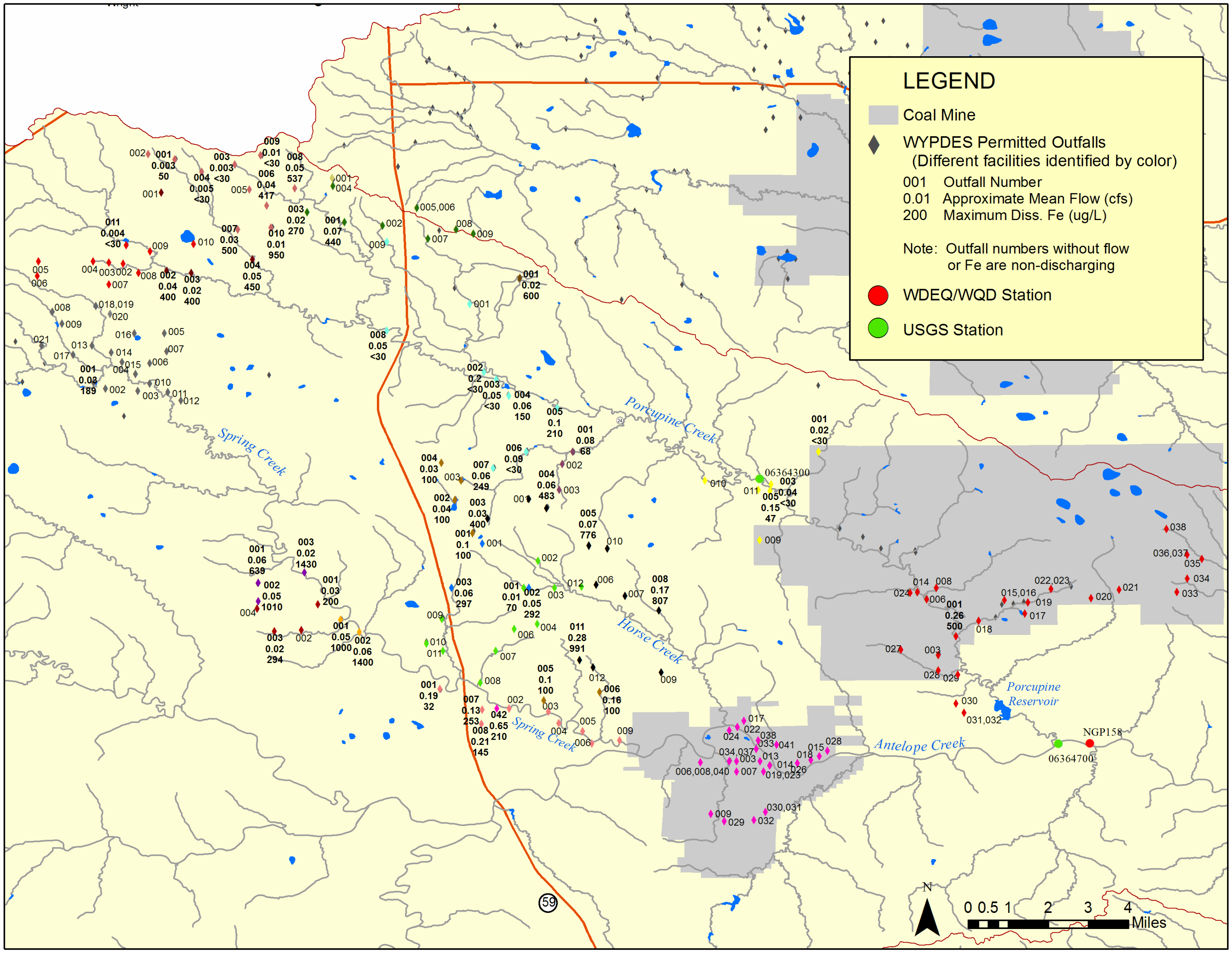
Red highlighted values are those that exceed the numeric human health criterion (300 ug/L) and/or chronic aquatic life criterion (1000 ug/L) for dissolved iron

Extensive mats of iron flocculent were present at the Cheyenne River at Dull Center (USGS station 06365900) in 2003 and 2004. Iron flocculent was also observed at both WDEQ/WQD Antelope Creek station NGP158 and Cheyenne River station NGP159 (both in close proximity to the aforementioned USGS stations on the same streams) in 2003. Iron flocculent was not observed at any other station.

Bartos and Ogle (2002) indicate elevated iron concentrations can be present in mine water and industrial wastes, particularly effluent derived from rocks and soil containing iron sulfides such as coal-beds. In addition, Bartos and Ogle (2002), Hodson et al. (1977), Lowry and Wilson (1986), Martin et al. (1988) and Rice et al. (2000) indicate dissolved iron concentrations can vary widely with a range from 190 to 5000 ug/L in groundwater of the Wasatch and Fort Union formations and coal-bed seams of northeastern Wyoming. Both formations lie in the upper Cheyenne River basin while varying thicknesses of coal lenses are scattered throughout the basin and can intersect the Cheyenne River and its tributaries (Figure 3). Coal-bed lenses were observed along the Cheyenne River near USGS Station 06365900 at Dull Center and along Antelope Creek near USGS station 06364700. Groundwaters in northeast Wyoming are alkaline with high bicarbonates and a pH >7. As a result of their alkalinity and high pH, dissolved iron in these groundwaters will readily oxidize and precipitate as iron oxyhydroxides and oxides upon contact with oxygen and light at the surface (Rice et al. 2000). Iron stained deposits on water discharge pipes from water wells, coal-bed natural gas and coal mine facilities in areas of northeast Wyoming are an indication of this reaction. After oxidation at the surface, groundwater from these formations will have little to non-detectable concentrations of dissolved iron. Indeed, information from the WDEQ/WQD WYPDES permitting program indicates dissolved iron in effluent discharged from facilities that mine coal beds in northeast Wyoming will generally oxidize and precipitate within a few hundred yards from the outfall, resulting in effluent with minimal to non-detectable concentrations of dissolved iron.

Discharges from nearby coal mines and coal-bed natural gas facilities may contribute to the high dissolved iron in Antelope Creek if the following conditions were to occur: 1) effluent with high dissolved iron was discharged within a very short distance from the stream, 2) sufficient effluent flows with high dissolved iron entered the stream prior to full oxidation or 3) effluent characterized by high dissolved iron and low pH had the potential to reach the stream. A review of discharge information on permitted coal-bed natural gas and coal mine discharges to tributaries of Antelope Creek was conducted to determine whether any of these scenarios could occur and contribute to the elevated dissolved iron concentrations in Antelope Creek. Most effluent discharges in the Antelope Creek drainage are to the ephemeral tributaries of Spring Creek, Horse Creek and Porcupine Creek (Figures 1 and 4). The dissolved iron permit effluent limits on outfalls in the area are ≤ 1000 ug/L. The vast majority of these outfalls, particularly from the coal mines, have not discharged in several years. These include outfalls in close proximity to Antelope Creek. Of the outfalls that regularly discharge, effluent flows are minimal (generally <0.5 cfs) and dissolved iron concentrations at the outfall are generally less than 1000 ug/L. There are a

Figure 4 – Tributaries to lower Antelope Creek and associated WYPDES permitted outfalls, WDEQ/WQD stations and USGS stations. Note – approximate mean flow and maximum dissolved iron concentrations for each outfall were determined from available discharge monitoring and inspection reports completed from 2005-2006.



handful of outfalls that discharge effluent to the middle sections of Spring Creek with dissolved iron concentrations >1000 ug/L. However, the combination of distance from Antelope Creek (>10 miles) and flows ≤ 0.6 cfs make it highly unlikely that the effluent would reach Antelope Creek, even when considering the cumulative effluent inputs to Spring Creek. Assuming the effluent does reach Antelope Creek, there is adequate distance to allow for oxidation and precipitation of the dissolved iron in addition to possible dilution through mixing with other effluent and local springs in the drainage. Under these circumstances, if effluent were to reach Antelope Creek, it would be reasonable to presume dissolved iron concentrations would be well below 1000 ug/L. Indeed, dissolved iron concentrations at the Porcupine Creek USGS station 06364300 have been ≤ 117 ug/L within the last several years, even with several upstream effluent discharges. Finally, facilities in the area discharge effluent with a pH between 7 and 8, conducive to precipitation of dissolved iron upon exposure to oxygen. Only at a pH less than 3 will iron remain in a dissolved soluble state under aerobic conditions (Hounslow 1995). Given all available information, the possibility for effluent from coal-bed natural gas and coal mine facilities to elevate dissolved iron in Antelope Creek is remote under the previous three scenarios.

Anecdotal information from landowners and permittees indicates flows from tributaries (which can receive coal mine and coal-bed natural gas effluent) into Antelope Creek have been negligible to non-existent in recent years. In fact, much of the effluent is used for dust suppression. Flows in Porcupine Creek below Porcupine Reservoir (which captures upstream coal-mine and coal-bed natural gas discharges) have been absent for much longer. According to the landowner, the reservoir has been dry and a release of anaerobic water near the bottom of the reservoir that contains elevated dissolved iron is not possible since the only outlet is located at the spillway. Contributions of dissolved iron to lower Antelope Creek from permitted coal-bed natural gas facilities that discharge to the upper headwaters of Antelope Creek appears to also be a remote possibility for the same factors described above (i.e., minimal to no effluent flow, dissolved iron concentrations <1000 ug/L, pH between 7 and 8, precipitation of iron within a short distance of the outfall, and long travel distances to lower Antelope Creek). Based on all information, there is reasonable assurance that effluent from permitted facilities represents a negligible contribution to elevated dissolved iron in Antelope Creek. No other sources of dissolved iron from anthropogenic activities in the area were noted.

With the removal of permitted discharges and other anthropogenic activities as significant sources of dissolved iron, it seems reasonable that the elevated dissolved iron in lower Antelope Creek probably coincides with local groundwater contributions that are naturally elevated in dissolved iron. To maintain elevated dissolved iron concentrations in oxygenated, alkaline, high pH surface water like Antelope Creek would require an almost continuous input from a nearby source, otherwise the dissolved iron would quickly precipitate. The most likely source of a continuous input would be from local springs. Natural groundwater inputs would also appear to be the most likely source of elevated dissolved iron in the

Cheyenne River at Dull Center. There are no nearby anthropogenic sources of dissolved iron near this location and contributions from permitted facilities in Antelope Creek appear remote. Another possible, but probably minor source of dissolved iron at both lower Antelope Creek and the Cheyenne River at Dull Center could be from seepage of dissolved iron from beaver dams where reducing conditions in the bottom of the ponds are present.

Dissolved concentrations of manganese in flowing water were well below the respective hardness-dependent numeric human health criteria (WDEQ/WQD 2001c and 2007) at all sites sampled by the USGS. Concentrations for total selenium at all USGS stations were less than the 5 ug/L criterion that is protective for aquatic life uses (WDEQ/WQD 2001c and 2007). Dissolved arsenic concentrations measured at all sampled USGS stations were below the maximum human health, fish consumption and drinking water criterion of 7 ug/L (WDEQ/WQD 2001c and 2007).

5.3 Physical Condition

(See Appendices 3 thru 12 for dataset) Longitudinal profiles, channel cross-sections, reachwide Wolman pebble counts and qualitative habitat assessments were conducted at WDEQ/WQD stations in 2003. Information on procedures for collecting longitudinal profiles, channel cross-sections and Wolman pebble counts can be found in Harrelson et al. (1994) and Rosgen (1996). Only qualitative habitat assessments were conducted at WDEQ/WQD stations in 2004. Total scores from the qualitative habitat assessments were not used in the evaluation of overall physical condition of a site because this method is not entirely applicable to intermittent streams. Rather, the categorical scores from the habitat assessments were used in conjunction with survey data, field observations and other assessments to evaluate physical conditions of the stream. Because no regional curves for bankfull parameters have been developed for streams in the Northwestern Great Plains ecoregion, there currently is no expected condition that can be compared to survey data gathered at the WDEQ/WQD stations in 2003. Therefore physical conditions determined from the 2003 data represent “baseline” information for comparisons to future data collections.

Antelope Creek (WDEQ/WQD Stations NGP156 and NGP158)

Geomorphic and Riparian Characteristics: Antelope Creek is a low gradient (<0.5%) pool-dominated stream that flows through a broad alluvial terraced valley (Rosgen Valley Type VIII) (Rosgen 1996). Antelope Creek at station NGP156 had a poorly defined channel and was classified as a Rosgen B5c. A large beaver dam complex was present at Antelope Creek station NGP158 that provided grade control and significantly influenced the morphology of the channel. The beaver dams at NGP158 appear to have been in place long enough that the channel has adjusted to the beaver influences. Based on channel bottom characteristics, the channel at NGP158 was estimated to be a Rosgen C5 channel. The streambed at both stations was composed entirely of sand with an abundance of organic detritus overlaying the sand at station NGP158. Both stations had a slight to moderately entrenched channel with adequate access to a well developed floodplain. In general, banks at both stations were considered stable with adequate riparian vegetation to stabilize and protect banks from disturbance and minimize erosion during high flows. There was no evidence of excessive bank erosion or deposition at either station. Sediment deposition was elevated (but not excessive) behind multiple beaver dams at station NGP158. Point bars at NGP158 were stable and had two or more age-classes of sedges and willows. Evidence of past beaver dam failures were present but there was no evidence of recent beaver dam failures. The channel at both stations appears to have downcut in the distant past, though there was no indication of active downcutting at either station. The riparian zone at both stations consisted primarily of sedges, rushes, and patches of cottonwood and willow saplings with an extensive decadent cottonwood and willow gallery on upper terraces. Livestock grazing was common at both stations with minimal disturbance to the riparian areas.


Antelope Creek WDEQ/WQD Station NGP156 (2003)

Aquatic Habitat Characteristics: NGP156 was a dry channel on the date of sampling. Sedges and rushes would provide most of the instream and overhead cover in pools when water was present. The entire channel at NGP158 was inundated by beaver dams with homogenous pond depths of 2 to 3 feet on the date of sampling. The aquatic habitat at NGP158 was more typical of a linear pond (lentic) rather than a stream environment. Submerged aquatic macrophytes, organic detritus and woody debris dominated the instream cover for pools at NGP158. Riparian sedges and grasses provided some overhead pool cover. Pool frequency as defined geomorphically, was high at this station with maximum bankfull pool depths of one foot. Undercut banks were not present at NGP156, however, this was within expectations considering the Rosgen B stream type and hydrology of the reach. Undercut banks were present though minimal at NGP158.


Antelope Creek WDEQ/WQD Station NGP158 (2003)

Black Thunder Creek (WDEQ/WQD Stations NGP163 and NGP164)

Geomorphic and Riparian Characteristics: Black Thunder Creek is a low gradient (<0.5%) pool-dominated stream that flows through a broad alluvial terraced valley (Rosgen Valley Type VIII). Black Thunder Creek at stations NGP163 and NGP164 was a deeply incised, moderately-entrenched, gravel-dominated channel classified as a Rosgen B4c. Pools with standing water at NGP164 were generally silt dominated overlain by a thin layer of organic detritus. The stream at both stations had experienced multiple episodes of channel downcutting in the past as evidenced by several terraces identified between the current floodplain and the top of the original floodplain where an old and decadent cottonwood/willow gallery exists. The stream continues to develop a new floodplain (albeit narrow) inside its old incised channel and has no access to its older floodplain in the decadent cottonwood/willow gallery. It is unknown as to the exact reasons for the past downcutting though it's suspected to be due to a combination of modifications to the flow regime, adjustments in land management and rapid changes associated with climate/weather (dry cycle followed by a wet cycle) and intense flood events. Considering the valley type, geology, soils and landscape characteristics, Black Thunder Creek may have been a Rosgen C channel in the distant past prior to the extensive channel changes that have occurred. In general, Black Thunder Creek appears to be on an improving trend towards re-establishment of a stable channel form. However, given the present climate, it's ephemeral to intermittent hydrologic conditions and assuming no major changes in land management occur, it may take several decades for Black Thunder Creek to re-establish a stable channel form. In any event, banks at both stations were considered moderately stable with adequate riparian vegetation and silt/clay soils to stabilize and protect most banks from disturbance and minimize erosion during high flows. Though there was no evidence of active downcutting, the channel at both stations appeared to be adjusting laterally along some meander bends as evidenced by bank sloughing and fracturing in these areas. In general, there was no evidence of excessive bank erosion or deposition at either station. Maximum bankfull riffle depths were near equal (1.4 ft) at both stations. The bankfull cross-sectional area at NGP163 (11.7 ft^2) was unexpectedly less compared to upstream NGP164


Black Thunder Creek WDEQ/WQD Station NGP164 (2003)


Black Thunder Creek WDEQ/WQD Station NGP163 (2003)

(15.1 ft^2). In general, bankfull cross-sectional area is expected to increase with distance downstream. Less than expected bankfull cross-sectional area at NGP163 is suspected to be the result of both natural and anthropogenic changes in the hydrology of the watershed from impoundment construction, surface water diversions, groundwater withdrawal from shallow aquifers, mining and losses to the alluvial aquifer (natural 'losing stream'). No evidence of past beaver dam failures or active beaver dams were present at either station. The active riparian zone (within the incised channel) at both stations consisted primarily of sedges, grasses, and a few cottonwood and willow saplings. Livestock grazing was common at both stations though there was minimal disturbance within the active riparian zones due to inaccessibility.

Aquatic Habitat Characteristics: Both NGP163 and NGP164 were generally dry channels on the dates of sampling. Small isolated pools were scattered throughout the sample reach at NGP164 with a large lentic-type pool located at the upper end of the sample reach where macroinvertebrates were sampled. Only wet areas were present within the sample reach at NGP163, though a few small shallow pools that may have been spring-fed were observed outside the reach on the date of sampling. Dominant in-stream cover for pools at both stations, when water is present, would consist primarily of small woody debris, organic detritus, gravels and sands, sporadic undercut banks and inundated sedges and grasses. Sedges and grasses would provide some overhead cover in pools when water is present. Pool frequency as defined geomorphically**,** was high at both stations with maximum bankfull pool depths of 2.9 ft at NGP164 and a deeper depth of 3.9 ft at NGP163. Pool spacing and pool length were greater at NGP163 compared to NGP164.

Cheyenne River – Upper and Middle (WDEQ/WQD Stations NGP159 and NGP162)

Geomorphic and Riparian Characteristics: The upper and middle sections of the Cheyenne River is a low gradient (<0.5%) pool-dominated stream that flows through a broad alluvial terraced valley (Rosgen Valley Type VIII). The Cheyenne River at station NGP159 was a sand dominated Rosgen C5 channel. The channel at NGP162 was classified as a gravel-dominated Rosgen C4 channel. The Rosgen C channel type was the expected natural stream type at both stations considering the valley type, geology, soils and landscape. In 2003, a large beaver dam complex at station NGP159 provided grade control and influenced the morphology of the channel throughout much of the reach. Most of the beaver dams were newly constructed and evidence of past beaver dam failures were scattered throughout the reach. Beaver appeared to have


Cheyenne River WDEQ/WQD Station NGP159 (2003)

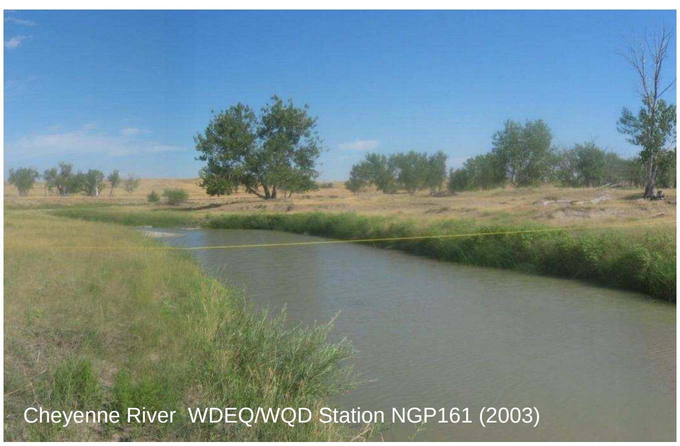
overtaken the reach at NGP159 in 2004. Beaver dams that were present in 2003 had increased in height, new beaver dams were present and appreciable tree felling by beaver had occurred throughout the reach. A few small beaver dams were present at station NGP162 in 2003, located near spring-fed pools. New beaver dams were also present at NGP162 in 2004 though not to the extent observed at NGP159. It is suspected that drought conditions in the basin resulted in longer periods of low water and a reduced frequency of scouring flows that facilitated an increase in woody riparian vegetation recruitment in these areas. Consequently, the increased supply of woody vegetation allowed beaver to readily colonize these areas with new dams and repaired/enhanced existing dams. Because of their natural stream type, the channels at both stations are susceptible to high rates of lateral migration and bank erosion that are influenced by the presence and condition of riparian vegetation and changes in flow and sediment regimes. Despite the recent beaver activities, banks at both stations were considered stable with adequate riparian vegetation and silt/clay soils to stabilize and protect banks from disturbance and minimize erosion during high flows. In addition, there was little evidence of active lateral channel migration or excessive bank erosion and deposition at either station. Sediment deposition was elevated (but not excessive) behind beaver dams at both stations. Point bars at both stations appeared stable and had two or more age-classes of sedges and cottonwoods/willows. Both stations had a slightly entrenched channel with adequate access to a well developed floodplain. The channel at both stations appears to have downcut in the distant past, though there was no indication of active downcutting at either station on the dates of sampling. Maximum bankfull riffle depths were near equal (~ 1 ft) at both stations. As expected, the bankfull cross-sectional area at NGP162 (10.4 ft^2) was greater relative to NGP159 (8.8 ft^2) due to an increase in watershed area. The width-to-depth ratio at NGP159 (76.0) was higher than at NGP162 (16.6) simply because the channel at NGP159 was less entrenched. NGP162 had incised over a long period of time, likely in response to greater peak flows as a result of a greater contributing watershed relative to NGP159. The riparian zone at both stations consisted primarily of sedges, rushes, and cottonwood and willow saplings with an extensive decadent cottonwood and willow gallery on the upper terraces. Some Russian olive, thistle and salt cedar were present in the riparian areas at both stations. Livestock grazing was common at both stations though minimally disturbed the riparian area. At station NGP159 in 2004, beaver had caused appreciable disturbance to the riparian woody vegetation zone by cutting numerous cottonwood trees and willow shrubs for dam building.


Cheyenne River WDEQ/WQD Station NGP162 (2004)

Aquatic Habitat Characteristics: On the dates of sampling, station NGP159 possessed several perennial segments maintained by springs and beaver dams while station NGP162 was generally a dry channel with a few beaver dams and spring-fed areas that appeared to persist year-round. Sedges, rushes, submerged aquatic macrophytes, small woody debris, organic detritus, large gravels and cobbles provided most of the instream cover in pools at both stations. However, there appeared to be more emergent and submerged aquatic and riparian vegetation in pools at NGP162 compared to NGP159. Overhead pool cover at both stations was provided by sedges, rushes, grasses and cottonwood and willow. Pool frequency as defined geomorphically, was high at both stations with maximum bankfull pool depths of 2.9 ft (NGP162) and 3.9 ft (NGP159). Undercut banks were common throughout NGP159 and NGP162.

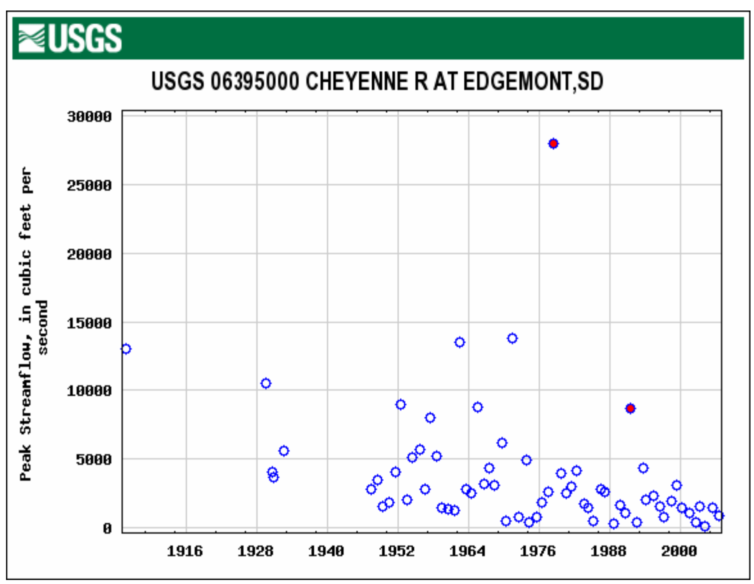
Cheyenne River – Lower (WDEQ/WQD Stations NGP160 and NGP161)

Geomorphic and Riparian Characteristics: The lower section of the Cheyenne River is a low gradient (<0.5%) pool-dominated stream that flows through a broad alluvial terraced valley (Rosgen Valley Type VIII). The Cheyenne River at stations NGP160 and NGP161 was a gravel dominated Rosgen F4 channel. A large beaver dam complex at station NGP161 provided grade control and influenced the morphology of the channel in some areas of the reach. Several of the beaver dams at this station were newly constructed and evidence of past beaver dam failures were scattered throughout the reach. Only a few small beaver dams were present at station NGP160. By classification, the channels at both of these stations are not in a stable form. Considering the valley type, geology, soils and landscape characteristics of the lower Cheyenne River, a stable Rosgen C channel type would be expected to occur at NGP160 and NGP161. As noted previously, Rosgen C channels are susceptible to high rates of lateral migration and bank erosion (followed by downcutting) influenced by the presence and condition of riparian vegetation and changes in flow and sediment regimes. Evidence of historical channel downcutting and widening and lateral migration were present at both stations. Extensive levee and ditch systems confined the channel along NGP161 and the mouth of Lance Creek which confluences the Cheyenne River immediately upstream of NGP161. According to records from the Wyoming State Engineers Office, groundwater withdrawals are scattered throughout the valley in the vicinity of both stations. Changes in the flow and sediment regime as a result of these activities, tributary impoundments, land use changes, modifications associated with climatic cycles (drought followed by a wet period) and intense flood-events may be the reason for channel changes that have occurred at


Cheyenne River WDEQ/WQD Station NGP161 (2003)

NGP160 and NGP161. There is some evidence to indicate that intense flood-events have contributed to recent channel changes. At NGP160, a line of young cottonwood was present on a recent terrace located immediately above the current flood-plain. This onset of growth likely coincided with a flood that occurred in the early 1990s based on peak flow information from a USGS station on the Cheyenne River just inside South Dakota (Figure 5). Above this line of young cottonwood was another terrace of older cottonwood which may have been recruited after a major flood that took place in the late 1970s (Figure 5). The incision of the channel since these floods is additional evidence to suggest that intense 'flashy' flows associated with a large watershed can have a significant influence on channel morphology of the lower Cheyenne River. The available information suggests the channel at both stations, particularly at NGP160, may transition back to a more stable Rosgen C channel type. However, as with other streams in the basin, given the present climate, its current hydrologic conditions and assuming no major change in land management occurs, it may take a long period of time for the lower Cheyenne River to re-establish a stable channel form. This is particularly relevant in light of channel changing processes associated with natural flood events. Despite such processes, banks at both stations were generally stable with adequate riparian vegetation and silt/clay soils to stabilize and protect most banks from disturbance and minimize erosion during high flows. Though there was no evidence of active downcutting, some bank sloughing and fracturing were present along meander bends at both stations suggesting some lateral migration is still occurring. Central and transverse bars were present at both stations, though most had or were becoming stabilized with vegetation. New channel bar deposits were minimal and only found immediately downstream of meander bends where bank sloughing and fracturing were occurring. Sediment deposition was elevated (but not excessive) behind beaver dams at

Figure 5 – Instantaneous peak flow hydrograph for stream discharge at USGS station 06395000. Peak flows in 1979 and 1992 are highlighted in red.



both stations. Stable point bars had developed at both stations and had two or more age-classes of sedges and cottonwoods/willows. Though entrenched, both stations were actively developing floodplains within their F channels. Maximum bankfull riffle depths were 0.7 ft at NGP161 and 1.3 ft at NGP160. As expected, the bankfull cross-sectional area at NGP160 (18.1 ft^2) was greater relative to NGP161 (14.5 ft^2) due to an increase in watershed area. The width-to-depth ratio at NGP160 (45.2) and NGP161 (55.4) were within expectations for an actively transitioning F4 channel type though exceedingly high compared to what would be expected for a C channel type at these stations. The riparian zone at both stations consisted primarily of sedges, rushes, and sizeable cohorts of cottonwood and willow saplings with an extensive decadent cottonwood and willow gallery on the upper terraces. Invasive vegetation such as thistle, Russian olive and salt cedar also occurred at both stations. Livestock grazing was common with minimal to moderate disturbance to the riparian area. On the dates of sampling, much of the upland vegetation at both stations was dry and brittle with minimal new growth due to the prolonged drought over much of the Cheyenne River basin. However, upland vegetation had also been close-cropped by livestock and large patches of bare ground were common at both stations.

Aquatic Habitat Characteristics: On the dates of sampling, stations NGP160 and NGP61 were intermittent channels with perennial segments maintained by minimal flows from Lance Creek and other tributaries, local springs and beaver dams. Sedges, rushes, submerged aquatic macrophytes, small woody debris, large gravels and cobbles provided most of the instream cover in pools at both stations. Overhead pool cover at both stations was provided by sedges, rushes, grasses and cottonwood and willow. Pool frequency as defined geomorphically, was high at both stations with maximum bankfull pool depths of 1.7 ft (NGP161) and 2.1 ft (NGP160). Undercut banks occurred sporadically throughout NGP160 and NGP161.

5.4 Aquatic Life Condition

(See Appendices 13 thru 16 for dataset) Aquatic benthic macroinvertebrates are used as the primary indicators of cumulative water quality change and aquatic life condition by WDEQ/WQD. All WDEQ/WQD sites on the Cheyenne River and its tributaries where biological data were collected contained less than 10% riffle habitat and were located on non-flowing pool-dominated intermittent reaches. Therefore, benthic macroinvertebrates were collected using a multi-habitat dip net sampling method. WDEQ/WQD collected benthic macroinvertebrate samples in 2003 at five locations. Benthic macroinvertebrate samples were also collected using a multi-habitat sampling technique by the USGS in 2005 at Antelope Creek near Teckla (station 06364700), Black Thunder Creek near Hampshire (station 06376300), Cheyenne River at Dull Center (station 06365900) and Cheyenne River near Spencer (station 06386500). The locations of the USGS stations are similar to that of most WDEQ/WQD stations. Therefore, macroinvertebrate data from both WDEQ/WQD and USGS stations generally were evaluated in conjunction with one another.

Conventional interpretation of benthic macroinvertebrate data in Wyoming generally is derived using two biological indicator models, the Wyoming Stream Integrity Index (WSII) and the WY RIVPACS (Hargett et al. *In Press*; Hargett and Zumberge 2006; Hargett et al. 2005). However, neither model was designed to assess aquatic life condition from intermittent streams. Consequently, without a known biological benchmark for intermittent systems, determinations of aquatic life use support using the models' narrative aquatic life condition ratings would result in erroneous assessments of aquatic life condition for intermittent streams. In lieu of using the models to directly assess aquatic life condition on intermittent systems, scores from the WSII and WY RIVPACS and professional judgment were instead used to look at overall spatial changes in assemblages along the Cheyenne River and its tributaries. The WY RIVPACS could not be applied to the USGS data due to insufficient information. In addition, WSII and WY RIVPACS scores for non-reference sites were compared directly to selected least-impacted reference sites to assess the percent comparability of the community to an intermittent stream reference condition. Two WDEQ/WQD sites on intermittent segments of the Cheyenne River (stations NGP159 and NGP162) were identified as least-impacted reference quality and used for comparison to other WDEQ/WQD and USGS stations on the Cheyenne River, Antelope Creek and Black Thunder Creek. These two intermittent stream reaches of the Cheyenne River Basin had received the least impact from alterations to the channel, riparian vegetative community and modifications to the natural flow regime relative to other streams in the basin and surrounding area. Specifically, sites NGP159 and NGP162 were characterized by a diversity of suitable habitat and riparian vegetative cover, stable channel form and pattern, minimal impact from upstream hydrologic modifications and few anthropogenic influences in their watersheds with sound land use practices at and near the sites. For purposes of this report and considering the dynamic complexities of intermittent streams, a percent comparability of ≥ 80% of the least-impacted reference condition will be considered full-support of the aquatic life use criteria.

At present, there is not an adequate biological indicator model for intermittent plains streams of the Cheyenne River Basin or elsewhere in the United States. However, there are individual metrics that may have potential as informative indicators in intermittent plains streams characterized by communities with naturally wide tolerance ranges, particularly when comparisons are made to local least-impacted reference reaches. Several taxa richness (number of taxa) measures can be used to determine the overall condition of aquatic life residing in pools of intermittent streams. In general, better water and habitat quality correspond to higher taxa richness. A greater proportion of taxa sensitive to pollution (i.e. mayflies, stoneflies and caddisflies) relative to tolerant taxa (i.e. aquatic worms and midges) may be indicative of a healthy stream community. However, this approach must be used with caution since midges (Chironomids) and other non-insects can be naturally taxonomically rich in intermittent streams. The richness of tolerant taxa in a community is another indicator that can be used to evaluate relative stress at a site. In general, sites that experience excessive environmental stress will have a higher richness of tolerant taxa relative to expected reference conditions. For example, a community characterized by low taxa richness and dominated by midge taxa can be indicative of poor water quality conditions in some circumstances. Metrics such as the relative abundance of particular taxa may also provide insight into the biological condition of intermittent systems. Intermittent stream macroinvertebrate communities have naturally broad tolerance ranges to environmental conditions and are inherently less diverse relative to perennial systems. Though midges as a group are quite common in intermittent habitats, the relative abundance of highly tolerant midges and to some extent other highly tolerant dipterans in the community, may increase in response to severely degraded conditions (Davis et al. 2003). This shift from a community with naturally broad tolerances to one comprised almost entirely of highly tolerant taxa could arise when environmental conditions are so severe that only the most tolerant taxa are able to survive and reproduce. Thus, severe environmental conditions such as very low dissolved oxygen, high concentrations of toxic metals or excessive sedimentation may select for these highly tolerant taxa while reducing the numbers of less tolerant (but not necessarily sensitive) taxa. Excessive nutrient enrichment is another example of severe conditions which may eliminate most of the indigenous taxa of an intermittent stream and replace them with a new highly tolerant dominant group of organisms, including aquatic worms (Oligochaetes) and highly tolerant midges. The relative abundance and richness of predator taxa may also provide a measure of the trophic complexity of a site (Kerans and Karr 1994). In general, less disturbed sites have plentiful habitat niches to support rich prey taxa which also support a rich predator assemblage. However, predator abundance and in some cases richness may be limited by fine sediment and limited in-stream habitat.

Lastly, the biological data were compared to narrative expectations derived from the literature. The benthic macroinvertebrates of ephemeral and intermittent streams will normally not contain the same species as what would inhabit a similar perennial stream. In general, intermittent and ephemeral streams will have diminished taxa richness and often simplified macroinvertebrate communities that consist of tolerant taxa than perennial streams due to regular flooding and drying events and their associated environmental impacts (Dodds et al. 2004; Peterson 1990). In intermittent and ephemeral streams where the duration and frequency of flow are highly variable, the indigenous macroinvertebrate community often will be comprised of taxa that can produce multiple generations within a season (such as multivoltine midges), are adapted to stranding and exposure and taxa that utilize temporary waters to complete a portion of their lifecycle. Late emerging taxa, taxa with a major growth period in the summer or taxa with long-lived cycles (semivoltine) would generally be absent. Low dissolved oxygen and warmer temperatures in intermittent and ephemeral streams may select for stress tolerant assemblages with sensitive taxa first to disappear as the environment becomes harsher. The abundance of deposited organic material in pool-dominated habitats are also conducive for colonization by collector-gatherer taxa. Geologic, landscape and other abiotic factors may also be critical in structuring macroinvertebrate assemblages of intermittent and ephemeral streams (Poff and Ward 1989). Common fauna of intermittent and ephemeral streams will be comprised of generalist taxa such as small crustaceans

(Amphipoda), flatworms (Turbellaria), beetles (Dytiscidae, *Dubiraphia*, etc.), tolerant caddisflies (Hydropsychidae), tolerant mayflies (Caenidae), water mites (*Acari*), dragon/damselflies (Odonata), backswimmers (Notonectidae), water boatmen (Corixidae), and a variety of midges (Chironomidae) and other fly larvae (Graham 2002; Peterson 1990, Zale et al. 1989).

<u>Antelope Creek (WDEQ/WQD Station NGP158 and USGS Station 06364700)</u>

Stations NGP158 and 06364700 are within one mile of one another and therefore represent the same stretch of lower Antelope Creek. Total taxa richness was between 30 and 32 at these stations which included up to 3 EPT (Ephemeroptera, Plecoptera and Trichoptera) taxa all of which were considered wide-spread tolerant generalists. Considering the pool environment and the abundance of decomposed organic material at this site it was not surprising that over one-half of the total number of taxa were collector-gatherers that feed on organic detritus. Midges comprised the largest number of the total taxa at both stations. The relative abundance of midges was some of the highest at these stations relative to other sampled stations perhaps due to the lentic-type conditions and abundance of aquatic macrophytes at these sites which can be conducive to midge recruitment. The mayfly *Caenis* was the most commonly identified macroinvertebrate at NGP158. Caenids are wide-spread collector-gatherers that predominantly occur in ponds and pools and are adapted to fine substrates (Merrit and Cummins 1996; Ward 1992). These mayflies are tolerant to a wide range of conditions such as moderately low dissolved oxygen and warmer water temperatures associated with slow moving or standing waters. Snails from the families Lymnaeidae and Physidae were the most common taxa collected at 06364700. Snails can commonly make up a large percentage of the macroinvertebrate community in slow-moving or standing, fine-sediment dominated habitats with abundant macrophytes (Thorp and Covich 2001) as was present in the lower section of Antelope Creek. Other common taxa in the samples included the amphipod *Hyallela* and the midges *Tanytarsus* and *Micropsectra*. Few oligochaetes were present in either sample suggesting severe environmental stressors like nutrient enrichment were not present. Predator taxa richness at both sites was high, similar to other stations and suggestive of diverse habitat. However, the relative abundance of predators at both sites was lower compared to other stations. Though there were a diverse number of habitat types, the relative proportion of fine sediment substrate was the dominant habitat type which may have limited predator relative abundance. As expected, a sizeable proportion of the total taxa at both sites were considered highly tolerant. All expected components of a typical intermittent stream community were represented at both stations. The WSII and WY RIVPACS assigned scores of 40.6 and 0.41, respectively to NGP158. The WSII score at 06364700 was 31. The lower score at 06364700 relative to NGP158 was due to fewer EPT taxa and the abundance of snails which inflated the percentage of collector-gatherers. Model results for both stations were >80% comparable to the mean expected reference condition for intermittent streams in the basin. Several age-classes of warm-water green sunfish (*Lepomis cyanellus*), plains killifish (*Fundulus zebrinus*) and common carp (*Cyprinus carpio*) were observed by WDEQ/WQD in pools at NGP158 in 2003. Eight species of fishes were collected by WGFD on Antelope Creek in the vicinity of NGP158 in 2004/2005 (WGFD 2007). These include three native fishes [fathead minnow (*Pimephales promelas*), sand shiner (*Notropis stramineus*) and white sucker (*Catostomus commersoni*)] and five non-natives [black bullhead (*Ameiurus melas*), plains topminnow (*Fundulus sciadicus*), plains killifish, green sunfish and common carp].

Black Thunder Creek (WDEQ/WQD Station NGP164)

Total taxa richness was 24 at NGP164 which included only two EPT taxa. Both EPT taxa were wide-spread generalist mayflies adapted to living under harsh conditions. Around one-half of the total taxa were considered highly tolerant. Collector-gatherer and predator taxa comprised over 70% of the total taxa in the sample. Midge richness was similar to that of other stations, though the relative abundance of this group was high, likely due to the lentic-type habitat of the sampled segment. The mayfly *Caenis* and the Coenagrionidae pond damselflies were the two most commonly collected macroinvertebrates in the sample. Coenagrionids are wide-spread generalist predators that inhabit ponds, streams and marshy areas with emergent vegetation for reproduction (Merrit and Cummins 1996; Ward 1992). Other common taxa in the sample included *Hyallela* and the midge *Paratanytarsus*. Predator richness and relative abundance were similar to that of other sites with coarser bed materials and suggestive of diverse habitat. Few oligochaetes were present in the sample. All expected components of a typical intermittent stream community were represented. WSII (33.0) and WY RIVPACS (0.27) scores for station NGP164 had an average 83% comparability to the mean expected reference condition. On the date of sampling, several age-classes of warm-water green sunfish, black bullhead and sand shiner were observed by WDEQ/WQD in the sampled pool at NGP164. Seven species of fishes were collected by WGFD on Black Thunder Creek in the vicinity of station NGP164 in 2004/2005 (WGFD 2007). These included five natives [flathead chub (*Platygobio gracilis*), fathead minnow, plains minnow (*Hybognathus placitus*), sand shiner and white sucker] and two non-natives (black bullhead and green sunfish).

Black Thunder Creek (USGS Station 06376300)

Total taxa richness at 06376300 was 39 which included two EPT taxa. As with NGP164, both EPT taxa were wide-spread tolerant mayflies and as expected, a large proportion of the total taxa were considered tolerant. Similar to NGP164, collector-gatherer and predator taxa comprised >90% of the total taxa richness with midges (21) making up the largest proportion of the total taxa richness. Much like NGP164, midge relative abundance was high and predator richness and relative abundance was comparable to other stations with coarser bed sediment. The mayfly *Caenis* and the midge *Chironomus* were the two most commonly collected taxa in the sample. No oligochaetes were collected and the community was representative of what would be expected in a typical intermittent stream. The WSII score was 41.3 or 108% comparable to the mean reference condition of the two Cheyenne River least-impacted reference sites. WGFD collected eight species of fishes near this USGS station in 2004/2005 (WGFD 2007). Fishes present included four natives (fathead minnow, plains minnow, sand shiner and white sucker) and four non-natives [black bullhead, green sunfish, largemouth bass (*Micropterus salmoides*) and plains killifish].

Cheyenne River – Upper/Middle (WDEQ/WQD Stations NGP159, NGP162 and USGS Station 06365900)

As mentioned previously, stations NGP159 and NGP162 were considered representative of least-impacted reference conditions for intermittent stream reaches of Cheyenne River Basin. In other words, the biological condition at NGP159 and NGP162 represent a reasonable expected condition for other intermittent streams in the Cheyenne River Basin. Though high dissolved iron concentrations were noted at USGS station 06365900 upstream of NGP159, the predominant source is believed to be natural. NGP162 contained a total of 33 taxa, the highest taxa richness of any macroinvertebrate samples collected in 2003. Though still diverse, fewer total taxa (22) were collected at NGP159 relative to NGP162. In 2005, 35 taxa were collected at 06365900 located just a few miles upstream of NGP159. Two of the total taxa at each station represented the EPT group. Of the total taxa, a sizeable number at all stations were considered highly tolerant taxa. As expected, over 70% of the total taxa collected at NGP159 and NGP162 were represented by collector-gatherers and predators. Only 50% of the total taxa at 06365900 were collector-gatherers. Midges comprised the largest number of total taxa (9 at NGP159, 12 at NGP162, 18 at 06365900) at each station though they were in relatively lower abundance compared to the lentic-type segments in Antelope Creek and Black Thunder Creek. The mayfly *Caenis* was the most commonly collected taxon at both WDEQ/WQD stations followed by *Hyallela* at NGP159 and the pond damselfly *Enallagma* (a member of the family Coenagrionidae) at NGP162. Similar to Antelope Creek station 06364700, snails from the families Lymnaeidae and Physidae were the most common taxa at 06365900. At all stations, oligochaetes were few in number and the community was typical of what would be expected in an intermittent plains stream. Predator richness at all three sites were comparable and suggestive of diverse habitat. Elevated fine sediment at NGP159 may have limited predator relative abundance to some degree compared to NGP162 and 06365900. WSII scores for NGP159 and NGP162 were 35.8 and 40.6, respectively. Likewise, WY RIVPACS scores for NGP159 and NGP162 were 0.41 and 0.27, respectively. Based on these model scores, the benthic macroinvertebrate community at station NGP159 had an average 108% comparability to the mean reference condition. Similarly, the macroinvertebrate community at NGP162 attained an average 93% comparability to the mean reference condition. The WSII score for 06365900 was 34.3 or 89% of the expected mean reference condition. At both WDEQ/WQD stations, several age-classes of green sunfish, plains killifish, plains topminnow and black bullhead were observed on the dates of sampling. A few individuals (8-12”) of largemouth bass were observed in the sampled pond at NGP162 by WDEQ/WQD. Near NGP159, WGFD collected eight species of fishes in 2004/2005 (WGFD 2007). These included three natives (fathead minnow, sand shiner and white sucker) and five non-natives (black bullhead, common carp, green sunfish, plains killifish, and plains topminnow). Likewise, near NGP162, WGFD collected twelve species of fishes which consisted of six natives [flathead chub, fathead minnow, plains minnow, river carpsucker (*Carpiodes carpio*), sand shiner and white sucker] and six non-natives (black bullhead, common carp, green sunfish, largemouth bass, plains killifish and plains topminnow).

<u>Cheyenne River – Lower (WDEQ/WQD Station NGP160 and USGS Station 06386500)</u>

Stations NGP160 and 06386500 are within one-half mile of another and therefore represent the same stretch of the lower Cheyenne River. The lowermost stations on the Cheyenne River yielded between 30 and 34 total taxa with most represented by midges. Samples from both stations consisted of two EPT taxa which were both wide-spread generalist mayflies. Tolerant taxa represented a large proportion of the total taxa richness at each station. As observed at other sites in the Cheyenne River basin, >70% of the total taxa richness at each station were represented by collector-gatherers and predators. The most common taxon collected at NGP160 was the midge *Tanytarsus. Tanytarsus* is a collector-filterer that inhabits aquatic macrophytes, feeds on suspended organic detritus and is adapted to moderately oxygenated, saline environments characteristic of station NGP160 (Merritt and Cummins 1996; Ward 1992). Greater than 75% of the macroinvertebrate community at NGP160 in 2003 was comprised of *Tanytarsus* and other midges. However, in 2005 the midge component of the community at 06386500 decreased to a more expected and reasonable relative abundance of 32%. The dominance of *Tanytarsus* may have been the result of flow limited conditions during the sampling of NGP160 in August versus the June sampling at 06386500. The dominant taxon at 06386500 was *Simulium*. The *Simulium* black flies are wide-spread collector-filterers that inhabit a variety of coarse-substrate habitats (Merritt and Cummins 1996). The midge *Dicrotendipes*, *Caenis*, and the dipteran *Ceratopogoninae* were also common taxa at NGP160. *Caenis* and the midge *Paratanytarsus* were common taxa at 06386500. Predator richness was 10 at both stations suggesting diverse habitat. Relative abundance of predators was slightly less compared to other Cheyenne River stations. Similar to other sampled sites, oligochaetes were few in number and the communities at both stations were typical of what would be expected in an intermittent plains stream. The WSII and WY RIVPACS assigned scores of 39.7 and 0.27, respectively to NGP160 with an average comparability of 92% to the mean reference condition. The WSII score for 06386500 was 30.6 or 80% of the mean reference condition. Several age-classes of the following warm-water fishes were observed at NGP160 on the date of sampling: plains killifish, plains topminnow, green sunfish, common carp, black bullhead, suckermouth minnow (*Phenacobius mirabilis*) and fathead minnow. Near NGP160, WGFD collected six native and four non-native fishes in 2004/2005 (WGFD 2007). Native fishes included channel catfish (*Ictalurus punctatus*), fathead minnow, shorthead redhorse (*Moxostoma macrolepidotum*), river carpsucker, sand shiner and white sucker. Non-natives included black bullhead, common carp, green sunfish and plains killifish.

Dissolved iron concentrations in flowing water in close proximity to station NGP158 on Antelope Creek and station NGP159 on the Cheyenne River near Dull Center exceeded the numeric chronic aquatic life criterion of 1000 ug/L on multiple occasions from 2002 to 2006. However, the available information implies that these exceedences are likely due to naturally elevated dissolved iron from groundwater contributions. Although dissolved iron does not cause acute toxicity to aquatic organisms, it can pose chronic toxicity primarily through habitat influences because of its deposition on stream substrate. At a pH greater than 3.5, iron can precipitate in the form of ferric hydroxide. Precipitation of ferric hydroxide may result in covering of the stream bottom and filling of interstitial spaces creating poor conditions for habitation of benthic organisms (Hoehn and Sizemore 1977). The iron precipitate may also coat the gills and body surfaces of fishes and macroinvertebrates and smother eggs (Gerhardt 1992). However, Gerhardt and Westermann (1995) found that neither iron precipitate nor elevated iron concentrations affected the survival of mayfly nymphs over three months. Thus, direct smothering by iron precipitate appears less important in structuring stream communities compared to its alterations to habitat. This is further supported by McKnight and Feder (1984) who concluded metal precipitates such as ferric hydroxide may have a greater adverse effect on stream communities (via alterations to habitat) than high concentrations of metals like dissolved iron. The effect of precipitated iron on aquatic life appears to be less severe in alkaline waters with high pH. Many fish and macroinvertebrates are tolerant to iron precipitate in alkaline waters, however, relative abundance and richness are generally lower than in unaffected perennial streams (Gerhardt 1992, Koryak et al. 1972, Parsons 1968, Roback and Richardson 1969 and Warner 1971).

The literature shows that intermittent streams harbor macroinvertebrate communities that contain mixtures of wide-spread opportunistic generalists that are tolerant to harsh environmental conditions. Furthermore, these communities may naturally have reduced richness and abundance relative to perennial streams. The macroinvertebrate communities among all sampled stations were similar to one another and comparable to narrative expected conditions for intermittent streams derived from the literature. Accounting for differences in taxonomic resolution, taxa collected at the Cheyenne River Basin sites were comparable to what was expected. The macroinvertebrate communities exhibited high taxa richness, few extremely tolerant taxa such as oligochaetes, a common but not overly dominant midge community and taxa suggestive of diverse habitat for an intermittent stream. For all sites, evaluations of macroinvertebrate community attributes (metrics) were not suggestive of an altered community outside of what would naturally be expected for an intermittent stream and there were no obvious indications that the communities were subjected to severe environmental stressors. Macroinvertebrate communities at all sites were ≥ 80% comparable to the mean reference condition derived from two least-impacted reference sites on the Cheyenne River. Though subjected to high dissolved iron, the macroinvertebrate communities in the Cheyenne River at Dull Center (stations NGP159 and 06365900) and lower Antelope Creek (station NGP158 and 06364700) were comparable to the mean expected reference condition. A lower biological condition was noted in lower Antelope Creek, Cheyenne River at Dull Center and the lower Cheyenne River near the stateline in 2005 compared to 2003. Lower flows, variation in pool permanence and drying and associated physicochemical changes due to the prolonged drought are likely responsible for the change in biological condition. Nevertheless, biological condition in these areas remained comparable to the mean expected reference condition for the area based on the two least-impacted reference reaches in the watershed.

6.0 HISTORICAL AND ANCILLARY DATA

USGS collected dissolved iron data at station 06365900 (Cheyenne River at Dull Center) from 1975 to 1981 and at station 06364700 (Antelope Creek near Teckla) from 1977 to 1981 followed by samples collected in 2000 and 2001 during periods of flow. The historical data at these stations indicated only two exceedences of the 300 ug/L human health criterion for dissolved iron at station 06365900 (Cheyenne River at Dull Center) (Table 3). No exceedences of the 1000 ug/L chronic aquatic life criterion for dissolved iron were noted at either station for the periods of record. For the sample periods, most dissolved iron concentrations at both stations were <100 ug/L. In comparison with recent data (2002-2006), both stations have experienced a significant increase in the frequency of dissolved iron concentrations that exceed the respective human health and/or chronic aquatic life criteria since the historical data was collected.

As described previously, available information suggests that anthropogenic activities such as permitted effluent discharges are a negligible contributor to the dissolved iron exceedences in lower Antelope Creek and the Cheyenne River at Dull Center. The increase in dissolved iron concentrations since the historical data was collected coincides with drought conditions in the Cheyenne River basin that have been present since at least 2000. In fact, virtually all exceedences of the human health and chronic aquatic life criteria for dissolved iron have occurred during extremely low flow conditions of ≤ 0.05 cfs (Figure 6). Several years of below normal precipitation can lead to decreased surface runoff and recharge to shallow aquifers. Reductions in surface runoff and aquifer recharge combined with higher vegetative evapotranspiration rates can concentrate constituents. With limited recharge and surface runoff, more demand is placed on the aquifer to maintain baseflows in the stream, thereby

Figure 6 – Instantaneous dissolved iron and streamflow (1975-2006) at USGS station 06365900 (Cheyenne River at Dull Center). Red circles designate samples collected during 2004-2006. Open circles are samples collected during 1975-1981.

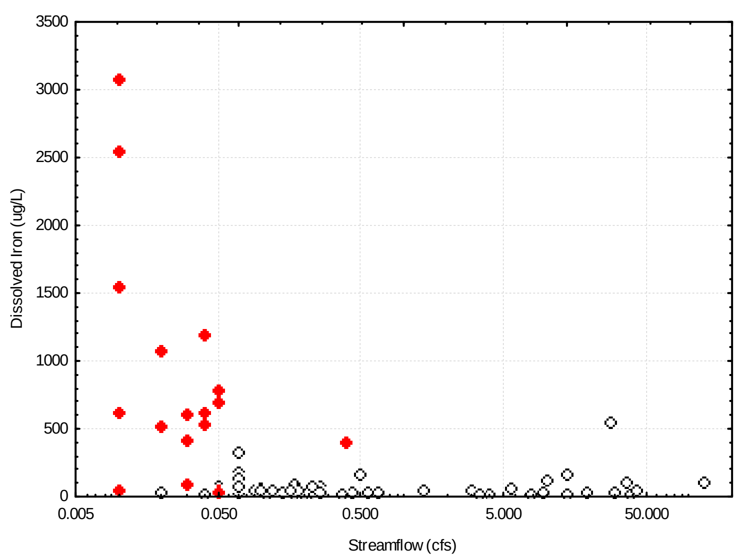


Table 3 – Historical dissolved iron concentrations and associated pH and discharge collected at USGS stations 06364700 (Antelope Creek near Teckla) and 06365900 (Cheyenne River at Dull Center).

	Cheyenne R. nr. Dull Center 06365900				Antelope Ck. nr. Teckla 06364700		
Collection Date	Discharge (cfs)	pH	D. Iron ug/L	Collection Date	Discharge (cfs)	pH	D. Iron ug/L
11/4/1975	0.2 est.	8.1	<10	11/4/1977	0.18	7.9	30
12/2/1975	0.5 est.	7.8	160	12/21/1977	0.13	7.4	50
2/3/1976	0.4 est.	7.7	<10	1/18/1978	0.15	8	20
5/4/1976	0.18	8.0	40	2/10/1978	0.19	7.9	280
6/9/1976	4	8.1	20	3/9/1978	37	7.7	60
7/8/1976	5.7	7.9	60	4/13/1978	1.6	8.1	340
8/3/1976	0.43	8.0	30	5/11/1978	33	8.3	30
9/1/1976	0.02	8.1	30	6/15/1978	5.7	8.2	20
9/28/1976	0.11	7.9	<10	7/13/1978	0.71	8.2	40
11/5/1976	0.07	7.9	30	8/3/1978	15	8.2	<10
12/8/1976	0.12	7.6	50	9/12/1978	0.12	8	20
2/4/1977	0.04	7.8	20	10/12/1978	0.14		50
3/31/1977	0.13	7.7	40	12/28/1978	0.33	7.9	30
4/28/1977	0.17	8.0	90	1/18/1979	0.28	7.7	190
5/25/1977	0.07	8.2	90	2/13/1979	0.86	7.8	50
7/7/1977	0.05	8.2	80	3/8/1979	17	8.1	40
8/2/1977	0.07	8.2	180	5/4/1979	16	8.2	30
8/30/1977	0.07	8.3	130	5/23/1979	3.7	8.1	<10
9/29/1977	0.01	8.2	50	6/21/1979	2.4	8	<10
11/9/1977	0.1	8.0	60	7/18/1979	0.11	7.9	<10
12/30/1977	0.18	7.5	20	8/15/1979	0.72	8	<10
2/1/1978	0.07	7.3	80	8/28/1979	37	8.3	<10
3/28/1978	14	8.7	160	10/4/1979	0.21	8	10
5/10/1978	128	7.9	100	11/13/1979	0.32	7.9	30
5/15/1978	39	8.3	<10	12/5/1979	0.48	7.7	130
6/6/1978	36	8.1	100	1/9/1980	0.24	7.8	40
7/19/1978	10	7.8	120	2/6/1980	0.42	7.8	10
8/16/1978	28	7.8	540	3/13/1980	25	8	20
9/13/1978	0.07	8.0	330	4/10/1980	9	8.2	20
10/11/1978	0.26	8.1	50	5/6/1980	3.7	8.1	20
11/8/1978	0.26	8.0	70	6/5/1980	6.5	8.2	20
3/13/1979	43	8.1	40	7/9/1980	0.03	7.7	30
4/14/1979	30	8.3	30	8/13/1980	0.02	8	30
5/9/1979	14	8.1	20	9/25/1980	0.06	8.1	30
6/9/1979	1.4	7.6	50	10/24/1980	0.11	8	40
7/18/1979	0.37	8.0	20	11/18/1980	0.2	7.4	50
8/14/1979	3	8.1	50	12/18/1980	0.2	7.9	70
9/11/1979	0.17	8.2	<10	1/13/1981	0.26	7.3	30
10/3/1979	0.2	8.3	10	2/11/1981	0.13	7.6	130
10/10/1979		8.2	30	3/15/1981	0.23	7.5	30
11/13/1979	0.24	8.0	10	4/14/1981	0.16	8	40
12/5/1979	0.26	7.7	30	5/20/1981	0.22	7.9	40
2/7/1980	0.18	7.5	60	6/16/1981	0.11	8	30
3/14/1980	9.4	7.9	30	8/11/1981	5.4	8.2	<10
4/9/1980	7.8	8.2	20	11/13/2000	0.15		547
5/9/1980	3.4	8.2	20	3/15/2001	0.28	7.3	est. 15
6/4/1980		8.4	20	5/7/2001	0.41	7.4	<30
6/11/1980		7.6	20	6/5/2001	0.21	7.3	<30
7/9/1980	0.14	7.9	30	7/10/2001	84	7.4	20
8/13/1980	0.09	8.2	50	11/13/2001	0.14	7.5	74
9/24/1980	0.17	8.3	40	12/5/2001	0.2	7.1	74
10/23/1980	0.23	8.3	70				
11/18/1980	0.18	7.3	40				
12/17/1980	0.17	8.2	50				
1/13/1981	0.11	7.3	40				
2/19/1981	0.56	8.2	30				
3/15/1981	0.18	7.6	50				
4/15/1981	0.12	8.2	50				
5/19/1981	0.66	8.4	30				
6/17/1981	0.16	8.2	50				
7/8/1981	0.04	8.1	20				
8/11/1981	19	8.3	30				
9/9/1981	0.1	8.2	40				
Green highlighted cells indicate no data was collected							
Red highlighted values are those that exceed the numeric human health criterion (300 ug/L) and/or chronic aquatic life criterion (1000 ug/L) for dissolved iron							

reducing water stored in the aquifer and leading to concentration of constituents both within the aquifer and the stream.

The WGFD collected fish survey data on Antelope Creek, Black Thunder Creek and the Cheyenne River in 2004/2005 (WGFD 2007). General conclusions from this survey were that all three drainages had intact native fish assemblages. In addition, no native species historically present in the drainages have been extirpated, though a few species were rare. Number of fish per mile along all three drainages varied with no linear pattern. Much of the variability appeared associated with the frequency and longevity of intermittent periods and limited in-stream and floodplain connectivity due to decreases in high stream flows and flooding events associated with the on-going drought conditions.

7.0 QUALITY ASSURANCE/QUALITY CONTROL

Station OA/QC reports are attached to this report. All physical, biological and chemical data collected by the WDEQ in 2003 and 2004 were determined to be complete and accurate.

8.0 SUMMARY AND CONCLUSIONS

8.1 Classification

The Cheyenne River is correctly classified as a Class 2AB warm-water stream. This conclusion is based on findings from the WDEQ/WQD stream assessments and fish collections conducted by WGFD. Field collections and observations by WGFD and WDEQ/WQD in the lower segment of Antelope Creek and Black Thunder Creek indicate these streams can support both non-game and game warm-water fishes at least seasonally and that their current 3B classification should be re-evaluated.

8.2 Water Quality

Water temperature and dissolved oxygen concentrations met the Wyoming water quality criteria of 30˚C and 5 mg/L, respectively, for Class 2AB warm-waters. The 30˚C water temperature criteria was exceeded only once (<10% of samples) on the lower Class 2ABww Cheyenne River during a three-year period of record. There are no numeric water temperature and dissolved oxygen criteria for Class 3B waters, though most values on these waters met the Class 2AB warm-water criteria. Water chemistry parameters without numeric criteria such as sulfate and specific conductance were elevated at all sites though within expected ranges for the Cheyenne River basin.

At Antelope Creek near Teckla (USGS station 06364700) the 1000 ug/L chronic aquatic life criterion for dissolved iron was exceeded twice (6% of total samples) from 2002-2005. Though the data is provisional, two additional exceedences of the chronic aquatic life criteria occurred in 2006. During 2004 and 2005, the Cheyenne River at Dull Center (USGS station 06365900), was characterized by ten exceedences (83% of total samples) of the 300 ug/L human health criterion and three exceedences (25%

of total samples) of the 1000 ug/L chronic aquatic life criterion for dissolved iron. Though the data is provisional, two and four additional exceedences of the numeric chronic aquatic life and human health criterion, respectively, occurred in 2006. The predominant source of dissolved iron appears to be from natural groundwater contributions to the streams exacerbated by the persistent drought conditions in the basin since at least 2000. Available data suggest effluent from permitted coal-bed natural gas and coal mine facilities is a negligible contributor to the dissolved iron exceedences.

The available information is insufficient to conclude whether nutrient enrichment (and resultant impacts to designated uses) is occurring in the Cheyenne River and its tributaries. All other measured water chemistry parameters did not exceed their respective numeric criteria and were conducive to support designated uses on the Cheyenne River and its tributaries.

8.3 Physical Condition

Throughout Antelope Creek, Black Thunder Creek and the upper and middle segments of the Cheyenne River, stream banks were generally considered stable, there was little to no evidence of excessive erosion or deposition and sufficient riparian vegetation complemented with silt/clay soils was present to dissipate energy and protect the banks during high flows. Though there was no evidence of active downcutting, Black Thunder Creek appeared to be migrating laterally along meander bends in response to historic perturbations as evidenced by some bank sloughing and fracturing in these areas. The active riparian zones of these streams were generally intact with minimal anthropogenic disturbances. Considering the geology, soils and hydrology of these streams, the resident pools provided adequate in-stream habitat and overhead cover for warm-water fishes and other aquatic life. Segments of the lower Cheyenne River continue to re-adjust their channel dimensions to more stable channels in response to historic perturbations and natural climatic cycles (drought followed by a wet cycle) and intense floods owing to a greater watershed area. The available information suggests that the lower Cheyenne River may transition back to a more stable channel form. However, given the present climate, current hydrologic conditions and assuming no major change in land management occurs, it may take a long period of time for the lower Cheyenne River to re-establish a stable channel form from past perturbations. Where excessive sedimentation and erosion had occurred in the past, much of the banks of the lower Cheyenne River were healed or healing and were generally stable with adequate vegetative cover complemented by silt/clay soils. In addition, riparian vegetation continued to stabilize channel bar deposits. New channel bar deposits were few and only found immediately downstream of meander bends where bank sloughing and fracturing were occurring as these areas continue to migrate laterally. The active riparian zone of the lower Cheyenne River was generally intact with minimal to moderate disturbances by anthropogenic activities such as grazing. Recruitment of upland and to some extent riparian vegetation in the lower Cheyenne River was inhibited primarily by the continued drought conditions and to a lesser extent by livestock grazing. Pools in this lower segment of the Cheyenne

River were generally shallower relative to the upper and middle segments due to their Rosgen F channels with high width-to-depth ratios and sloughing banks along the meander bends contributing sediment to the pools. Though shallow, pools continued to provide adequate instream habitat and overhead cover for warm-water fishes and other aquatic life. In general, the current anthropogenic activities on these streams appeared adequately managed. Localized human disturbances may be occurring in some of these reaches. However, the available information indicates that the vast majority of channel changes and any potential impact to the ability of the streams to support designated uses appeared related to intense flood events, drought cycles and the legacy of historical land use practices in the basin. In summary, the weight of physical evidence suggests that habitat conditions of Antelope Creek, Black Thunder Creek and the Cheyenne River were not significantly limiting the ability of these streams to support aquatic life and other uses.

8.4 Aquatic Life Condition

The ephemeral to intermittent hydrology and associated harsh physicochemical conditions of Antelope Creek, Black Thunder Creek and the Cheyenne River, is the primary factor that constrains the ability of these systems to support diverse and abundant macroinvertebrate communities comparable to those that inhabit perennial streams. The biological condition of the benthic macroinvertebrate communities in these streams, as evaluated by the WSII and WY RIVPACS, were generally similar to one another and comparable to least-impacted reference conditions for the area. Each stream also contained a rich macroinvertebrate community that was suggestive of diverse habitat and was within the general narrative expectations for intermittent plains streams. Furthermore, evaluation of macroinvertebrate community attributes (metrics) were not suggestive of an altered community outside of what would naturally be expected for an intermittent stream. Though subjected to what is considered naturally high dissolved iron concentrations that exceed the chronic aquatic life criteria, biological condition in the Cheyenne River at Dull Center (Stations NGP159 and 06365900) and Antelope Creek (Stations NGP158 and 06364700), were comparable to other stations in the Cheyenne River basin. In addition, fish surveys conducted by the WGFD indicate Antelope Creek, Black Thunder Creek and the Cheyenne River continue to support an intact native fish assemblage comparable to historical data. Based on this weight-of-evidence, the narrative aquatic life use criterion appears to be achieved in Antelope Creek, Black Thunder Creek and the Cheyenne River.

9.0 DETERMINATION

Based on a weight-of-evidence evaluation of the chemical, physical and biological information collected on Antelope Creek, Black Thunder Creek and the Cheyenne River in addition to other sources of information suggest these waterbodies were, on the dates of sampling:

1) **Fully supportive of warm-water fisheries, non-game fisheries and/or aquatic life**

other than fish in the Cheyenne River from the Wyoming/South Dakota stateline upstream to its headwaters, the mouth of Black Thunder Creek upstream to its headwaters and the mouth of Antelope Creek upstream to its headwaters. Even though the chronic aquatic life dissolved iron criterion was exceeded multiple times in the Cheyenne River at Dull Center and lower Antelope Creek and may be limiting the aquatic life in these areas, the available information indicates the dissolved iron exceedences were predominantly due to natural groundwater contributions rather than anthropogenic activities. Therefore, a full support determination was chosen because no link could be established between dissolved iron concentrations and anthropogenic activities in the watershed.

2) **Fully supportive of wildlife, industrial, scenic value and agricultural uses** in the Cheyenne River from the Wyoming/South Dakota stateline upstream to its headwaters, the mouth of Black Thunder Creek upstream to its headwaters and the mouth of Antelope Creek upstream to its headwaters. WDEQ/WQD generally assumes that these uses are supported if aquatic life uses in these segments are also supported.
3) **Fully supportive of drinking water uses** in the Cheyenne River from the Wyoming/South Dakota stateline upstream to its headwaters, the mouth of Black Thunder Creek upstream to its headwaters and the mouth of Antelope Creek upstream to its headwaters. Even though the human health numeric criterion of 300 ug/L for dissolved iron was exceeded in >10% of samples collected on the Cheyenne River at Dull Center (USGS station 06365900) between 2002 and 2006, available information indicates the dissolved iron exceedences were predominantly due to natural groundwater contributions rather than anthropogenic activities. Therefore, a full support determination was chosen because no link could be established between dissolved iron concentrations and anthropogenic activities in the watershed.
4) Review of biological and chemical data are **insufficient to determine contact recreation and fish consumption** use support for Antelope Creek, Black Thunder Creek and the Cheyenne River.

10.0 RECOMMENDATIONS

1) The presence of warm-water game and non-game fishes warrants a re-evaluation of the current 3B classification of lower Antelope Creek and Black Thunder Creek.
2) Implement efforts to develop site-specific human health and/or chronic aquatic life criteria for dissolved iron on Antelope Creek and the Cheyenne River.
3) Continued monitoring of Antelope Creek, Black Thunder Creek and the Cheyenne River to track changes in chemical, biological and particularly physical conditions.

4) Continued monitoring of dissolved iron at USGS stations on Antelope Creek and the Cheyenne River to determine whether dissolved iron concentrations decrease as drought conditions subside.
5) Future monitoring on Antelope Creek, Black Thunder Creek and the Cheyenne River should include *E. coli* monitoring to determine contact recreation use support.
6) Gather spatial and temporal information on background nutrient concentrations during periods of flow on the Cheyenne River and its tributaries.
7) Fish tissue sampling should be conducted to evaluate fish consumption use support.

11.0 SIGNATURES

Author ____

Peer Reviewer ____

Monitoring Supervisor ____

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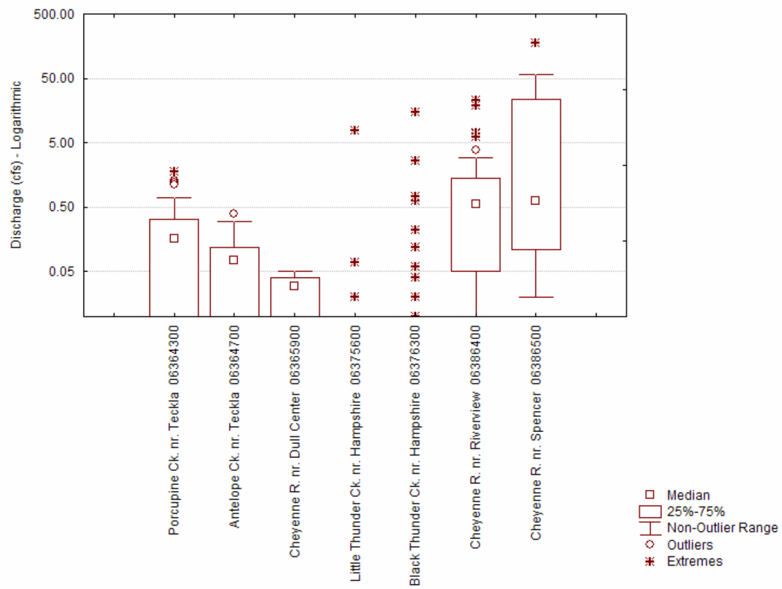
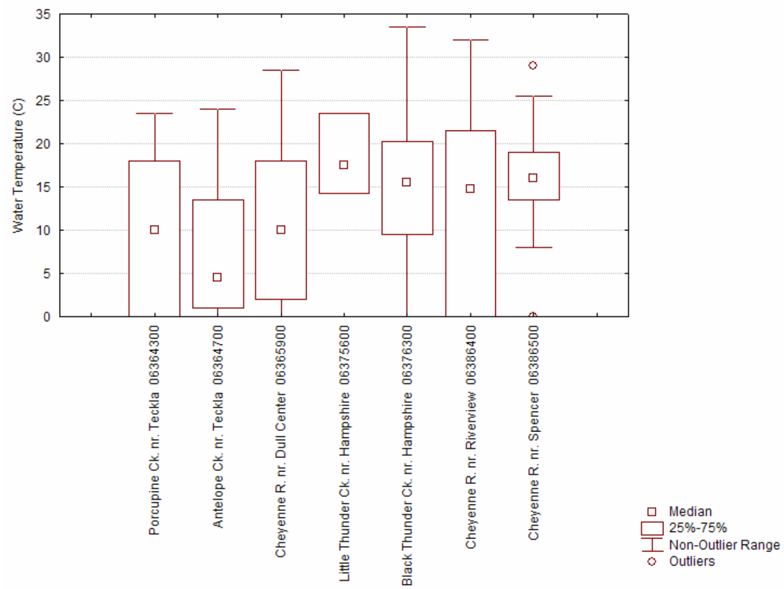
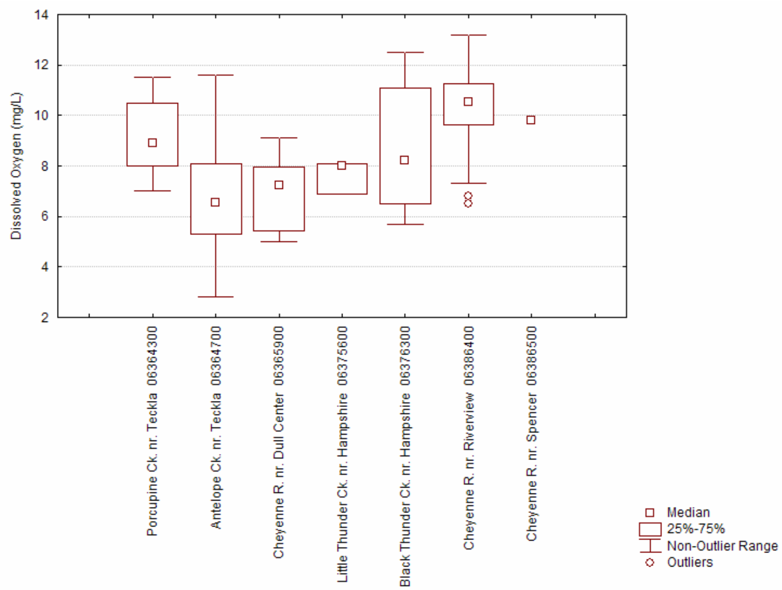
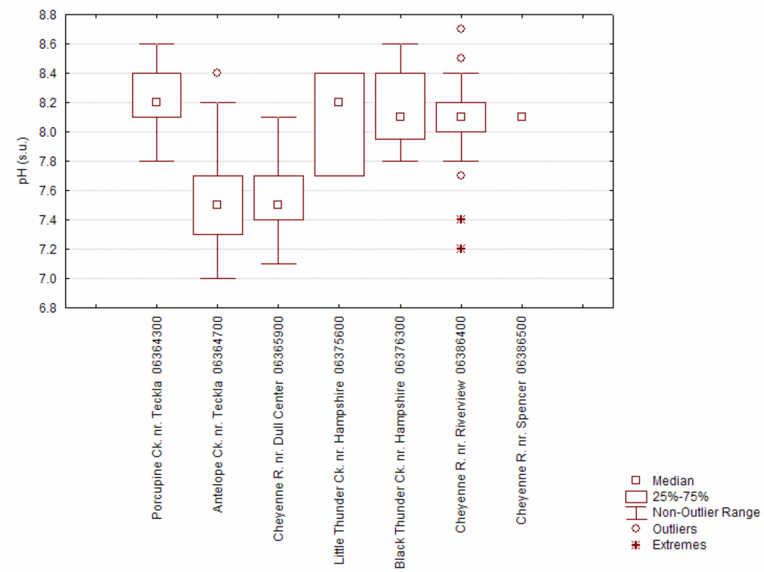
APPENDIX

Appendix 1 – Summary of constituent concentrations at seven USGS fixed stations on the Cheyenne River and selected tributaries (2002-2005). Boxes represent the 25-75%ile range, whiskers represent the non-outlier range, squares are median values, circles are outliers and asterisks are extremes.

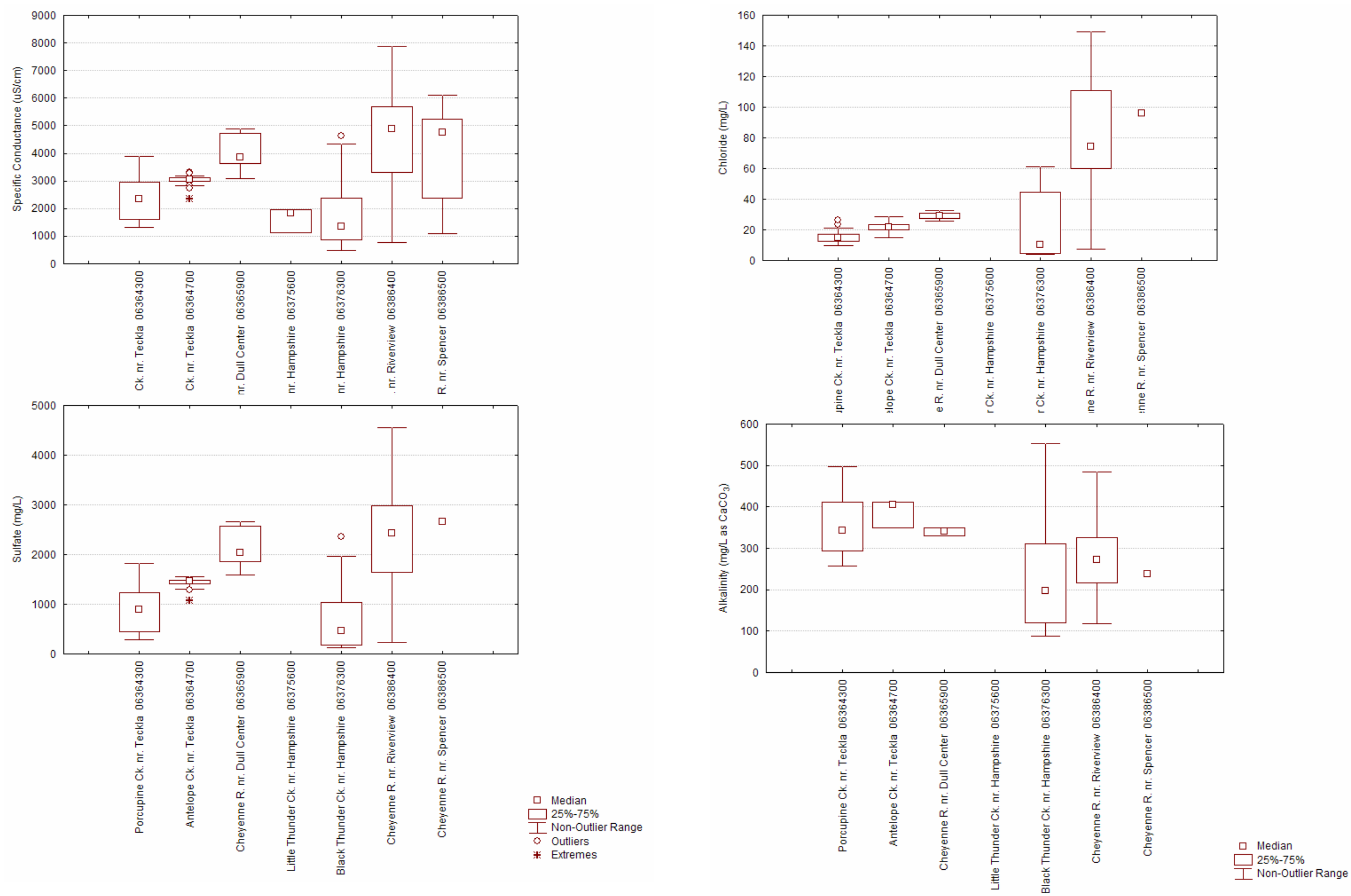








Appendix 1 (cont.) – Summary of constituent concentrations at seven USGS fixed stations on the Cheyenne River and selected tributaries (2002-2005). Boxes represent the 25-75%ile range, whiskers represent the non-outlier range, squares are median values, circles are outliers and asterisks are extremes.



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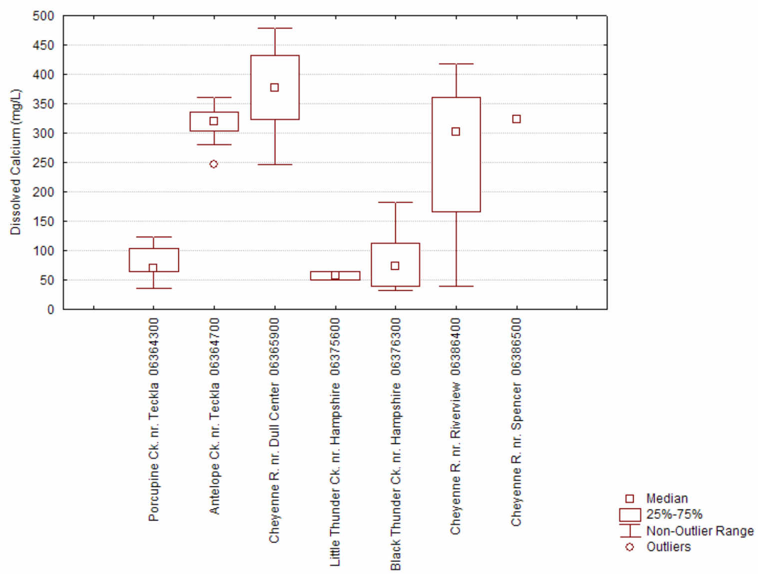

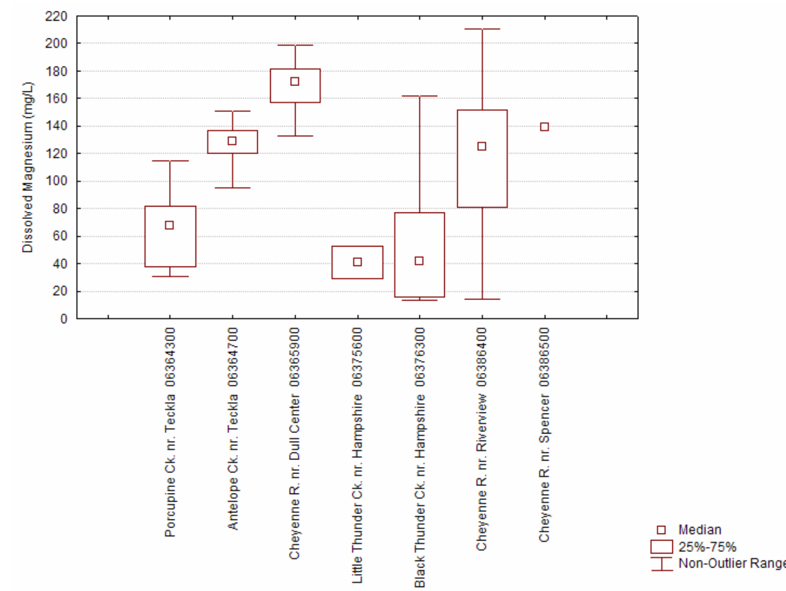

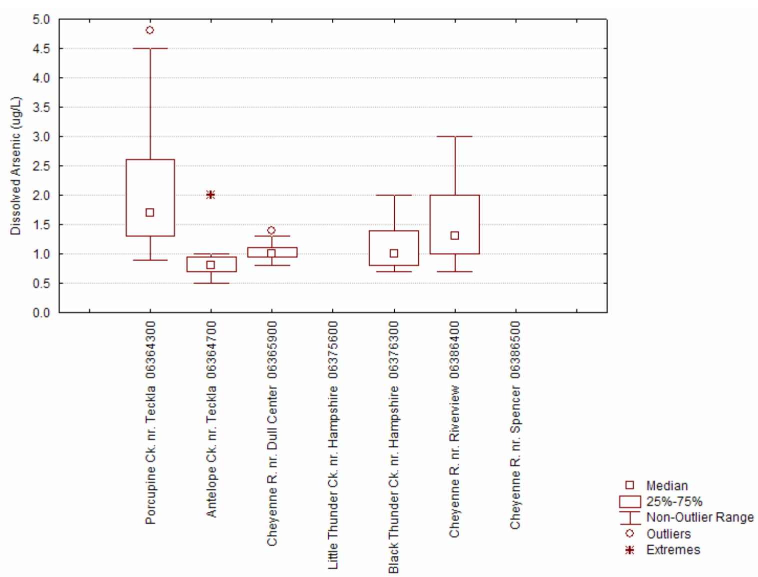

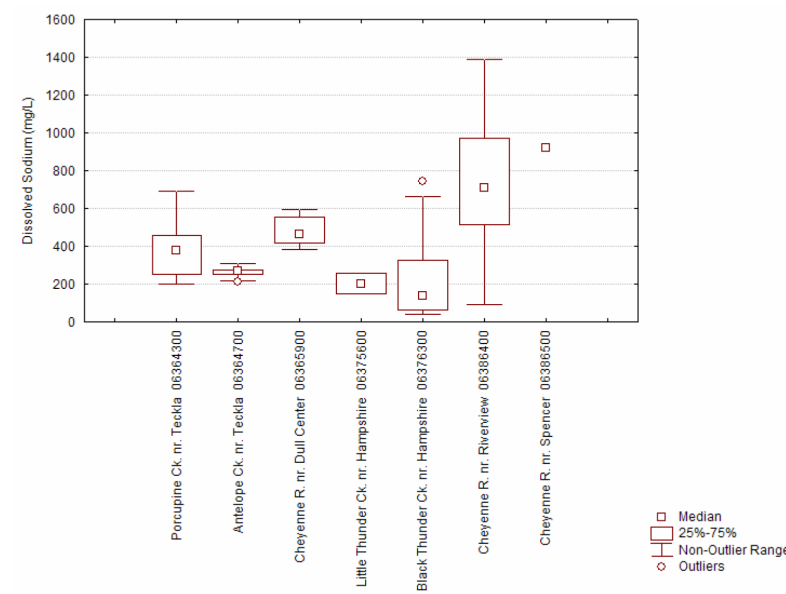

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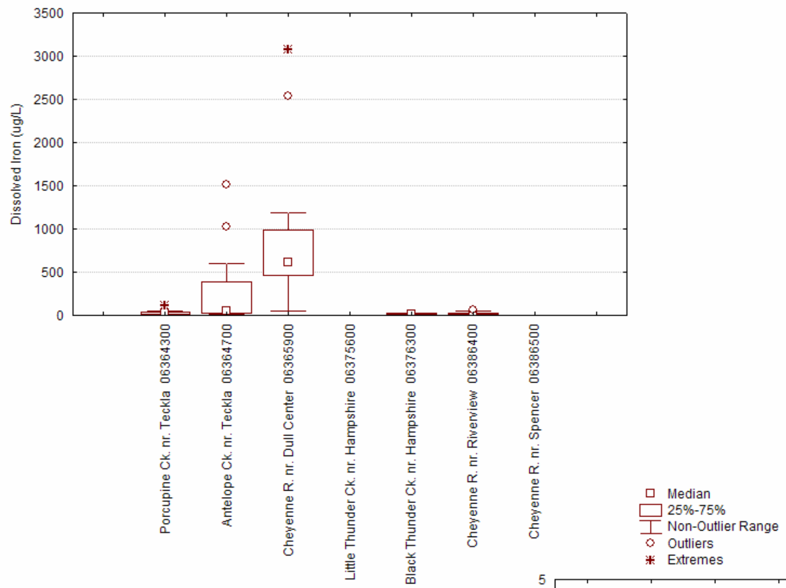
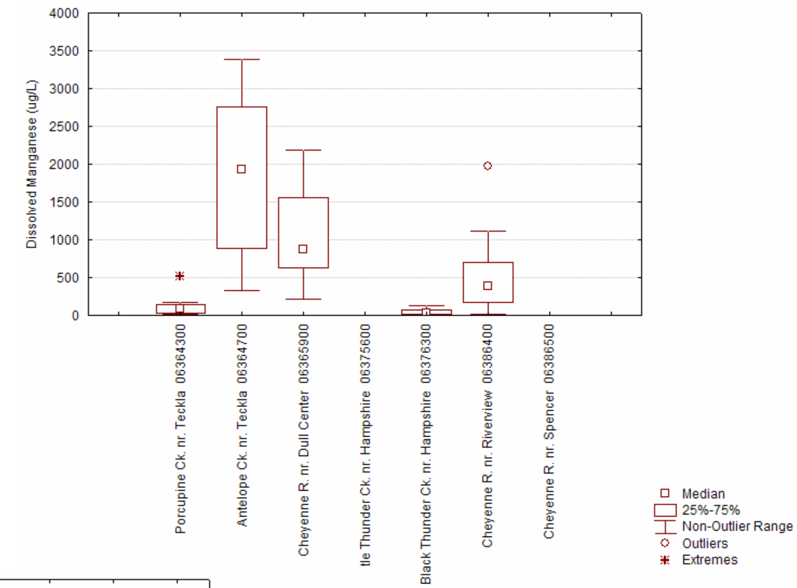
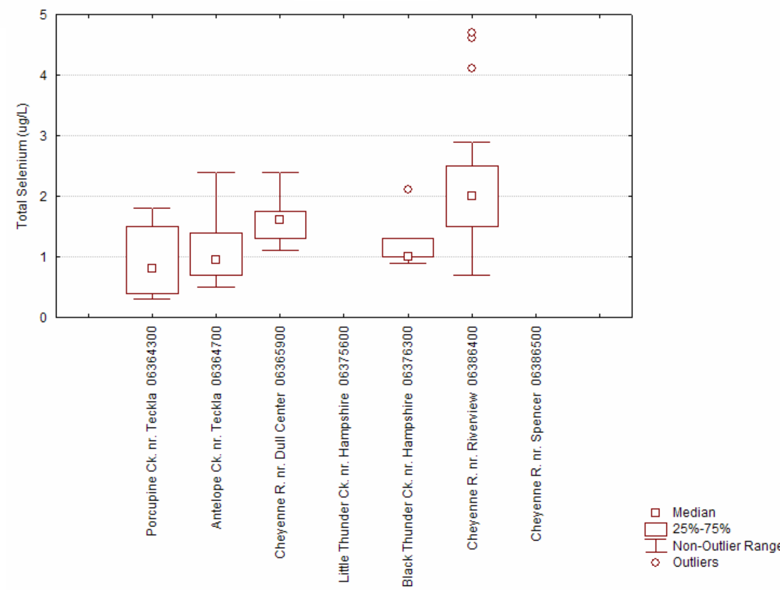






Appendix 2 – Physicochemical results at WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River (2003-2004).

Chemistry Parameters	**Antelope Creek**	**Black Thunder Creek**	**Cheyenne River**					
Station ID	**NGP 158**	**NGP164**	**NGP159**		**NGP162**		**NGP161**	**NGP160**
Date	8/6/03	8/20/03	8/19/03	6/1/04	8/28/03	6/2/04	8/27/03	8/26/03
Time	0945	0925	0845	1245	0950	0845	0910	0840
Temperature C	22.0	18.1	20.7	18.5	19.9	14.5	22.4	19.7
pH	7.4	8.1	7.9	8.2	8.0	8.0	8.1	7.1
Conductivity (uS/cm)	2700	628	4880	4520	2900	4470	3900	4640
Dissolved Oxygen (mg/L)	1.9	6.2	5.0	9.0	6.6	8.9	6.9	5.8
Turbidity (NTU)	12.1	380.5	37.1	4.8	5.9	2.2	9.9	14.3
TSS (mg/L)	12	148	76	2	5	2	7	15
Alkalinity (mg/L as CaCO3)	450	130	230	265	400	290	300	230
Sulfate (mg/L)	1308	185	2887	2685	1334	2367	1904	2434
Chloride (mg/L)	20	<5	37	20	32	49	72	82
Nitrate (mg/L as N)	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1
Total Phosphorus (mg/L)	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Hardness (mg/L as CaCO3)	450	184	1884	1810	702	1212	932	1024
Sodium (mg/L)	217	98	499	571	412	732	524	713
Calcium (mg/L)	215	42	289	412	95	324	163	164
Magnesium (mg/L)	123	20	197	178	99	151	112	116
Sheen	Biofilm	None	None	Biofilm	None	Biofilm	None	None
Color	Brown/Green	Gray/Green	Green/Gray	None	Green/Yellow	None	Brown	None
Odor	Anaerobic	None	Anaerobic	None	Anaerobic	None	None	None
Discharge (cfs)	0	0	0	0	0	0	0	0
NM = Not Measured								

Appendix 3 – Qualitative habitat assessment and biological indicators for WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

Habitat Parameters for <10% Riffle/Run (Max. Score)	**Antelope Creek**	**Black Thunder Creek**		**Cheyenne River**					
Station ID	**NGP 158**	**NGP 164**	**NGP 163**	**NGP159**		**NGP162**		**NGP161**	**NGP160**
Date	8/6/03	8/20/03	8/21/03	8/19/03	6/1/04	8/28/03	6/2/04	8/27/03	8/26/03
Bottom Substrate/ Available Cover (20)	17	11	12	13	16	16	15	17	16
Pool Substrate Characterization (20)	13	12	16	16	16	17	18	15	16
Pool Variability (20)	5	10	6	13	18	17	16	15	16
Channelization/Alteration (20)	19	19	19	20	18	19	19	17	19
Sediment Deposition (20)	4	12	14	15	18	13	18	12	15
Channel Sinuosity (20)	6	9	9	7	7	9	9	7	7
Channel Flow Status (20)	19	3	4	5	5	7	4	13	10
Bank Vegetation Protection at Bankfull (10)	10	6.5	8	9	7	7	9	8	8
Bank Stability (10)	10	6.5	7.5	9	7	8	9	7	8
Disruptive Pressures (Riparian Zone) (10)	9	9	9	9	6	9	9	7	9
Riparian Vegetative Zone Width from Bankfull to upland (10)	7	6	6	7	8	7	8	7	6
HABITAT ASSESSMENT TOTAL <10% Riffle/Run (180 possible)	**119**	**104**	**110.5**	**123**	**126**	**129**	**134**	**125**	**130**
HABITAT ASSESSMENT (Percent of Maximum Score)	**66.1**	**57.8**	**61.4**	**68.3**	**70.0**	**71.7**	**74.4**	**69.4**	**72.2**
Average Pool Quality Score (10)	NM	NM	NM	NM	NM	NM	NM	NM	NM
Estimated Percentage of Pools in Reach at least 1.5' deep	NM	NM	NM	NM	NM	NM	NM	NM	NM
Biological Indicators*									
Periphyton	2	2	2 (in wet areas)	2	2	2	2	2	2
Filamentous Algae	0	1	3 (in wet areas)	1	1	1	1	1	1
Rooted Macrophytes	4	0	1 (in wet areas)	2	2	3	3	2	2
Detritus	2	2	1	1	1	1	1	1	1
Floating Macrophytes	0	0	0	0	0	0	0	0	0
Fish	2	2	2**	2	2	2	2	2	2
Slimes	0	0	0	0	0	0	0	0	0

* 4-Dominant, 3-Abundant, 2-Common, 1-Rare, 0-Absent

** Observed in a small shallow pool (<1" depth) outside site reach

NM = Not Measured

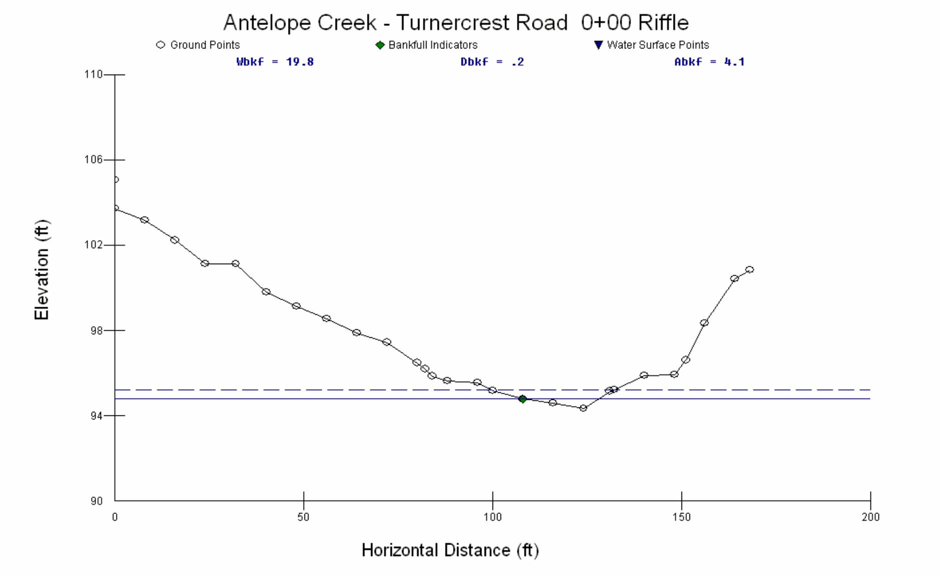
Appendix 4 – Geomorphic parameters for WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

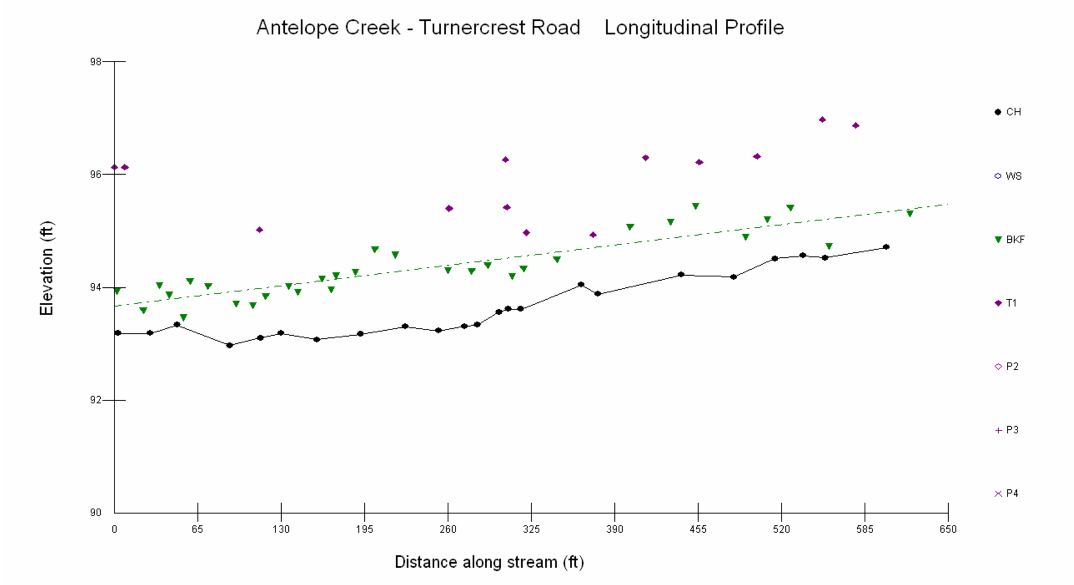
Stream	**Antelope Creek**		**Black Thunder Creek**		**Cheyenne River**			
Station ID	**NGP156**	**NGP158**	**NGP164**	**NGP163**	**NGP159**	**NGP162**	**NGP161**	**NGP160**
Survey Date	8/4/2003	8/6/2003	8/20/2003	8/21/2003	8/19/2003	8/28/2003	8/27/2003	8/26/2003
Valley Type	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VIII
Valley Slope (ft/ft)	0.0038	0.0029	0.0042	0.0023	0.0017	0.0019	0.0020	0.0022
Valley Slope (%)	0.38	0.29	0.42	0.23	0.17	0.19	0.20	0.22
Mean Bankfull Width (ft)	19.81	18.03 est.	11.58	9.38	25.83	13.1	28.24	28.45
Mean Riffle Depth at Bankfull (ft)	0.20	1.06 est.	1.32	1.25	0.34	0.79	0.51	0.63
Mean Flood-Prone Width (ft)	32.77	40.48 est.	16.52	17.04	58.07	78.23	32.38	32.74
Channel Materials (mm) d50	1.00	1.00	3.29	2.25	0.94	5.13	3.14	3.48
Channel Materials (mm) d84	1.00	1.00	25.60	9.72	11.47	19.77	25.49	19.30
Water Surface Slope (ft/ft)	0.0028	0.0017 est.	0.0023	0.0012	0.0014	0.0010	0.0015	0.0017
Water Surface Slope (%)	0.28	0.17 est.	0.23	0.12	0.14	0.10	0.15	0.17
Sinuosity	1.38	1.68	1.83	1.90	1.20	1.90	1.30	1.28
Bankfull Cross Sectional Area (ft^2)	4.06	19.01 est.	15.13	11.69	8.75	10.35	14.54	18.05
Entrenchment Ratio	1.65	2.25 est.	1.43	1.82	2.25	5.97	1.15	1.15
Width to Depth Ratio	99.05	17.01 est.	8.77	7.50	75.97	16.58	55.37	45.16
Rosgen Stream Classification	B5c	C5 est.	B4c	B4c	C5	C4	F4	F4
*Mean Pool to Pool Spacing (ft)	229.6	[a]	182.6	275.7	401.0	115.2	161.7	136.8
*Mean Pool Length (ft)	263.4	[a]	108.3	223.6	564.8	112.3	106.1	112.8
*Mean Maximum Pool Depth at Bankfull (ft)	1.00	[a]	2.87	3.90	3.89	2.89	1.72	2.09
*Mean Maximum Riffle Depth at Bankfull (ft)	0.56	[a]	1.42	1.36	1.07	1.02	0.71	1.27
Drainage Area (mi^2)	261.0	960.0	217.0	552.7	1535.0	2329.0	5062.8	5313.6
Reachwide Wolman Pebble Count - Summary								
Silt/Clay (%)	0.0	0.0	0.0	0.0	0.0	12.7	13.3	14.0
Sand (%)	100	100	41.3	48.7	64.3	26.7	28.5	24.7
Gravel (%)	0.0	0.0	52.9	50.0	33.8	57.3	50.3	58.0
Cobble (%)	0.0	0.0	5.8	0.0	2.0	3.3	5.3	3.3
Boulder (%)	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0
Bedrock (%)	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0
Pool (%)	86	95	67	69	65	73	95	91
Non-Pool (%)	14	5	33	31	35	27	5	9
Portions of Reach Influenced by Beaver Activity	No	Yes	No	No	Yes	Yes	Yes	Yes

[a]Entire reach inundated by beaver ponds - difficult to accurately estimate some bankfull parameters

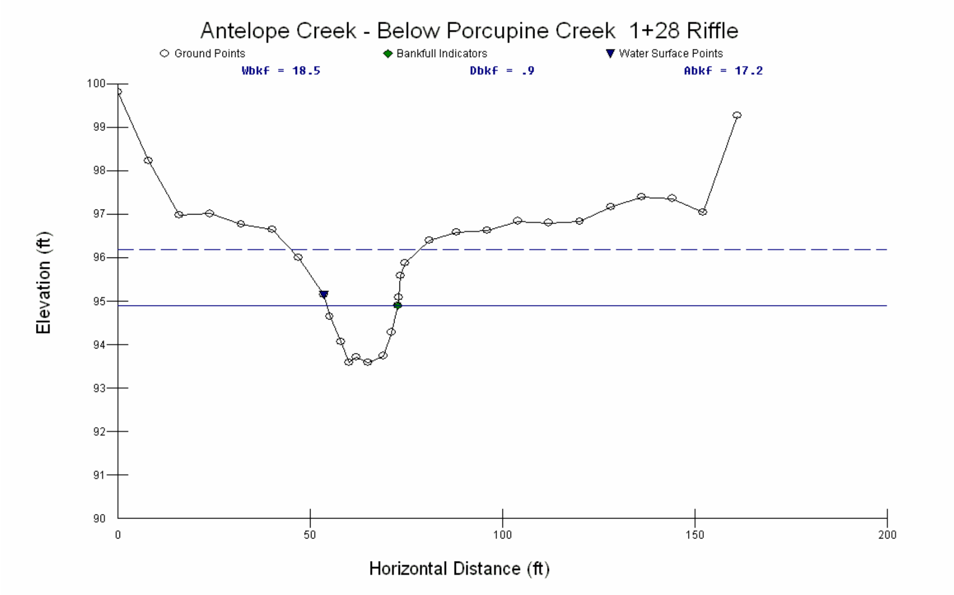
*Does not include beaver ponds

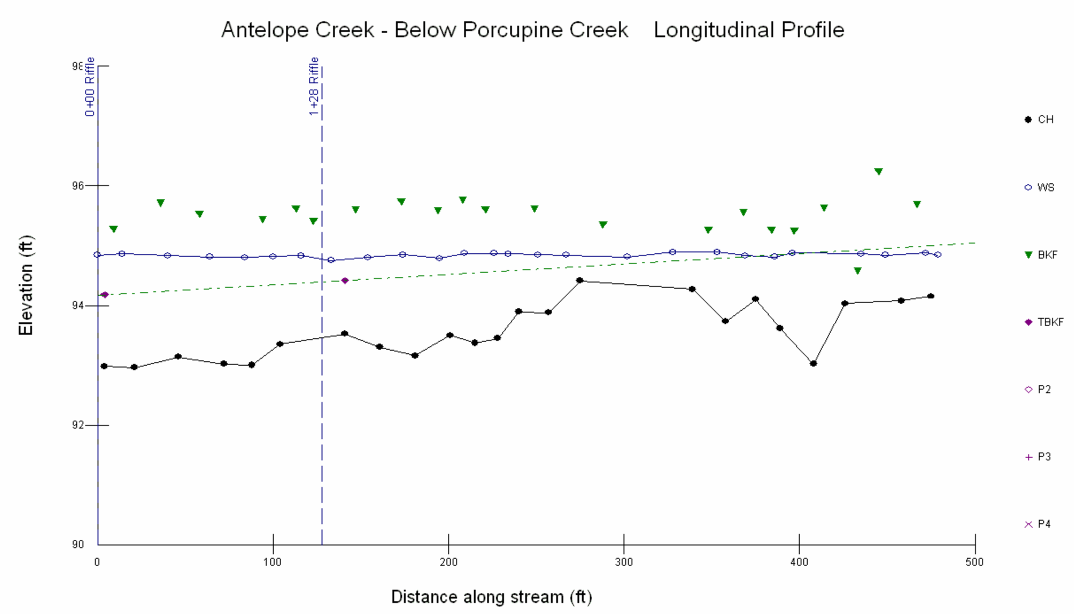
Appendix 5 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP156 (Antelope Creek- Turnercrest Road).



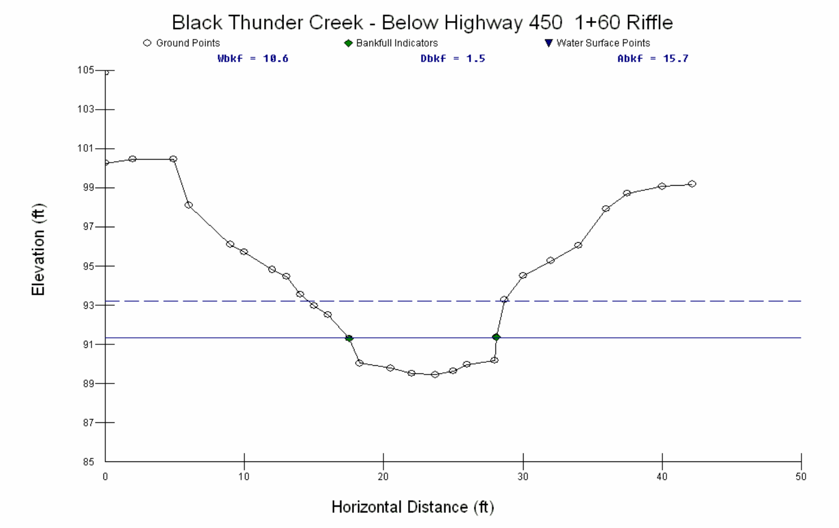


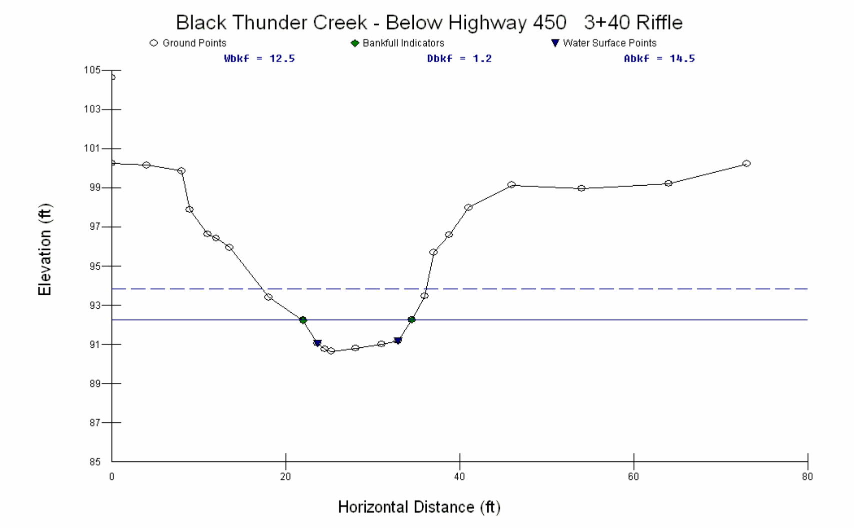
Appendix 6 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP158 (Antelope Creek- Below Porcupine Creek).

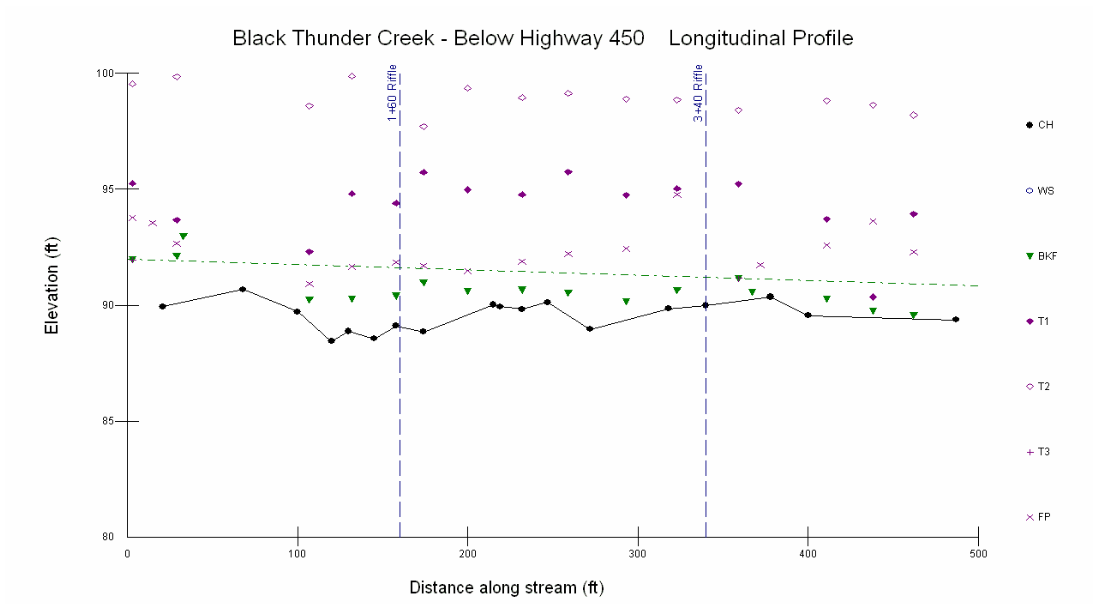




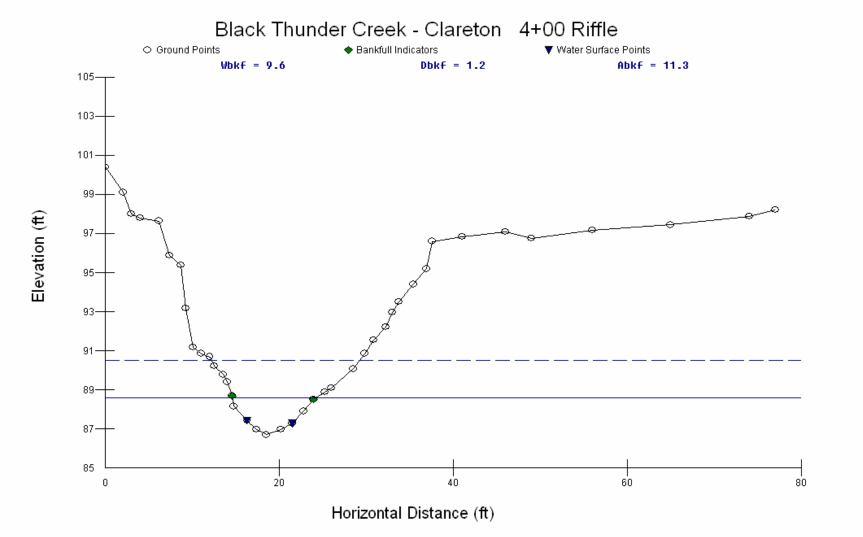
Appendix 7 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP164 (Black Thunder Creek – Below Highway 450).

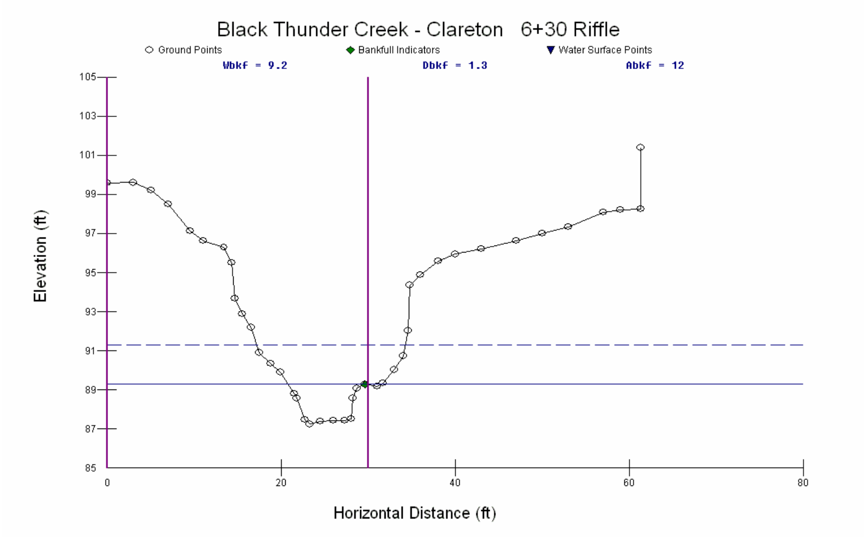


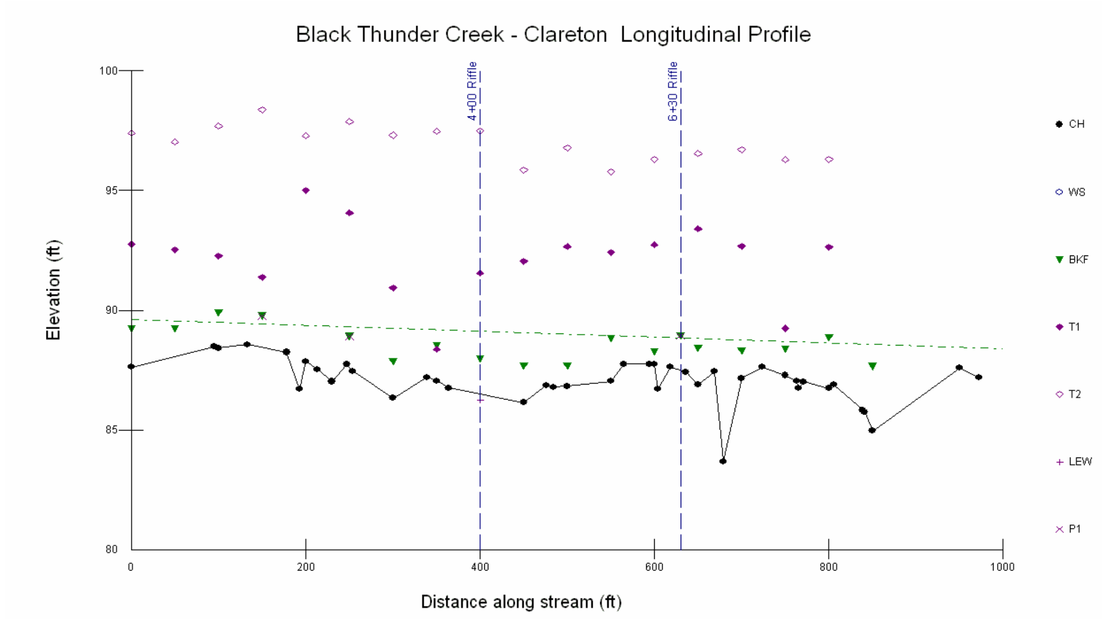




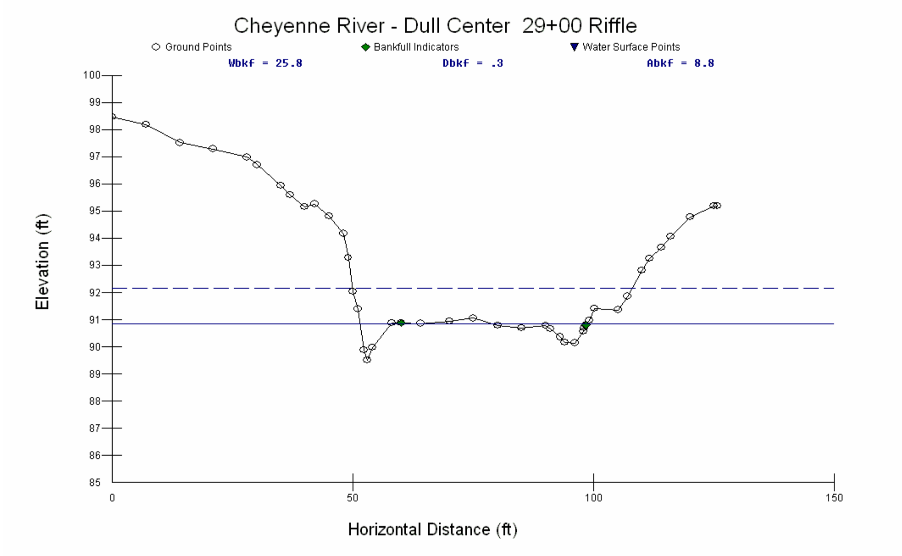
Appendix 8 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP163 (Black Thunder Creek – Clareton).

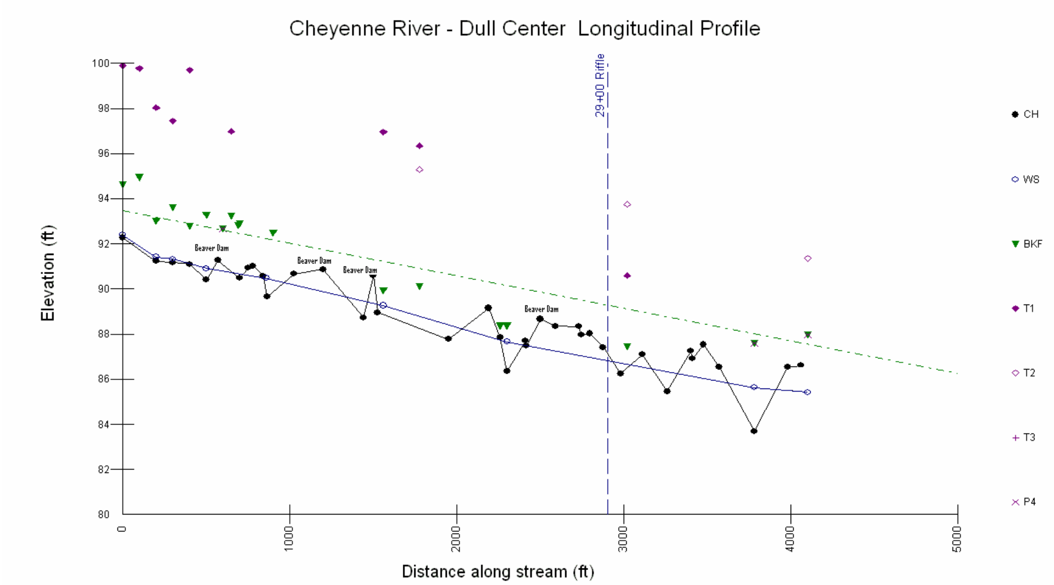




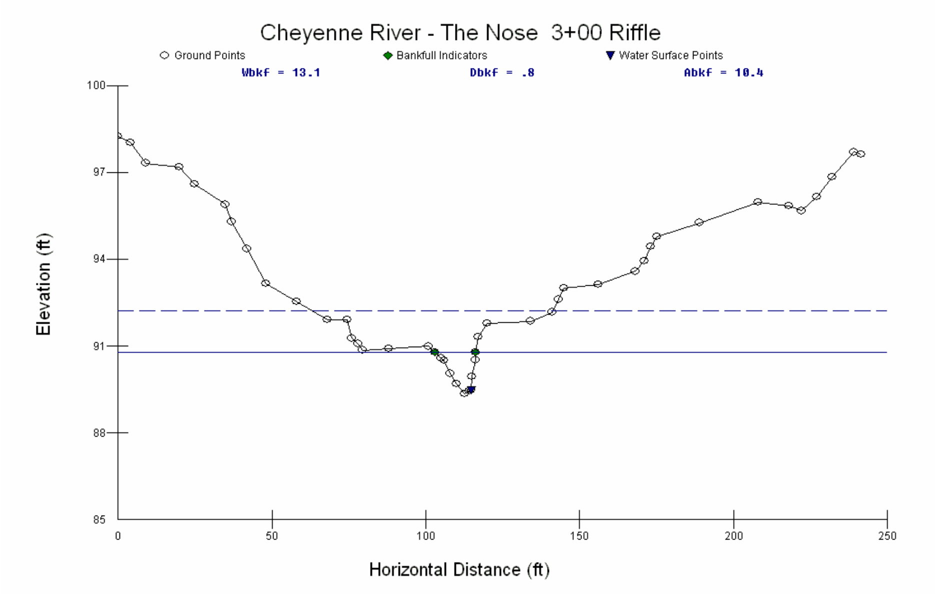


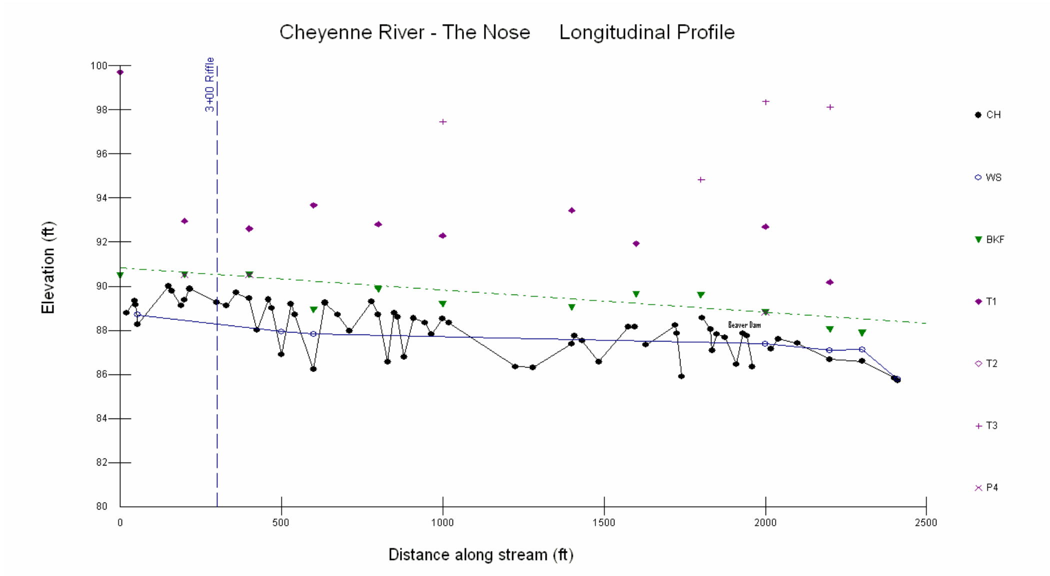
Appendix 9 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP159 (Cheyenne River – Dull Center).



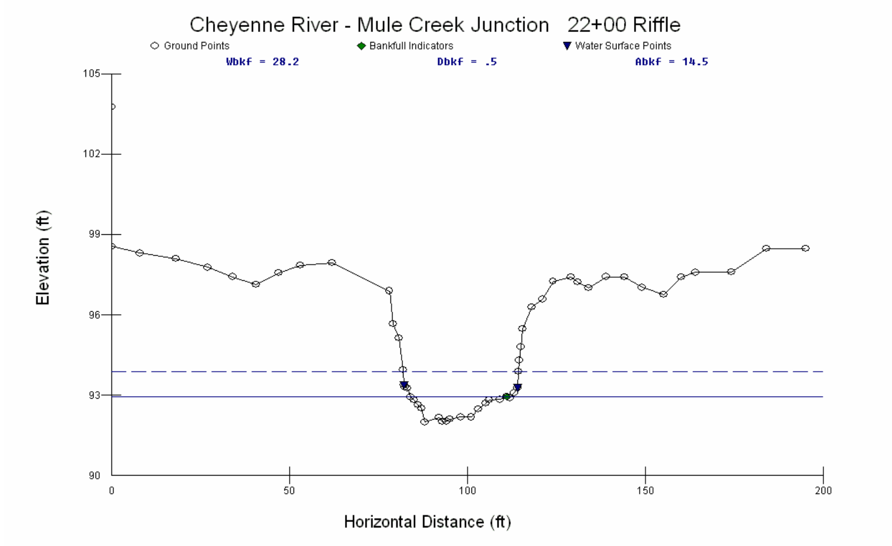


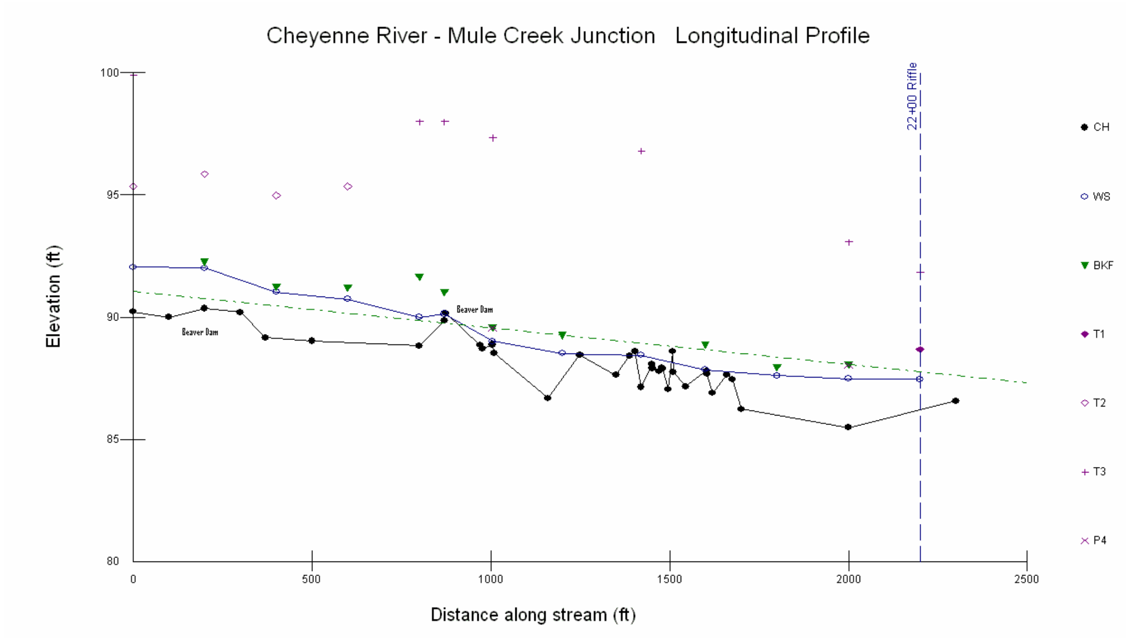
Appendix 10 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP162 (Cheyenne River – The Nose).



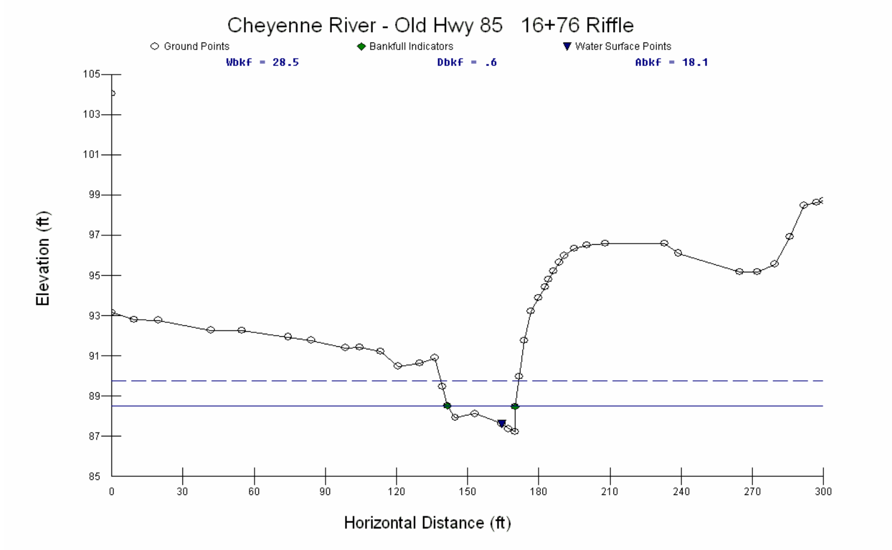


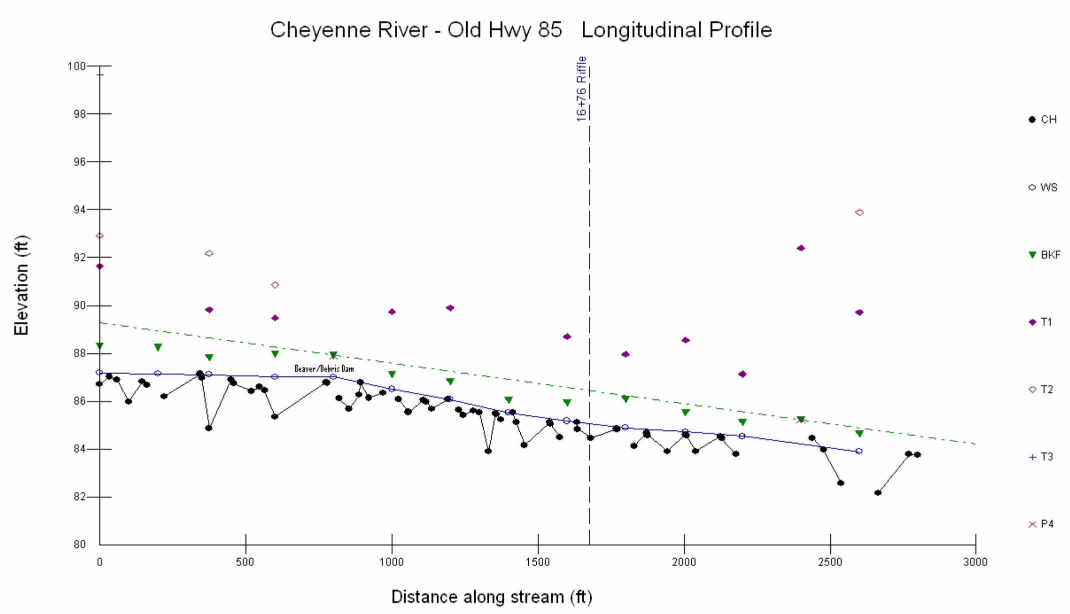
Appendix 11 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP161 (Cheyenne River – Mule Creek Junction).





Appendix 12 – Cross-sectional and longitudinal profile plots for WDEQ/WQD station NGP160 (Cheyenne River – Old Highway 85).





Appendix 13 – Summary of 2003 macroinvertebrate collection results at WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

		Antelope Creek		Black Thunder Creek		Cheyenne River					
		NGP 158		NGP164		NGP 159		NGP162		NGP 160	
	Taxon	Abundance	% Composition	Abundance	% Composition	Abundance	% Composition	Abundance	% Composition	Abundance	% Composition
Oligochaeta	*Nais*	46	1.8								
	Imm. Tubificid w/ cap setae	40	1.6					121	1		
Gastropoda	*Gyraulus*	6	0.2	4	0.2						
	Helisoma	17	0.7								
	Lymnaeidae	6	0.2								
	Physidae	87	3.4					430	3.4	753	3.4
	Pisidium					27	0.2				
Amphipoda	*Hyalella*	323	12.5	182	8.4	3147	25.2	861	6.8	54	0.3
Hirudinea	*Helobdella stagnalis*	6	0.2								
Arachnida	*Acari*	63	2.4	8	0.4	215	1.7	40	0.3		
	TOTAL - NON-INSECTS	594	**23**	194	**9**	3389	**27.1**	1452	**11.5**	807	**3.7**
Insecta	*Argia*							14	0.1	27	0.1
	Coenagrionidae			553	25.6						
	Enallagma	156	6.1	129	6	350	2.8	2260	17.9	161	0.7
	Somatochlora							148	1.2		
	TOTAL - ODONATA	156	**6.1**	682	**31.6**	350	**2.8**	2422	**19.2**	188	**0.8**
	Corixidae			109	5.1			135	1.1	81	0.4
	TOTAL - HETEROPTERA			109	**5.1**	0	**0**	135	**1.1**	81	**0.4**
	Caenis	1066	41.3	508	23.5	5891	47.1	6617	52.4	1856	8.5
	Callibaetis	52	2	8	0.4			135	1.1	54	0.3
	TOTAL - EPHEMEROPTERA	1118	**43.3**	516	**23.9**	5891	**47.1**	6752	**53.5**	1910	**8.8**
	Cheumatopsyche									135	0.6
	Oecetis	6	0.2								
	TOTAL - TRICHOPTERA	6	**0.2**			0	**0**	0	**0**	135	**0.6**
	Berosus	6	0.2			699	5.6	444	3.5	27	0.1
	Coptotomus							14	0.1		
	Dubiraphia			69	3.2	538	4.3	215	1.7	350	1.6
	Hydrobius									135	0.6
	Laccobius							14	0.1		
	Laccophilus							14	0.1		
	Liodessus									27	0.1
	Ochthebius							14	0.1		
	Paracymus	12	0.5					14	0.1		
	Stenelmis									27	0.1
	TOTAL - COLEOPTERA	18	**0.7**	69	**3.2**	1237	**9.9**	729	**5.7**	566	**2.5**
	Sialis							27	0.2		
	TOTAL - MEGALOPTERA					0	**0**	27	**0.2**	0	**0**
	Ceratopogoninae	63	2.4	4	0.2	538	4.3	148	1.2	1345	6.1
	Ephydridae									81	0.4
	Sciomyzidae									27	0.1
	Tabanidae							14	0.1	81	0.4
	TOTAL - DIPTERA	63	**2.4**	4	**0.2**	538	**4.3**	162	**1.3**	1534	**7**
	Ablabesmyia	23	0.9	113	5.2	81	0.6	40	0.3	350	1.6
	Chironomus	6	0.2								
	Cladopelma					108	0.9			242	1.1
	Constempellina							14	0.1		
	Cryptochironomus	6	0.2	12	0.6	27	0.2	14	0.1	323	1.5
	Cryptotendipes									323	1.5
	Dicrotendipes	167	6.5	16	0.7	81	0.6	296	2.3	2018	9.2
	Endochironomus	6	0.2			296	2.4	54	0.4		
	Glyptopendipes			28	1.3						
	Labrudinia					27	0.2				
	Limnophyes	6	0.2								
	Nanocladius									27	0.1
	Nilotanypus							14	0.1		
	Orthocladius complex	6	0.2					14	0.1		
	Parachironomus			24	1.1						
	Paratanytarsus			246	11.3	350	2.9	14	0.1		
	Phaenopsectra					54	0.4	14	0.1		
	Polypedilum	6	0.2	61	2.8			40	0.3	81	0.4
	Procladius	23	0.9	81	3.8	81	0.6	242	1.9		
	Psuedochironomus	46	1.8					202	1.6	484	2.2
	Tanypus			4	0.2						
	Tanytarsus	329	12.8							11809	54
	Thienemannimyia									1022	4.7
	TOTAL - CHIRONOMIDAE	624	**24.3**	585	**27**	1105	**8.8**	958	**7.5**	16679	**76.2**
	GRAND TOTAL	2579	**100**	2159	**100**	12510	**100**	12637	**100**	21900	**100**

Appendix 13 (cont.) – Summary of 2003 macroinvertebrate collection results at WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

		Antelope Creek	Black Thunder Creek	Cheyenne River		
		NGP 158	NGP164	NGP 159	NGP162	NGP 160
Selected Biometrics	No. Total Taxa	30	24	22	33	30
	No. EPT Taxa	3	2	1	2	3
	No. Chironomidae Taxa	11	9	9	12	10
	No. Non-Insect Taxa	9	3	3	4	2
	No. Diptera Taxa (non-Chironomi d)	1	1	1	2	4
	No. Coleoptera Taxa	2	1	2	7	5
	No. Odonata Taxa	2	3	1	3	2
	No. Tolerant Taxa (TV 8-10)	15	12	8	11	10
	No. Mod. Tolerant Taxa (TV <8)	10	6	7	14	14
	% Collector-gather	61.3	38.6	60	64.5	24.5
	No. Collector-gather taxa	16	9	11	13	11
	% Predator	9.9	33.2	12.4	22.6	14.6
	No. Predator taxa	7	8	6	10	10
	% Collector-filterer	10.9	0	0	0	54.1
	No. Collector-filterer taxa	1	0	0	0	2
	% Scraper	3.6	0.6	0.6	3.4	3.4
	No. Scraper taxa	3	2	3	2	1
	No. Semivoltine taxa	3	2	2	7	6
	WSII Score	40.6	33	35.8	40.6	39.7
	Percent comparability to mean WSII score (38.2) from reference stations NGP159 and NGP162	106.3	86.4	93.7	106.3	103.9
	WY RIVPACS Score	0.41	0.27	0.41	0.27	0.27
	Percent comparability to mean WY RIVPACS score (0.34) from reference stations NGP159 and NGP162	120.6	79.4	120.6	79.4	79.4

Appendix 14 – Summary of 2005 macroinvertebrate collection results at USGS stations on Antelope Creek, Black Thunder Creek and the Cheyenne River. Note that this data is provisional and subject to revision.

		Antelope Creek		Black Thunder Creek		Cheyenne River			
	USGS Station ID	06364700		06376300		06365900		06386500	
	Collection Date	6/8/2005		6/8/2005		6/27/2005		6/6/2005	
	Taxon	**Abundance**	**% Composition**	**Abundance**	**% Composition**	**Abundance**	**% Composition**	**Abundance**	**% Composition**
	Lymnaeidae	3579.3	17.5			413.6	15.0		
Gastropoda	*Physidae*	5179.7	25.4	200.6	9.1	1068.1	38.7	8.0	0.4
	Pisidium	95.8	0.5						
Amphipoda	*Hyalella*	1671.3	8.2	72.5	3.3	68.6	2.5		
Hirudinea	*Helobdella stagnalis*	32.0	0.2						
	TOTAL - NON-INSECTS	10558.1	**51.7**	273.1	**12.4**	1550.2	**56.2**	8.0	**0.4**
	Aeshnidae					5.6	0.2		
	Argia								
	Coenagrionidae	162.7	0.8	74.2	3.4	199.5	7.2	46.3	2.4
	Enallagma								
	Gomphidae			1.0	0.0				
	Lestidae			135.8	6.2	13.7	0.5		
	Libellulidae					11.1	0.4		
	TOTAL - ODONATA	162.7	**0.8**	211.0	**9.6**	229.9	**8.3**	46.3	**2.4**
	Corixidae			101.7	4.6	42.1	1.5	16.0	0.8
	Gerridae			3.8	0.2	13.7	0.5		
	TOTAL - HETEROPTERA	0.0	**0.0**	105.4	**4.8**	55.8	**2.0**	16.0	**0.8**
	Baetidae							2.7	0.1
	Caenis	95.8	0.5	514.0	23.4	64.0	2.3	178.7	9.1
	Callibaetis			22.6	1.0	69.0	2.5		
	TOTAL - EPHEMEROPTERA	95.8	**0.5**	536.6	**24.4**	133.0	**4.8**	181.3	**9.2**
	Agabus	32.0	0.2	9.5	0.4				
	Berosus			15.1	0.7	32.0	1.2		
	Coptotomus			4.8	0.2				
	Curculionidae	63.9	0.3	3.8	0.2	13.7	0.5		
	Dubiraphia			71.5	3.3			8.0	0.4
	Gyrinus							1.0	0.1
	Haliplus	191.7	0.9	3.8	0.2	9.1	0.3	1.0	0.1
	Hydrophilidae	32.0	0.2						
	Laccophilus			18.8	0.9				
	Ochthebius			3.8	0.2				
	TOTAL - COLEOPTERA	223.6	**1.1**	131.0	**6.0**	54.8	**2.0**	10.0	**0.5**
	Ceratopogoninae	159.8	0.8	56.5	2.6	32.0	1.2	2.7	0.1
	Sciomyzidae	33.0	0.2			13.7	0.5		
	Simulium	63.9	0.3					1069.3	54.4
	Stratiomyidae	32.0	0.2			4.6	0.2		
	TOTAL - DIPTERA	288.6	**1.4**	56.5	**2.6**	50.3	**1.8**	1072.0	**54.5**
	Ablabesmyia	32.0	0.2	56.5	2.6	4.6	0.2	58.7	3.0
	Acricotopus	926.5	4.5			13.7	0.5		
Insecta	*Chironomus*	63.9	0.3	278.6	12.7			13.3	0.7
	Cladopelma	127.8	0.6			4.6	0.2		
	Cladotanytarsus			67.8	3.1	13.7	0.5	61.3	3.1
	Corynoneura	191.7	0.9	60.2	2.7	4.6	0.2		
	Cricotopus bicinctus	63.9	0.3					26.7	1.4
	Cricotopus (Isocladius)	32.0	0.2	11.3	0.5	18.3	0.7	18.7	0.9
	Cryptochironomus			3.8	0.2	9.1	0.3	66.7	3.4
	Cryptotendipes			15.1	0.7	27.4	1.0	48.0	2.4
	Dicrotendipes	383.4	1.9	71.5	3.3	100.6	3.6	77.3	3.9
	Diplocaldius	32.0	0.2						
	Endochironomus			11.3	0.5	9.1	0.3	2.7	0.1
	Glyptopendipes	32.0	0.2					2.7	0.1
	Hydrobaenus			18.8	0.9			2.7	0.1
	Larsia	95.8	0.5						
	Limnophyes					4.6	0.2		
	Mircropsectra	4952.1	24.3	7.5	0.3	105.1	3.8	37.3	1.9
	Orthocladius complex			15.1	0.7			10.7	0.5
	Parachironomus			33.9	1.5	4.6	0.2	8.0	0.4
	Paracladopelma			33.9	1.5			2.7	0.1
	Parakiefferiella							16.0	0.8
	Paramerina	32.0	0.2			4.6	0.2		
	Paraphaenocladius							2.7	0.1
	Paratanytarsus	1853.0	9.1	94.1	4.3	27.4	1.0	114.7	5.8
	Paratendipes							5.3	0.3
	Phaenopsectra			15.1	0.7				
	Polypedilum			7.5	0.3			2.7	0.1
	Procladius			18.8	0.9	192.0	7.0	16.0	0.8
	Psectrocladius			3.8	0.2				
	Psuedochironomus	95.8	0.5	3.8	0.2	59.4	2.2	21.3	1.1
	Tanypus	32.0	0.2						
	Tanytarsus	32.0	0.2	56.5	2.6	68.6	2.5	8.0	0.4
	Thienemannimyia							8.0	0.4
	TOTAL - CHIRONOMIDAE	8977.7	**44.0**	884.8	**40.2**	671.8	**24.3**	632.0	**32.2**
	GRAND TOTAL	**40709.0**	**100.0**	**4397.0**	**100.0**	**5491.9**	**100.0**	**3931.4**	**100.0**

Appendix 14 (cont.) – Summary of 2005 macroinvertebrate collection results at USGS stations on Antelope Creek, Black Thunder Creek and the Cheyenne River. Note that this data is provisional and subject to revision.

		Antelope Creek	Black Thunder Creek	Cheyenne River	
	USGS Station ID	06364700	06376300	06365900	06386500
	Collection Date	6/8/2005	6/8/2005	6/27/2005	6/6/2005
Selected Biometrics	No. Total Taxa	32	39	35	34
	No. EPT Taxa	1	2	2	2
	No. Chironomidae Taxa	17	21	18	24
	No. Non-Insect Taxa	5	2	3	1
	No. Diptera Taxa (non-Chironomid)	4	1	3	2
	No. Coleoptera Taxa	4	8	3	3
	No. Odonata Taxa	1	3	4	1
	No. Tolerant Taxa (TV 8-10)	12	13	14	11
	No. Mod. Tolerant Taxa (TV <8)	16	17	15	18
	% Collector-gather	75	64.2	74.6	84.1
	No. Collector-gather taxa	20	19	18	22
	% Predator	3.6	19.7	20.9	11.1
	No. Predator taxa	15	17	18	10
	% Collector-filterer	0.6	2.7	9.1	0.4
	No. Collector-filterer taxa	2	2	2	1
	% Scraper	0	0.7	0	0
	No. Scraper taxa	0	1	0	0
	No. Semivoltine taxa	1	3	8	5
	WSII Score	31	41.3	34.3	30.6
	Percent comparability to mean WSII score (38.2) from WDEQ/WQD reference stations NGP159 and NGP162	81.2	108.1	89.8	80.1

Appendix 15 – WSII metric values, scores and site ratings for WDEQ/WQD stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

NGP158 Antelope Creek - Below Porcupine Creek				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	3	37.5
Trichoptera taxa	100*X / 95th%ile	9	1	11.1
Total taxa	100*X / 95th%ile	42	30	71.4
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0.19	0.9
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	35.3	64.9
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	61.3	43.3
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	6.93	54.9
			Index score	**40.6**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

NGP164 Black Thunder Creek - Below Highway 450				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	24	57.1
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	22.9	42.1
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	38.6	69.7
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	7.74	36.9
			Index score	**33.0**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

NGP159 Cheyenne River - Dull Center [LEAST-IMPACTED REFERENCE STATION]				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	1	12.5
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	22	52.4
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	45.4	83.5
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	59.9	44.9
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	6.82	57.3
			Index score	**35.8**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

NGP162 Cheyenne River - The Nose [LEAST-IMPACTED REFERENCE STATION]				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	33	78.6
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	50.6	93.0
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	64.5	39.6
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	7.24	48.0
			Index score	**40.6**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

NGP160 Cheyenne River - Old Highway 85				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	1	11.1
Total taxa	100*X / 95th%ile	42	30	71.4
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	8.4	15.4
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	24.5	86.1
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	6.3	68.9
			Index score	**39.7**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

Appendix 16 – WSII metric values, scores and site ratings for USGS stations on Antelope Creek, Black Thunder Creek and the Cheyenne River.

Cheyenne River nr. Spencer 06386500				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	34	81.0
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	9.1	16.7
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	84.1	16.8
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	6.05	74.4
			Index score	**30.6**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

Cheyenne River at Dull Center 06365900				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	35	83.3
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	2.3	4.2
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	74.6	27.8
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	2.53	100.0
			Index score	**34.3**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

Black Thunder Creek nr. Hampshire 06376300				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	2	25.0
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	39	92.9
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	23.4	43.0
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	64.2	39.9
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	5.44	88.0
			Index score	**41.3**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**

Antelope Creek nr. Teckla 06364700				
Metric	Metric Scoring Formulae	5th or 95th %-ile (as per formula)	Metric Value	Metric Score
Ephemeroptera taxa	100*X / 95th%ile	8	1	12.5
Trichoptera taxa	100*X / 95th%ile	9	0	0.0
Total taxa	100*X / 95th%ile	42	32	76.2
% Trichoptera (less Hydropsychidae) (% within community)	100*X / 95th%ile	20.7	0	0.0
% Ephemeroptera (less Baetidae) (% within community)	100*X / 95th%ile	54.4	0.5	0.9
% collector-gatherers	100*(98.5-X) / (98.5-5th%ile)	12.6	75	27.4
HBI	100*(9.4-X) / (9.4-5th%ile)	4.9	3.89	100.0
			Index score	**31.0**
90% CONFIDENCE INTERVAL: ±4.8			Rating	**indeterminate**