WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER QUALITY DIVISION

BENEFICIAL USE RECONNAISSANCE PROGRAM
FINAL MONITORING AND ASSESSMENT REPORT

Waterbody: Sulphur Creek Watershed: Bear River

Hydrologic Unit Code: WYBR16010101 Segment: 016-2

Investigators: Jack Smith (WDEQ/WQD) and Benita Gustafson (Uinta Co. CD), (1998).
Glen Garton (WDEQ/WQD) and Ty Mack (WDEQ/WQD Intern), (1999).

INTRODUCTION

The entire reach of Sulphur Creek is classified by the Wyoming Surface Water Classification List (Table A) as a Class 2AB, cold water game fish stream (WDEQ/WQD,2001a). Designated uses for Sulphur Creek include: Agriculture (stock watering and irrigation), Fisheries (coldwater game fish), Industry, Drinking Water, Recreation, Scenic Value; Aquatic Life other than Fish; Wildlife; and Fish Consumption.. Sulphur Creek originates along the northern slopes of the Uinta mountains in Utah and enters Wyoming in the southwestern corner of that state. The creek flows to the north, and drains into Sulphur Creek Reservoir. From this point it then flows to the northwest and joins the Bear River south of Evanston. The monitoring segment assessed in this report extends from a confluence with an unnamed tributary in Section 10, Township 12N, Range 119W downstream to the confluence with the Bear River.

Sulphur Creek was included in the WDEQ/WQD Monitoring Program because inconclusive information suggested partial use support for aquatic life, cold water fish, agriculture, and agriculture - irrigation (WDEQ/WQD, 1996). The reported causes of impairment were salinity/ total dissolved solids/ chlorides and unknown sources. The reported sources of impairment were rangeland and nonirrigated crops.

Assessments have been conducted in 1998 and 1999 at three locations. Appendix A provides a map with the location of the reach and sample stations. The 1998 work was conducted approximately one mile upstream of the confluence with the Bear River, downstream from the outlet of Sulphur Creek Reservoir. Due to the timing and magnitude of the release from the reservoir, benthic macroinvertebrates were not sampled. Water chemistry was collected and some habitat evaluations were conducted. In 1999, two bioassessment stations were established: upstream of the reservoir, near the confluence with La Chapelle Creek (WB-97), and one below the reservoir at the location of the 1998 station (WB-98). The samplers judged that these locations would adequately assess this reach of Sulphur Creek. Water chemistry, biological (benthic macroinvertebrates), and physical (habitat quality) data were collected at these two 1999 stations in accordance with the department's bioassessment sampling and analysis plan (King, 1993a), Nonpoint Source Program Quality Assurance Project Plan (WDEQ/WQD, 1993), and Surface Water Quality Assurance Project Plan (WDEQ/WQD, 1989).

The weather at the time of the assessment was clear and calm with an air temperature of 60°F. The samplers observed precipitation at the 1999 stations 4 days prior to sampling. The samplers did not believe the recent precipitation resulted in abnormal water chemistry or biological conditions at the stations at the time of sampling.

DESCRIPTION OF BIOASSESSMENT STATIONS

A description of the two bioassessment and two water quality stations established on Sulphur Creek and its major tributary, is presented in Table 1.

Table 1. Sulphur Creek Bioassessment and Water Quality Stations, 1998 and 1999.

Site Name	*Section Township-Range*	*Latitude*	*Longitude*	*Elevation Feet asl*	*USGS Map*
Bioassessment Stations:					
1999:Upper, La Chapelle	SE1/4 SW1/4 Sec. 2 T.13N, R.119W	41° 07' 42.28"	-110 °48'30.41"	7200	Sulphur Creek Res. 1978
1999: S.20 T14,* R119	NE1/4 NW1/4 Sec. 20 T.14N, R.119W	41° 10' 59.61"	-110°51 57.14	7020	Sulphur Creek Res. 1978
Water Quality only Stations:					
1998: Cornelison*	NE1/4 NW1/4 Sec.20 T.14N, R.119W	41° 10' 59.61"	-110 °51' 57.14"	7020	Sulphur Creek Res. 1978
1999: La Chapelle Creek	SE1/4 SW1/4 Sec. 2 T. 13N, R.119W	41° 07' 38.42"	-110 °48' 26.51"	7240	Sulphur Creek Res. 1978

*These are the same locations, visited on separate years.

The latitude-longitude coordinates were determined from corrected GPS readings. These sites are within Uinta County, Wyoming.

RESULTS AND DISCUSSION

Physical Setting

These stations were located to assess the integrity of Sulphur Creek, the influences upon and from the reservoir, and the overall effect on the Bear River system. These stations are within the Wyoming Basins ecoregion. The upper reaches of the watershed are predominantly comprised of Forest Service and BLM land and have dense forest cover. The lower reaches of the watershed near the assessment stations are sage covered grasslands and irrigated haylands. The predominant geology in the immediate area of the 1998 and 1999 ('Cornelison' or 'Section 20') lower station, downstream

from the reservoir, was determined to be part of the Wasatch Formation. This formation is comprised mainly of claystone, siltstones, carbonaceous shales and buff sandstones. The Evanston Formation also influences this region of the watershed and is of similar lithology with gray siltstones, red sandstones and lignite beds (Love and Christiansen, 1985). The state wide digital soils map of Wyoming (Munn and Arneson, 1998) lists the general soil taxonomy (order/suborder/great group/subgroup) at this station to be Aridic Haplustolls and Ustic Haplocambids; fine-loamy, frigid. Haplustolls are mollisols (dark mollic epipedon) formed in dry climates (ust) with minimal horizonation (hapl). Haplocambids are aridisols (mineral soils found in dry climates) with a cambic (changed by physical movement or chemical reaction) horizon. These soils occur on Tertiary age parent material along the edges of the basins under sagebrush-grasslands.

Above the reservoir, at the upper site (La Chapelle) the predominant geology is the Frontier Formation, which is composed of sandstones and shales. Much of the La Chapelle watershed, which contributes to Sulphur Creek, is influenced by the Wasatch Formation (Love and Christiansen, 1985). The state wide digital soils map of Wyoming (Munn and Arneson, 1998) lists the general soil taxonomy (order/suborder/great group/subgroup) at the Upper site, above the reservoir, to be comprised of rock outcrops and Typic Torriorthents; loamy-skeletal, mixed, frigid. Torriorthents are entisols (mineral soils without natural genetic horizons), common (orth) and dry (torr). These stony soils occupy ridges, are often much coarser than the soils on the adjacent slopes, and contain hard clasts (rock fragments).

Irrigated hayland was determined to be the primary land use with livestock grazing as the secondary land use at the lower (Cornelison) station. Primary and secondary land uses were not determined for the upper (La Chapelle) station. Additional stream characteristics are presented in Table 2. Discharge was calculated on-site using the velocity-area method with a Global FlowProbe®. Discharge at the Lower Cornelison station was visually estimated in 1998. Drainage areas and stream orders were calculated off U.S.G.S. 7 ½ minute quadrangle maps.

Table 2. **Sulphur Creek Assessment, Stream Characteristics**.

Station Name	*Discharge (C.F.S.)*	*Drainagae Area (square miles)*	*Stream Order*
1998: Cornelison	60-80 (est)	84.9	4
1999:Upper, Below La Chapelle	6.12	54.8	4
1999: Lower, Cornelison	5.75	84.9	4
1999: La Chapelle Creek	2.68	26.2	3

The Sulphur Creek and Sulphur Creek West oil fields are located in the Sulphur and La Chapelle Creek watershed south (upstream) of the assessment stations. In addition, a major gas pipeline corridor, consisting of 4 major pipelines, crosses both streams in the vicinity of the gas fields (De Bruin, 1996). There are no discharge points in these oil fields.

The Bear River Canal and associated ditches divert water from the Bear River near the Wyoming / Utah state line and bring that water to the Sulphur Creek watershed for irrigation in the Hilliard Flats region. This canal and ditch network is shown on the *Pine Knoll* 7 ½ minute U.S.G.S. quadrangle. The City of Evanston diverts Bear River water near the Meyers Ranch and that water travels via a 36-inch pipeline to Sulphur Creek Reservoir for storage and release. Contributions from this pipeline represent the major input to the reservoir for most of the year. A small transbasin diversion that brings Green River Basin water into the Sulphur Creek watershed via La Chappell Creek is also present.

Stream Channel Fluvial Morphology

The 1998 site on Sulphur Creek system, below the reservoir, indicated morphological adjustment in response to reservoir releases. High releases from the reservoir have made for atypical morphological changes as the system does not respond to the seasonal patterns of a natural hydrograph. High flows may be extreme, and short lived, in response to a particular release. In this system such flows have washed through some creek meanders and transported sediment high above the bankfull level. Bedload carrying capacities will also have to adjust with strongly variant flow. This can significantly influence substrate size and benthic macroinvertebrate habitat quality.

This site, as documented in the 1998 sampling, appeared to be a Rosgen'C' stream, reestablishing itself within the parameters of a preexisting 'F' type of channel. The adjustments, and transitional nature of the channel type, are likely an influence of the reservoir release patterns. A C3/C4 channel is a slightly entrenched, meandering, rifle/pool, cobble/gravel dominated channel with a well developed floodplain (Rosgen, 1996). The streambanks are commonly composed of unconsolidated, heterogeneous, non-cohesive, alluvial materials that are finer than the bed material. This makes the system vulnerable to bank erosion and the rates of lateral adjustment are mainly a function of the rooting integrity and general condition of the riparian vegetation. When hay meadows are cropped in close proximity to the channel, as indicated in this system, such integrity may be compromised further.

This lateral adjustment of the system's 'C' characteristics, is what brings the active channel up against the 'F' confines of the channel. Rosgen 'F4' streams are typically gravel dominated, entrenched, meandering channels deeply incised into gentle terrain. The erosional rates and sediment delivery are quite high due to exposed banks and mass wasting which further enhance the degree of fluvial entrainment. Riparian vegetation plays a relatively minor role in streambank stability since the bank height exceeds the rooting depth of riparian plant species. It is the incision and entrenchment that mainly distinguish an 'F' from a 'C', the latter having flood plain development and access. The central flood plain access in this system is mainly on the inner part of a meander, as opposed to the outer banks, which are high and unconsolidated. If flows exceed the capacity of the C system, these higher banks will be accessed and jeopardized. The ability for a C channel to function in a stable manner within the outer banks of an entrenched F is determined by the degree to which energy is dissipated across the flood plain at higher flows and the potential for lateral

migration (sinuosity increase) within the abandoned terrace. These dynamics will be largely influenced by the timing and magnitude of the reservoir releases.

Photographs taken at the sampling station include: upstream, downstream, and panoramic views. These photographs can be found in the Sulphur Creek assessment file. The sample riffles are observable in the photographs, as are the land uses, haying activity and general channel morphology.

Water Quality

Water quality samples were taken at the Sulphur Creek sampling location on October 20, 1998 and October 19, 1999. The samples were collected, preserved, transported and analyzed in accordance with procedures outlined in the department's Surface Water Quality Assurance Project Plan (WDEQ/WQD, 1989). All water quality data were evaluated for quality assurance and quality control and met data quality objectives. Water quality parameters and results for the Sulphur Creek station are found in Table 3.

Table 3. Water Quality Parameters and Results, Sulphur Creek.

Parameter (units)	Sulphur Cr - Lower, Cornelison	Sulphur Cr. - Upper, La Chapelle	Sulphur Cr. - Lower, Cornelison	La Chapelle Cr.
Date	10/20/1998	10/19/1999	10/19/1999	10/19/1999
Time (hours)	12:20	15:10	16:50	13:50
Temperature (°C)	8.2	7.0	6.7	3.9
pH (Standard Units)	8.26	7.68	7.53	7.49
Conductivity (µS/cm)	483	550	548	782
Dissolved Oxygen (mg/l)	10.15	9.19	10.1	10.85
Turbidity (NTU)	6.1	3.31	7.21	3.12
Total Suspended Solids (mg/l)	12	3	8	4
Alkalinity (mg/l)	220	270	310	240
Chlorides (mg/l)	13	20.5	13.6	57.8
Sulfate (mg/l)	23	23.4	28.9	42
Total Hardness (mg/l)	251	288	265	357
Total Phosphorus (mg/l	<0.1	<0.1	<0.1	<0.1
Nitrate Nitrogen (mg/l)	<0.1	0.2	0.1	0.3

The water temperature observed in Sulphur Creek for the 1998 and 1999 sampling ranged from 3.9 to 8.2° C and was well below the WDEQ/WQD (2001b) maximum allowable stream temperature of 20.0° C for cold water fisheries. These temperatures were collected in mid- to late afternoon and probably accurately reflect late October maximum water temperatures. Summer maximum temperatures were not determined in this assessment.

The pH values observed in Sulphur Creek (ranging from 7.49 to 8.26 standard units) were slightly basic (greater than 7 standard units) but were below the WDEQ/WQD (2001b) upper limit standard of 9.0 standard units. The highest pH reading was observed in 1998 when significant releases from Sulphur Creek Reservoir were observed. This pH may have been a function of the biological condition of the reservoir at that time.

Dissolved oxygen is the amount of free oxygen available to aquatic organisms. As with temperature and pH, it can vary greatly within a given day. With an increase in temperature the oxygen content of the water can decrease. In systems with heavy algal growth the dissolved oxygen may fluctuate greatly as photosynthesis increases oxygen concentrations during the day and respiration reduces oxygen concentrations during the night. Dissolved oxygen levels observed in Sulphur Creek were greater than the 4.0 mg/l one day minimum coldwater criteria for non-early life stages and above the 8.0 mg/l needed for early life stages (WDEQ/WQD, 2001b).

Conductivity is a field measurement used to evaluate the level of dissolved constituents in the water. The more dissolved substances present, the higher the conductivity measurement. There are no WDEQ/WQD surface water quality standards for conductivity, however King (1990) reported aquatic organism negative response when conductivities were greater than 6,900 µS/cm. The conductivity values for the Sulphur Creek got as high as 782 µS/cm, but were well below the suggested threshold. Such levels are not uncommon for waters flowing through a watershed with sedimentary rock geology. These conductivities do not support the suggested salinity stressor condition in Sulphur Creek, under base flow conditions. The conductivity from La Chapelle was at least 200 µS/cm higher than that at the other locations. The conductivity at the Lower, Cornelison station, observed in 1998, was the lowest observed and likely reflects the increased flow witnessed at this time. The chloride levels, as explained later in this report, corroborate this difference, and provide a probable explanation for this spatial variation.

Turbidity is an optical property of water where total suspended solids (TSS) and some dissolved material cause light to be scattered. An increase in turbidity and TSS has been shown to decrease the production and abundance of plant material, decrease abundance of fish food organisms, and decrease production and abundance of fish (Lloyd, 1987). The WDEQ/WQD (2001b) numeric standard for turbidity deals with turbidity increases attributable to the activities of man. The WDEQ/WQD (2000) narrative standard for floating and suspended solids states that activities attributable to man shall not cause significant degradation of habitat for aquatic life or adversely affect plant life or wildlife. Lloyd's (1987) literature review of the effects of turbidity on salmonids suggested that turbidities in the 10-25 NTU range and TSS concentrations near 35 mg/l can have deleterious effects on fish. Newcombe and Jensen's (1996) literature review suggest TSS values

between 18 and 35 mg/l can result in reduced feeding and abundance, and TSS values in the range of 50 to 66 mg/l can result in reduced rates of weight gain and avoidance behavior in adult rainbow and cutthroat trout. For the Sulphur Creek system, the turbidity ranged from 3.12 to 7.21 NTU and the TSS values were as high as 12 mg/l. The higher readings were below the reservoir, and increased with a corresponding increase in reservoir releases. Judging by the morphology it would appear that the sediment delivery could be quite high at peak flow when the channel moves against the outer unconsolidated and steep Rosgen 'F' banks that are not capable of being stabilized with riparian vegetation.

Alkalinity refers to the capacity of water to neutralize the addition of acid. Alkalinity is also important for primary production (bacteria and algae) in streams, which directly affects the macroinvertebrate community. Generally, as alkalinity increases, stream production increases (King, 1993a). There is no numeric alkalinity standard in Wyoming, but a minimum limit of 20 mg/l has been set by the U.S. Environmental Protection Agency (1986). Sulphur and La Chapelle Creek levels were all above this minimum threshold.

Chlorides and sulfates are the two principle dissolved components in water. Increased chloride or sulfate levels can have a negative effect on benthic macroinvertebrates. WDEQ/WQD (2001b) water quality standards set aquatic life acute and chronic chloride standards of 860 mg/l and 230 mg/l, respectively. There is no surface water numeric standard for sulfates in Wyoming, however, King's (1993a) review suggests sulfate levels below 150 mg/l were optimal for macroinvertebrates. Acute chloride levels ranged from 13 to 20.5 mg/l for Sulphur Creek and were 57.8 for La Chapelle Creek. These levels do not support the chloride stressor condition suggested for Sulphur Creek in the 1996 Wyoming Water Quality Assessment Report. The sulfates were between 23 and 28.9 mg/l for Sulphur Creek and a higher 42 mg/l for La Chapelle Creek. These levels suggest that these parameters were not causing a negative impact to the aquatic life. The sulfates for Sulphur Creek stations were also below levels which would threaten the macroinvertebrate community. However, it is important to note that the higher readings for both these parameters were recorded at the La Chapelle Creek tributary.

Total hardness in stream water is related to the concentration of metals (metallic ions). Common metallic ions that contribute to hardness include calcium and magnesium. When the hardness is numerically greater than the sum of carbonate and bicarbonate alkalinity, the excess is called noncarbonate hardness. Other metallic ions comprising the noncarbonate hardness may include iron, strontium, and manganese. There is no total hardness water quality standard in Wyoming, however, if a large disparity between total hardness concentrations are observed between reference streams and the stream being assessed, sampling for specific metals should be conducted (King, 1993a). The Sulphur Creek samples indicated 'hard' water while the La Chapelle Creek sample (357 mg/l) indicated 'very hard' water.

Phosphorus is an essential element for plant growth and is considered one of two primary nutrients associated with human-induced pollution. Even low levels of phosphorus (>0.2 mg/l) can stimulate

growth of algae, periphyton, and bacteria. Naturally occurring phosphorus enters the stream primarily by soil erosion and sediment transport. Additional sources of phosphorus can include municipal and industrial effluents, and runoff from animal feeding areas and fertilized lands (King, 1993a). Wyoming has not established water quality standards for phosphorus, however, King's (1993a) literature review suggests total phosphorus levels should not exceed 0.05 mg/l in a stream that enters a lake or reservoir(as in this case) and suggests a target total phosphorus concentration of $\leq$1.0 mg/l for streams that do not directly enter lakes. The total phosphorus levels for Sulphur Creek and La Chapelle Creek were <0.1 mg/l and do not suggest a phosphorus loading problem under base flow conditions.

Several forms of nitrate nitrogen are present in nature. WDEQ bioassessments sample and analyze nitrate → nitrite nitrogen. Nitrate is considered the other of the two primary nutrients associated with human induced pollution. Sources of human induced nitrate concentrations can be from municipal and industrial effluents, animal feeding operations, fertilizer use, and other human and animal waste runoff (King, 1993a). Wyoming does not have a nitrate standard for aquatic life, however, the human health standard for nitrate nitrogen is 10 mg/l (WDEQ/WQD, 2001b). Nitrate nitrogen levels for Sulphur Creek were below the detectable limit for one of the four sampling events; the 1998 Lower, Cornelison station below the reservoir. For all 1999 sampling, nitrate-nitrogen levels ranged from 0.1 mg/l to 0.3 mg/l, with the highest reading being at La Chapelle Creek. Nitrate concentrations at these levels suggest the addition of nutrients to the system and can induce algal growth in the reservoir and creek.

For Sulphur Creek in 1999, the stream exhibited no surface sheen, or odors at the time of the sampling, but had a light brown color above the reservoir and a greenish-brown color below the reservoir.

Macroinvertebrates and Biological Condition

Macroinvertebrate samples were taken from a riffle habitat at each of the two bioassessment stations. Eight surber samples were randomly located at each site and a composite sample was obtained. Samples were collected and preserved according to WDEQ/WQD bioassessment protocols (King, 1993a).

Macroinvertebrate samples were sent to WDEQ/WQD's contract laboratory (Aquatic Biology Associates, Corvallis, OR) where they were processed and subsampled according to WDEQ/WQD protocol and standard taxonomic effort (King, 1993a). All biological data were evaluated for quality assurance and quality control and met data quality objectives.

Core metrics have been utilized for assessing the integrity of the stream. These metrics, and their values for Sulphur Creek, are shown on Table 4. The converted 'scores' are simply the value of the given metric placed on a scale from 0-100, with a higher score indicating a more optimal condition. The scores are developed in relation to the given bioregion of the site. Secondary metrics have been

used to augment the bioassessment and further elaborate upon the biologic patterns of the benthic community. The core metrics have been selected through work done by Tetra Tech (Stribling et al., 2000) in their multivariate analyses of Wyoming macroinvertebrate data. These were the metrics that were the most effective, and statistically credible, in indicating the condition of Wyoming stream systems. The composition of this suite of metrics is diverse, and relatively non-overlapping, in its ecological characterization. Two benthic macroinvertebrate stations were established on Sulphur Creek; the Lower, Cornelison 1999 station and the Upper, La Chapelle station above the reservoir, also sampled in 1999.

Table 4. Basins Ecoregion Core Biometric Values and Scores Sulphur Creek, October 19th, 1999

Core Metric	Basin Bioregion Reference Condition (95th or 5th Percentile)	Metric Value: *Upper, La Chapelle*	Metric Score: *Upper, La Chapelle*	Metric Value: *Lower, Cornelison*	Metric Score: *Lower, Cornelison*
Total Number Taxa	45	42	93.3	32	71.1
Ephemeroptera Taxa	9	6	66.7	8	88.9
Plecoptera Taxa	7	2	28.6	2	28.6
Trichoptera Taxa	10	6	60	6	60.0
% Plecoptera	16.5	1.32	8	0.34	2.1
% Non-insects*	0.04	9.41	78.3	4.18	86.7
% 10 Dominant Taxa*	71	79.52	70.6	92.15	27.1
BCI CTQa*	62.5	88.5	42.9	78.5	64.8
No. Scraper Taxa	8	5	62.5	5	62.5
% Collector-gatherers*	13	45.13	63.1	38.96	70.2
Index Score (∑ /10)			**57.4**		**56.2**
Verbal Score			**Fair**		**Fair**

* Metric where the trend increases with increasing stress (positive TwI). Higher values indicate a negative response. Reference Condition 5th percentile is utilized to calculate the score for positive TwI metrics.

Metrics Discussion

Taxa richness refers to the total number of taxa in the sample. The number of taxa generally decreases with decreasing water quality. An exception are high quality, low productivity alpine

streams with naturally low concentrations of dissolved constituents and correspondingly low taxa richness (King, 1993a). The Sulphur Creek stations are not high elevation, alpine sites. The Wyoming Basin Bioregion reference condition (95th percentile) is 45 taxa. There were 42 taxa at the Upper station (score=93.3) and 32 taxa below the reservoir at the Cornelison site, with a lower score of 71.1. The Upper station is comparable to reference condition with respect to this metric, the Lower station exhibits a significant decrease in taxa numbers. The taxa lost between sites were primarily non-insect and Family Chironomidae of the Order Diptera.

The Order Ephemeroptera (mayflies) contains approximately 700 species in North America. Because of the large number of species, mayflies will normally be found in most samples collected in stream riffle habitats during any time of the year. Their presence in riffle habitats is generally associated with good to excellent water quality while their absence from riffle habitats is a strong indicator of poor water quality (King, 1993b). The functional feeding groupings of mayflies are primarily scrapers, collector gatherers, or shredders. The 95th percentile for the Basins ecoregion is 9 distinct Ephemeroptera taxa. The Sulphur Creek samples had 6 (Upper, La Chapelle) and 8 (Lower, Cornelison) resulting in scores of 66.7 and 88.9, respectively. This indicates a moderate to good capacity for the system to support these more intolerant taxa.

Taxa in the Order Plecoptera (stoneflies) are found in cool, well-oxygenated streams with good to excellent water quality. These taxa are the most sensitive of all aquatic macroinvertebrates to water pollutants and their presence is considered a barometer of good water quality. Because of this, the presence of numerous distinct stonefly taxa and a significant relative stonefly abundance are good indicators of good to excellent water quality (King, 1993b). Each of the Sulphur Creek Stations had only 2 Plecoptera taxa relative to the Basin Bioregion reference condition upper value (95th percentile) of 7 taxa. The resulting score was a low 28.6. In three of the four cases (2 taxa at each of two stations), only one individual of each specific taxa was collected. Siltation of the substrate, and potential high temperature/low oxygen reservoir release waters are likely factors in limited stonefly diversity and abundance.

The Percent Plecoptera was correspondingly low. This metric addresses the relative *abundance*, as opposed to the *diversity*, of the Plecoptera representation within the sample. The scores for Sulphur Creek were 8 and 2.1 (Upper, La Chapelle and Lower, Cornelison, respectively) with a minimal representation of Plecoptera within the sample. The ecological context is not supporting a relatively abundant Plecoptera population, indicating poor water quality and habitat. Since the substrate appeared to be of suitable size (see habitat discussion in this document), the high degree of substrate siltation was a likely habitat factor in the minimal Plecoptera diversity and abundance.

Taxa of the Order Trichoptera (caddisflies) are commonly found in most aquatic habitats. These taxa should be found in all riffle samples with the exception of streams with very poor water quality. Caddisflies either live in cases or are free-living (without cases). It is not unusual to find from 5 to 10 different types of caddisflies in stream riffles with good water quality (King, 1993b). The numbers of Trichoptera taxa at each station (6) were moderately represented relative to the Basin Bioregion reference condition (95th percentile) of 10 taxa.

A high percentage of non-insects, commonly pollutant tolerant members of the Phyla Annelida (segmented worms) and Platyhelminthes (flatworms), generally indicates poor water quality. The percentage of non-insects in both Sulphur Creek stations was higher than the Bioregion reference condition (5^{th} percentile value of 0.04 %). The Upper site had 9.41% non-insects (score=78.3) and the Cornelison station was 4.18% resulting in a score of 86.7. These metrics indicate some degree of water quality stressors present to cause an increase in these more intolerant taxa types.

The percent contribution of the dominant taxa is an indication of community balance. A community dominated by a single taxon or by relatively few taxa indicates environmental stress due to poor water quality or habitat quality (King, 1993a). The percentage of the sample comprised of the ten most abundant taxa for the Upper site sample was 79.52, with a score of 70.6. Below the reservoir, at the Cornelison site, 92.15% of the benthic macroinvertebrate sample was comprised of the ten most dominant taxa, resulting in a low score of 27.1. The Chironomid genus *Rheotanytarsus* comprised over 25% of the overall sample. This invertebrate is a collector-filterer with a relatively high tolerance value of 6, out of a possible 10 (with a 10 being the most pollution tolerant).

The Biotic Condition Index (BCI), Actual Community Tolerance Quotient (CTQ_a) is the product of values derived from the taxon's tolerance levels of alkalinity and sulfate plus selectivity for or against fine texture substrate materials and low stream gradients. Values range from 2 to slightly greater than 100 with the larger values indicating greater taxon tolerance (Winget and Mangum, 1979; Platts et. al, 1983). The CTQ_a is a mean of the tolerance quotient of the macroinvertebrates collected from any station on any given date. The BCI - CTQ_a value for Sulphur Creek was 88.5 at the Upper site (score=42.9) and 78.5 (score=64.8) for the Cornelison site. These BCI - CTQ_a values were considerably higher than the Basin Bioregion reference condition (5^{th} percentile) of 62.5 and indicate perturbations to the system.

Scrapers are the functional feeding group of macroinvertebrate taxa that scrape rock, twig, and leaf surfaces for food such as periphyton (King, 1993b). Scrapers tend to increase with an increase in the abundance of diatoms and decrease as filamentous algae (indicative of organic and nutrient enrichment) increases (King, 1993a). Taxa in this functional feeding group tend to be relatively intolerant to stressors such as sediment that reduce or eliminate their feeding areas. The number of scraper taxa for the Basin Bioregion reference condition (95^{th} percentile) is 8 taxa. Indicating limitations upon their diatomaceous food source, or the effects of silt-covered substrate, the scraper diversity in Sulphur Creek was relatively low, with only 5 distinct taxa present for each station. The percent abundance of overall scrapers was quite low, with 6.4 % and 3.69% of the sample comprised of this functional feeding group at the Upper, La Chapelle and Lower, Cornelison stations, respectively.

Collector - Gatherers are a functional feeding group of macroinvertebrate taxa that eat decomposing fine organic matter such as decayed plants, leaves and materials in stream bottom sediments. A high percentage of collector - gatherer taxa can be indicative of organic enrichment from vegetative material, manure, or sewage. An increase in this functional feeding group may also indicate increased stream sedimentation (King, 1993b). The percentage of collector - gatherer taxa in

Sulphur Creek was 45.13 at the Upper, La Chapelle station and 38.96 at the Lower, Cornelison station. The reference value (5th percentile) for percent collector - gatherer taxa for Basin Bioregion reference condition is 13 %. The scores for this metric were poor to moderate and are suggestive of nutrient loading. For the Upper, La Chapelle site this functional feeding group was markedly the dominant type.

Additional Metrics

Additional biological metrics were calculated for the Sulphur Creek bioassessment station. The following metrics are included to further describe the macroinvertebrate community as it pertains to water quality and habitat integrity. These metrics did not have as high discrimination efficiencies as the core metrics previously discussed, however, these data are useful in further understanding the biological community and ecological dynamics in the Sulphur Creek system. The following biometrics cover the aspects of density, tolerance levels, EPT representation, Trichoptera composition, aquatic worm abundance and voltinism.

The total macroinvertebrate densities at the two Sulphur Creek stations were 42,932 and 24,129 organisms per square meter for the Upper, (La Chapelle) and Lower, (Cornelison) stations, respectively. The density at the upper station is extremely high and suggests a direct response due to nutrient enrichment in the system. The density at the lower station decreased significantly, most likely a reflection of nutrients being retained in Sulphur Creek Reservoir. However, the total macroinvertebrate density at the lower station remains quite high.

The modified Hilsenhoff Biotic Index (HBI) involves summation of the pollution tolerances of organisms into a single value. Tolerance values ranging from 0 to 10 are assigned to each organism contained in the sample. Organisms assigned higher values are more tolerant to organic and possibly nutrient and sediment pollutants. A high HBI value indicates that the macroinvertebrate community is comprised of organisms with greater tolerance to pollutants. King (1993a) provides references and additional discussion on this index. Modified HBI value for the Upper, La Chapella station of 4.94 indicates moderate to high tolerance values, showing a strong representation of pollution tolerant taxa. The modified HBI for the Lower,Cornelison station was higher at 5.19.

The EPT/Chironomid ratio is a metric that examines the relative abundance of the intolerant EPT taxa compared with that of the more tolerant Chironomid taxa. The Chironomid taxa may increase in relative abundance and diversity due to increases in organics and sediment. A balanced community will have a strong representation of the more sensitive taxa. A predominance of Chironomid taxa may indicate limited habitat quality or water quality pollution. For both the Upper, La Chapella and Lower, Cornelison stations, the abundance of the EPT taxa approximates that of the Chironomid, (ratios of 1.0 and 1.14 respectively. These ratios indicate water quality and/or habitat limitations have precluded the relative proliferation of the more sensitive EPT taxa.

Percent Hydropsychidae to total Trichoptera is a metric that measures the density of the generally mild pollution tolerant Hydropsychidae family (primarily filtering collectors) to the density of total Trichoptera (relatively sensitive to water pollution)(King, 1993a). King (1993a) assigns the highest biological score to samples where density of Hydropsychidae is less than 20% of the total Trichoptera. The percentage for Sulphur Creek was 80% and 91% (Upper, La Chapelle and Lower, Cornelison, respectively) demonstrating the relative proliferation of the more tolerant taxa among the Trichoptera.

The ratio of Scraper to Collector - Filter macroinvertebrates reflects the food base utilized by these functional feeding groups. Scrapers increase with an increase in the abundance of diatoms and decrease as filamentous algae (indicative of organic and nutrient enrichment) increases. Collector - Filters increase due to the presence of filamentous algae (algae provides good habitat) and to an increased source of fine particulate organic matter (associated with organic enrichment) used as food (King, 1993a). For the two Sulphur Creek stations the percentage of Collector-Filter representation was 13.36 for the Upper site and 44.48 for the Lower site. In terms of the ratio of Scraper to Collector - Filters the two Sulphur Creek stations had ratios of 0.48 and 0.08 for the upper and lower stations, respectively. These ratios indicate that Collector - Filters are more than twice the density of Scrapers at the Upper, La Chapella station and more than 12-times the density of Scrapers at the Lower, Cornelison station. Reference quality stations in the Bear River watershed commonly have a Scraper to Collector - Filter ratio of approximately 0.75. The Lower, Cornelison station represents approximately 11% of reference condition. King (1993a) gives those stations having less than 20% reference condition the lowest "biological condition scoring" for this metric.

Community voltinism is a measure of the distribution of taxa with various life cycle requirements. Multi-voltine taxa are those that exhibit several life cycles during a single year. Uni-voltine taxa are those requiring a year to complete a single life cycle, while semi-voltine taxa are those that require several years to complete a life cycle. An even distribution of these three assemblages suggests a stable community. The dominance of multi-voltine taxa suggest possible seasonal degradation of water quality or that periodic pulses of pollutants through the system have limited the survival of uni-voltine and semi-voltine taxa. A strong representation of semi-voltine taxa is a positive indicator that the habitat and water quality is conducive to organisms that need a longer period of time to complete a life-cycle. It indicates that their biological needs are being supported. The Sulphur Creek stations exhibited an imbalance of voltinism in the macroinvertebrate community with a pronounced inability to support the semi-voltine species. The semi-voltine representation at the Upper, La Chapelle station and 4.7% and 2.68% at the Lower, Cornelison station. The multi-voltine representation at the Upper, La Chapelle station was 40.27% and 55.35% at the Lower, Cornelison station. These data suggest an imbalanced biological community that is under stress either continually, or stressed on a frequent basis during the year.

Shredders, macroinvertebrates that chew and consume plant material such as leaves, wood , and plant parts that originate primarily from the riparian zone, are generally pollution-intolerant taxa of the Orders Plecoptera and Trichoptera; and to a lesser extent Ephemeroptera, and Lepidoptera (King, 1993a). The Upper, La Chapelle sample completely lacked a Shredder component, while the Lower,

Cornelison sample contained only one Shedder taxa, comprising 0.17% of the entire sample. The extremely low Shredder component may be a result of water quality stressors, a lack of riparian woody material, or both factors.

Biomonitoring Observations

Additional Sulphur Creek biomonitoring observations made by the investigators are presented in Table 5. The "abundant" observation of filamentous algae at both stations, along with the "abundant" observation of rooted macrophytes at the Lower, Cornelison station support the macroinvertebrate data of a high percentage of Collector - Filter functional feeding group and also the assumption of nutrient enrichment.

Table 5. Biomonitoring Observations, Sulphur Creek, 1999.

Stream Station	Filamentous Algae	Floating Macrophytes	Rooted Macrophytes	Periphyton	Slimes	Fish
Upper, La Chapelle	abundant	not observed	rare	dominant	not observed	not observed
Lower, Cornelison	abundant	not observed	abundant	common	not observed	common

General Biological Observations

At the site below the reservoir, the Lower, Cornelison station, the 1999 sampling indicated that large mats of rooted macrophytes were in both riffle and pool habitats. The fish observed ranged from <2 inches in length to over 7 inches. One large, 14 inch brown trout was observed and a small shiner was caught in the surber net during the substrate sampling.

Habitat Quality

Physical (habitat quality) data were collected and analyzed according to WDEQ/WQD bioassessment protocols (King, 1993a). All data were evaluated for quality assurance and quality control and met data quality objectives.

For each site substrate composition and silt cover (embeddedness) were recorded at eight, one square foot sample points randomly located within the riffle where macroinvertebrates were collected. Water velocity was also recorded at each of these points. A summary of these data are presented in Table 6.

The two Sulphur Creek sample riffles were composed primarily of cobble and coarse gravels. Fines at the Upper, La Chapelle riffle comprised 10% of the sample (6% sand 4% silt). Fines at the Lower,

Cornelison station were comprised of 11% sand with no silt substrate being documented. The presence of rock and gravel in flowing streams is generally considered the most desirable habitat for a diverse macroinvertebrate community (Plafkin et al., 1989).

The weighted embeddedness rating is an assessment of the silt covering of the cobble and gravels across the eight macroinvertebrate subsample locations. The weighted embeddedness ranges from 20 to 100 with a rating of 100 being relatively sediment free. The mean water velocities at these two riffles, 1.33 and 1.16 feet per second, should be sufficient to keep cobble and gravels relatively silt cover free under normal sediment loads. The Sulphur Creek weighted embeddedness ratings of 30.4 and 38.8 indicate the substrate is significantly silt covered. Such substrate siltation inhibits the diversity and abundance of the more sensitive benthic taxa, and can threaten the foodbase for fish. These data substantiate the low percentage of Scraper taxa observed in the macroinvertebrate data.

Table 6. Mean Substrate Composition, Weighted Embeddedness, and Water Velocity at the two 1999 Sulphur Creek Sample Riffles.

Mean Percent Substrate (Eight 1 ft.^{2} Quadrats)								
Station	Cobble (2.5-10")	Coarse Gravel (1 - 2.5")	Fine Gravel (0.3 -1")	Silt* (<0.3", fine)	Sand (<0.3", gritty)	Clay (Hard Pack)	Organic (fine, black)	Precipitate (Oil, WWTF)
Upper, La Chapelle	68	17	6	4	6	0	0	0
Lower, Cornelison	53	26	10	0	11	0	0	0

Station	**Weighted Embeddedness - Silt Coverage (Range 20 to 100)** Eight 1 ft.^{2} Quadrats	**Mean Water Velocity (ft./sec.)** Eight Quadrat Locations
Upper, La Chapelle	30.4	1.33
Lower, Cornelison	38.8	1.16

* Silt substrate is where the silt covering is greater than 1/4 inch deep

The qualitative habitat quality assessment for Sulphur Creek covered a segment upstream from the riffle used for macroinvertbrate sampling. The reach length is determined by multiplying the bankfull width by 20, or at a minimum, 360 feet. Thirteen habitat parameters (5 primary parameters, 4 secondary parameters, and 4 tertiary parameters) were evaluated within this reach (Table 7). Evaluation of these parameters allow for a total habitat score ranging from zero to 200 points. High total point scores equate to high quality habitat. Specifics of the individual habitat parameters are contained in King (1993a) and the department's procedures paper *Beneficial Use Reconnaissance Project - Wadable Stream Monitoring Methodology* (WDEQ/WQD, 2000).

Table 7. Habitat Assessment Values, Sulphur Creek, 1999.

Parameter	Upper, La Chapelle	Lower, Cornelison
Total Primary	60	55
Total Secondary	33	40
Total Tertiary	26.5	17
Total Score	119.5	112

These habitat scores, which have been incorporated into the overall biometric generation, indicate relatively poor habitat quality. Both stations exhibit a high degree of silt cover on the riffle substrate, where the substrate materials are >75% covered by silt. The instream cover for fish was minimal, the width-to-depth ratio was high, and the banks were relatively unstable. Willow species were minimal and the dominant vegetation did not have root masses capable of holding the banks together. The vegetation was lacking in riparian species and the vegetation provided minimal capacity to protect the banks and dissipate energy.

The Upper, La Chapelle station had riparian zone stressors on the left bank(facing upstream) and the Sulphur Creek report document contains photos showing excavation equipment being used along the channel. Also visible in the file are photos showing banks that have collapsed and the use of automobiles for bank support.

The Lower, Cornelison station had particularly unstable banks, with minimal vegetation protection and evident pressures on the riparian zone. Sudden high-volume releases from the reservoir, in response to water use demands, have cut off meanders on the channel. These artificial flood dynamics are substantiated by gravel deposition above the bankfull level. The monitoring photos indicate the height (6 to 8 feet) and condition of the banks, which at higher flows could be a significant sediment source and would explain the siltation in the riffle environments. The investigators noted significant depositional bar development in the system. The willow cover was minimal and the streambank was not comprised of plants that have root masses capable of withstanding high streamflow events. The floodplain and channel characteristics did not appear adequate to dissipate energy for the higher reservoir releases.

Pool Quality

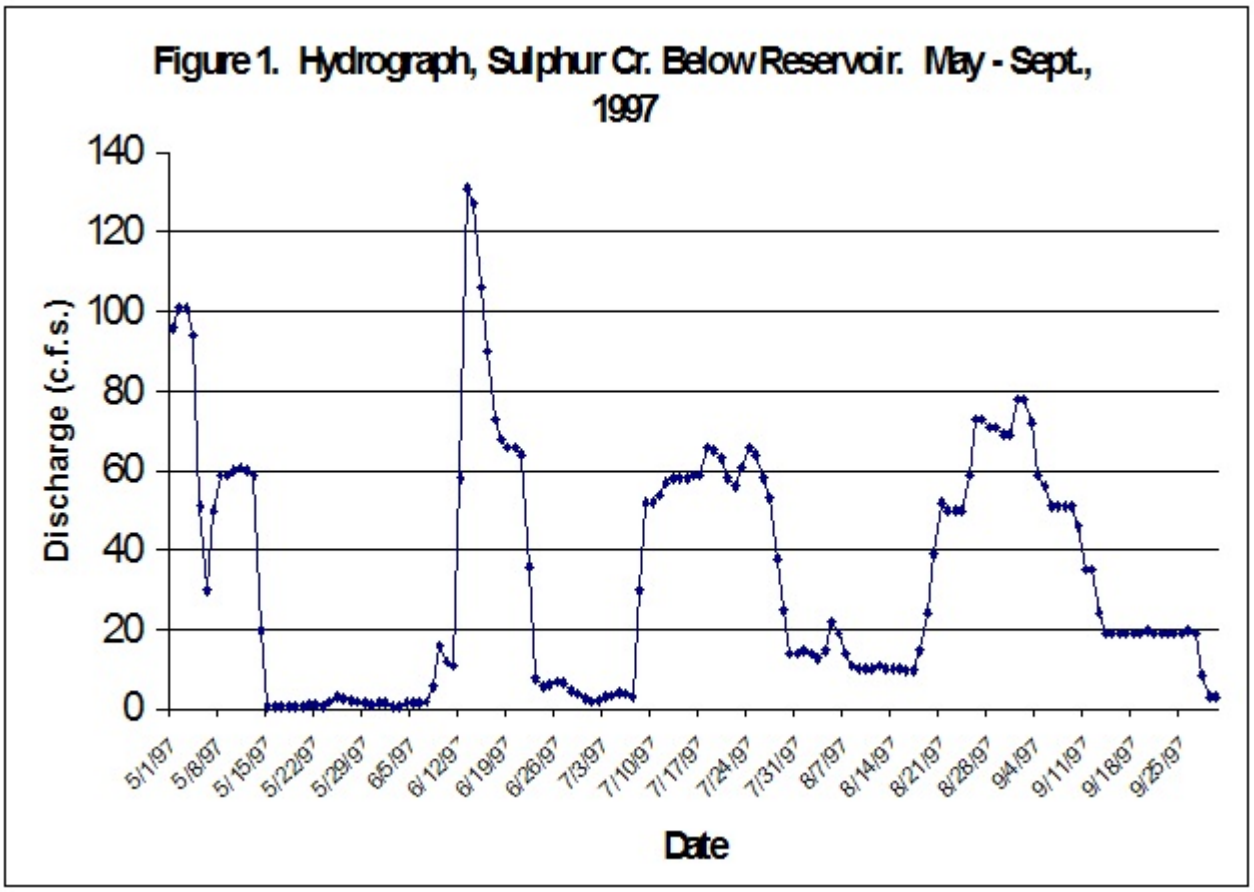
Pool quality assessments were made in the first four pool habitats upstream of the macroinvertebrate sample riffle. Pool quality scores range from 0 to 10, with 10 exhibiting the highest pool quality. Pool quality at the Upper, La Chapelle station were: 3; 3; 3; and, 5. Scores were depressed due to poor overhead cover, relatively poor subsurface cover, and somewhat poor bank cover. Pool quality at the Lower, Cornelison station were: 3; 2; 4; and , 4. Scores were depressed due to poor substrate composition in the pool (samplers noted pools were dominated by silt) and poor overhead cover. Subsurface cover and bank cover were relatively poor. The presence of deeper pool areas in this reach (residual pool depth) was the only assessment factor that was good.

Historical and Ancillary Information

Discharge Data

Multiple U.S.G.S. stations were operated in the Sulphur Creek system following construction of the reservoir. These stations have been placed above the reservoir, below the reservoir and at locations to assess the quantities being diverted into the Sulphur Creek watershed. Stream flow data collected in 1997 below the reservoir illustrate the high degree of discharge fluctuation as a result of reservoir holding and flow release (Figure 1). These data show that discharge below the reservoir can go from 60 cfs down to less than 1 cfs in 3 days. Conversely, discharges were shown to increase from 1.9 cfs to 131.0 cfs in 6 days.

Such abrupt flow reductions and flow increases are known to have a drastic effects upon the fish and benthic habitat. These abrupt flow changes can lead to instabilities of the stream bed and banks, destruction of organisms vital to the fish food chain, and elimination of cover (Skinner and Stone, 1983). Abrupt flow changes can result in significant bank breakdown when the stream water level quickly drops below the level of heavy, water-laden bank soils. Abrupt flow increases are then able to remove the soil that has spoiled into the channel before those soils have the opportunity to stabilize with vegetation.



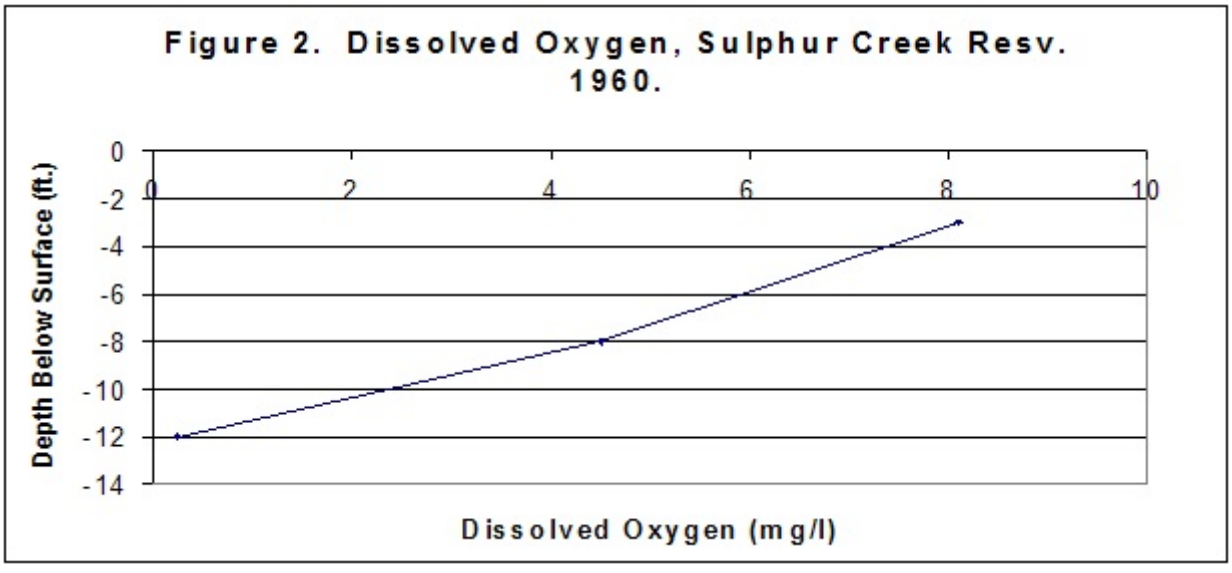
Water Chemistry Data

Historical water chemistry data are limited on Sulphur Creek. Western Wyoming College collected water chemisty data in Sulphur Creek below Sulphur Creek Reservoir in 1976 and 1977 (Table 8). These data are similar to those collected by the WDEQ/WQD assessment crews. Of note are the total phosphate data that support the assessment data suggesting nutrient enrichment in the Sulphur Creek system.

Table 8. Historical Water Quality Data, Sulphur Creek, 1976 - 1977.

Parameter	November 10, 1976	April 20, 1977
Water Temperature (°C)	1.0	2.5
Specific Conductance (uS/cm)	320.0	570.0
pH (Standard Units)	8.58	8.40
Nitrate Nitrogen (mg/l)	0.05	< 0.01
Total Phosphate (mg/l)	0.28	0.36
Sulfate (mg/l)	44.80	38.29
Chloride (mg/l)	54.70	Not Collected

The Wyoming Game and Fish collected dissolved oxygen data in Sulphur Creek Reservoir on March 19, 1960. An oxygen/depth profile was constructed from these three data points (Figure 2). Dissolved oxygen levels dropped below 4.0 mg/l at approximately 8.5 feet below the surface. Dissolved oxygen levels below 1.0 mg/l occurred at approximately 11 feet below the surface. No additional information were presented with these data (secchi disk or chlorophyll *a*).



Biological Data

The Wyoming Game and Fish has surveyed fish species within Sulphur Creek and also within Sulphur Creek Reservoir. The creek was surveyed above the confluence with the Bear River, below Sulphur Creek Reservoir, in Section 8, Township 14 north, Range 119 west. Within the creek the non-game species have been abundant and include: mountain sucker, sculpins, longnose dace, speckled dace, Utah chub, redside shiners, and a few leatherside chubs (Miller, no date). The game species have included large spotted cutthroat (Bonneville), mountain whitefish, and rainbow trout. Water temperatures as high as 80 degrees Fahrenheit have been recorded.

Sulphur Creek Reservoir was originally constructed in 1958. The reservoir was enlarged in 1964 to form a 374 acre impoundment. The reservoir was again enlarged in the late 1980's to its current 630-acre size. The water is stored for irrigation and municipal purposes. Historically, gill netting documentation by the Wyoming Game and Fish has indicated that rainbow trout, cutthroat trout, brown trout, brook trout, Utah suckers, and redside shiners have been found in the reservoir. Prior to 1970 the reservoir was stocked with rainbow trout (years 1958-1970) and brook trout were planted in 1965, 1968 and 1970 (Miller, no date). More recently, the Wyoming Game and Fish has managed the reservoir with Bonneville cutthroat trout. The management effort has resulted in Sulphur Creek above the reservoir being closed to fishing from April 1 until June 30 to protect cutthroat trout spawing. Sulphur Creek Reservoir is also the site for an annual ice fishing derby. The 2001 weekend-long derby resulted in 710 fish being caught through the ice, the largest being a 20.5 inch rainbow trout (Kemmerer Gazette, 2001).

SUMMARY AND CONCLUSIONS

Classification

Sulphur Creek is correctly classified as a Class 2AB, Coldwater game fish waterbody. This conclusion is based on: Wyoming Game and Fish data that show the creek historically has supported rainbow, Bonneville cutthroat, and mountain whitefish; the inlet to Sulphur Creek Reservoir presently has spring fishing restrictions to protect spring-spawning Bonneville cutthroat trout; and, Sulphur Creek Reservoir support cold water game fish as shown by Game and Fish records and the local through-the-ice fishing derby.

Water Quality

Base flow water quality on Sulphur Creek (October 19, 1999) did not identify any water quality standards exceedences. Nitrate-nitrogen levels in these samples were somewhat elevated and suggest nutrient enrichment to the system. That suggestion is supported by the observed response in filamentous algae, rooted macrophytes, and collector - filter macroinvertebrates in the system.

Macroinvertebrates and Biological Condition

Bioassessment primary metrics indicate that Sulphur Creek's macroinvertebrate community is depressed as comparable to that of reference condition for the given ecoregion. Specific biometrics (Percent Non-Insects, Number Plecoptera Taxa, Percent Plecoptera, Percent 10 Dominant Taxa, Number Trichoptera Taxa, and Number Scraper Taxa) suggest the system is stressed by nutrients and sediment. Supplemental biometrics (Total Density, Scraper/Collector-Filter Ratio, and Community Voltinism) and biomonitoring observations (Filamentous Algae and Rooted Macrophytes) substantiate the presence of these stressors.

Physical and Habitat Quality

The physical assessment scores for Sulphur Creek (119.5 and 112 points) are relatively poor. The following factors contributed to the depressed scores: high Percent Silt Cover (Embeddedness); low Instead Cover for Fish; high Width-to-Depth Ratio; and low Bank Stability. Actual silt cover measurements resulted in low Weighted Embeddedness rating of 30.4 and 38.8. Pool Quality was low due to a high degree of fines in the pools, poor subsurface cover, and poor overhead cover.

Historical and Ancillary Data

Discharge data collected below Sulphur Creek Reservoir in 1997 indicates a high degree of flow variation due to water holding and release from the reservoir. Rapid and highly fluctuating water releases are known to result in stream channel instability and reduced benthic and fisheries communities.

The limited amount of historical water quality data also supports the idea of nutrient enrichment in the Sulphur Creek system.

FINAL ASSESSMENT AND SIGNATURES

Review of the chemical, biological, and physical data collected on Sulphur Creek on September 19, 1999 indicates that Sulphur Creek, a tributary of the Bear River, is a Class 2AB (cold water) waterbody under WDEQ/WQD Rules and Regulations (2001b).

These data suggest that Sulphur Creek is only partially supporting the designated use of "Aquatic Life Other than Fish". The stressor that results in this partial support is sediment. The causes of these stressors appear to be flow alteration below Sulphur Creek Reservoir and undetermined landuses above Sulphur Creek Reservoir.

This reach of partial support extends from the confluence with the Bear River upstream to Sulphur Creek Reservoir and from the inlet to Sulphur Creek Reservoir an undetermined distance upstream.

A weight-of-evidence review of the chemical, biological, physical and historical data was used to make this determination. This decision is based on the following items, presented in order of weight:

1. Depressed macroinvertebrate community characteristics;
2. Benthic macroinvertebrate metrics that suggest sedimentation and nutrient stressors;
3. Habitat assessment data that support the occurrence of sedimentation stressors (Weighted Embeddedness in the sample riffle, Pool Quality Evaluations, Bank Stability, etc.); and
4. Discharge data below the reservoir that show rapid and widely-fluctuating releases, supporting the occurrence of sediment stressors.

Evidence that is contrary to this decision is presented below, in order of weight:

1. No exceedence of a numeric water quality standard was observed in the October 20, 1998 or October 19, 1999 samples.

This latter evidence was determined not to be sufficient to alter the recommended partial-support of the Aquatic Life Other than Fish designated use determination.

Additional chemical, biological, and historical data suggest that nutrients may also be a stressor in Sulphur Creek. These items are presented below and support the need for additional nutrient monitoring in this system:

1. Macroinvertebrate metric data that suggest a response due to nutrient enrichment (Percent Collector-Filterers, Ratio of Scrapers to Collector-Filterers);
2. Biomonitoring observations (abundant Filamentous Algae and Rooted Macrophytes) that suggest the occurrence of nutrient enrichment;
3. Water quality data (Nitrate-nitrogen and Total Phosphorus) that have the potential to be nutrient enrichment stressors;
4. Historic oxygen sags observed in Sulphur Creek Reservoir; and,
5. Historical data suggesting the presence of historic nutrient (Total Phosphourus) stressors.

This assessment recommends additional nutrient (Nitrate-nitrogen and Total Phosphours) sampling in Sulphur Creek, along with a more extensive dissolved oxygen sampling program (diurnal monitoring). Such monitoring should occur during various flow regimes.

Assessment Report Author (signature and printed name)	Date
Assessment Report Author (signature and printed name)	Date
Assessment Report Author (signature and printed name)	Date
Monitoring Supervisor (signature and printed name)	Date

REFERENCES

De Bruin, R.H. 1996. Oil and gas map of Wyoming. Map Series 48. Wyoming Geological Survey. Laramie, WY.

Kemmerer Gazette. 2001. Annual Ice Fishing Derby. Article by Wade Williams. February 16, 2001.

King, K. 1990. Effects of oil field produced water discharges on pond zooplankton populations. Wy. Dept. Env. Qual., Water Qual. Div., Cheyenne, WY 26pp.

King, K. 1993a. A bioassessment method for use in Wyoming stream and river water quality monitoring. Draft. Wy. Dept. Env. Qual., Water Qual. Div., Cheyenne, WY 84pp.

King, K. 1993b. A laboratory manual and illustrated guide to orders of common Wyoming stream macroinvertebrates. Wy. Dept. Env. Qual., Water Qual. Div., Cheyenne, WY 68pp.

Lloyd, D. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North Amer. J of Fisheries Mgmt. 7:34-45.

Love, J.D., and A.C. Christiansen, 1985. Geologic Map of Wyoming. Wyoming Geologic Survey. Laramie, Wyoming.

Miller, D.D., no date. Comprehensive Survey of the Bear River Drainage. Wyoming Game and Fish Department, Fish Division Completion Report. Project 4077-01-6602, Cheyenne, WY. 81 pp

Munn, L.C. and C.S. Arneson. 1998. 1:500,000-scale digital soils map of Wyoming. Univ. Wyo. Agric. Exper. Stn., Univ. Wyo. Laramie, WY.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bio-assessment protocols of use in streams and rivers - benthic macroinvertebrates and fish. U.S. Environmental Protection Agency, Office of Water. EPA/444/4-89-001. May, 1989.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S.D.A. Forest Service, Gen. Tech. Rep. INT-138. Ogden, UT. 70pp.

Rosgen, D. 1996. Applied river morphology. Illustrated by H.L. Silvey. Wildland Hydrology, Pagosa Springs, CO.

Skinner, M.M. and M.D. Stone. 1983. Identification of instream hazards to trout habitat quality in Wyoming. U.S. Dept. Interior. Fish and Wildlife Service. FWS/OBS - 83/13. Washington, D.C. 69pp.

Stribling, J.B., B.K. Jessup, and J. Gerritsen. 2000. Development of biological and physical habitat criteria for Wyoming streams and their use in the TMDL process. March, 2000. Tetra Tech, Inc., Owings Mills, MD. 46pp.

U.S. Environmental Protection Agency. 1983. Turbidity. Pages 180.1 - 180.4 *in* Methods for chemical analysis of water and wastes. USEPA, Office of Research and Development, EPA-600/4-79-020, Cincinnati, OH.

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

Winget, R.N. and F.A. Mangum. 1979 Biotic Condition Index: Integrated Biological, Physical, and Chemical Stream Parameters for Management. U.S.D.A. Forest Service. Ogden, UT. Contract No.40-84M8-8-524 51 pp.

Wyoming Dept. Environ. Qual., Water Qual. Div. 1989. Surface water quality assurance project plan. August 1989. Cheyenne, WY. 40pp.

Wyoming Dept. Environ. Qual., Water Qual. Div. 1993. Nonpoint source program quality assurance project plan. November 1993. Cheyenne, WY. 25pp.

Wyoming Dept. Environ. Qual., Water Qual. Div. 1998. Beneficial Use Reconnaissance Project - Wadable Stream Monitoring Methodology. Draft, August. 18, 1998. Cheyenne, WY. 33pp.

Wyoming Dept. Environ. Qual., Water Qual. Div. 2001a. Wyoming Surface Water Classification List (Table A). June 21, 2001. Cheyenne, WY.

Wyoming Dept. Environ. Qual., Water Qual. Div. 2001b. Water quality rules and regulations, Chapter 1. Wyoming Surface Water Quality Standards. Cheyenne, WY.

APPENDIX A. SULPHUR CREEK MAP