SUPPORT OF AQUATIC LIFE USES IN MIZPAH CREEK BASED ON THE COMPOSITION AND STRUCTURE OF THE BENTHIC ALGAE COMMUNITY

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SUMMARY

Composite periphyton samples were collected from natural substrates at 2 sites on Mizpah Creek in northern Powder River County in southeastern Montana. Samples were collected following standard operating procedures of the Montana Department of Environmental Quality, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Diatom metrics assigned both sites to the same use support categories to which they were assigned in 1999. UMC-1 fully supported aquatic life uses, with only minor impairment noted from organic loading and a few abnormal diatom frustules. UMC-1 proved to be a suitable local reference site for use in Protocol II.

LMC-7 provided only partial support of aquatic life uses when compared to UMC-1 and to other least-impaired prairie streams. The major causes for less than full support at LMC-7 were organic loading, sedimentation, and a much different diatom assemblage than the upstream control site (UMC-1). Some of the organic loading at LMC-7 may be internal and therefore natural in origin.

The algal assemblages at the two sites also indicated that LMC-7 had larger concentrations of nitrogen and dissolved solids, and higher water temperatures, than did UMC-1.

INTRODUCTION

This report evaluates the biological integrity, support of aquatic life uses, and probable causes of impairment to those uses in Mizpah Creek, Powder River County, Montana. The purpose of this report is to provide information that will help the State of Montana determine whether Mizpah Creek is water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

The evaluations in this report are based on the structure and species composition of the periphyton or phytobenthos community. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity of Montana streams (Bahls et al. 1992).

Periphyton is a diverse assortment of simple photosynthetic organisms called algae, and other microorganisms that live attached to or in close proximity of the stream bottom. Many algae, such as the diatoms, are microscopic. Diatoms are distinguished by having a cell wall composed of opaline glass--hydrated amorphous silica. Diatoms often carpet a stream bottom with a slippery brown film.

Some algae, such as the filamentous greens, are conspicuous and their excessive growth may be aesthetically displeasing. Algae may also deplete dissolved oxygen, interfere with fishing and fish spawning, clog water filters and irrigation intakes, create tastes and odors in drinking water, and generate toxins that may be lethal to livestock and other animals.

Plafkin et al. (1989) and Stevenson and Bahls (1999) list several advantages for using periphyton in biological assessments of streams:

- Algae are universally present in large numbers in all streams and unimpaired periphyton assemblages typically support a large number (>30) of species;
- Algae have rapid reproduction rates and short life cycles, making them useful indicators of short-term impacts;
- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, dissolved salts, and toxins;
- Sampling is quick, easy and inexpensive, and causes minimal damage to resident biota and their habitat;
- Standard methods and criteria exist for evaluating the composition, structure, and biomass of algal associations;
- Identification to species is straightforward for the diatoms, for which there is a large body of taxonomic and ecological literature;
- Excessive algae growth in streams is often correctly perceived as a problem by the public.
- Periphyton and other biological communities reflect the *biological integrity*[1] of waterbodies; restoring and maintaining the biological integrity of waterbodies is a goal of the federal Clean Water Act;
- Periphyton and other biological communities integrate the

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

effects of different stressors and provide a measure of their aggregate impact; and

- Periphyton and other biological communities may be the only practical means of evaluating impacts from non-point sources of pollution where specific ambient criteria do not exist (e.g., impacts that degrade habitat or increase nutrients).

PROJECT AREA AND SAMPLING SITES

The project area is located near Powderville in northern Powder River County in southeastern Montana (Map 1). Mizpah Creek heads about 12 miles west of the town of Broadus and flows northeasterly about 70 miles to the point where it meets the Powder River near Mizpah, Montana.

The project area is within the Northwestern Great Plains Ecoregion (Woods et al. 1999). The surface geology of the watershed consists of coal-bearing deposits of the Fort Union Formation (Renfro and Feray 1972). Upland vegetation is mixed grassland with some open ponderosa pine forest in the headwaters (USDA 1976). The main land use is livestock grazing, with hay production in the valley bottom.

Periphyton samples were collected at 2 sites on Mizpah Creek on August 28, 2000 (Table 1). These 2 sites bracket a 20-mile section of upper Mizpah Creek that extends from Highway 59 north of Broadus to the Custer County line (Map 1). Elevations at the sampling sites range from about 3,200 feet above mean sea level at the upper site to 2,900 feet at the lowest site. Mizpah Creek is classified C-3 in the Montana Surface Water Quality Standards.

METHODS

Periphyton samples were collected following standard operating procedures of the Planning, Prevention, and Assistance Division of the Montana Department of Environmental Quality. Using appropriate tools, microalgae were scraped, brushed, and/or sucked from natural substrates in proportion to the rank of those substrates at the study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's solution (APHA 1998).

Samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Dillard (1999), Prescott (1978), Smith (1950), and Whitford and Schumacher (1984). These books also served as references on the ecology of the soft algae, along with Palmer (1977).

After the identification of soft algae, raw periphyton samples were cleaned of organic matter using sulfuric acid, and permanent diatom slides were prepared using Naphrax, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). For each slide, between 430 and 445 diatom cells (860 to 890 valves) were counted at random and identified to species. The following were used as the main taxonomic and autecological references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975.

Lowe (1974) was also used as an ecological reference for the diatoms. Bahls et al. (1984) provide autecological information on important diatom species that live in the Fort Union Region of Montana, including many of the diatom species found in Mizpah Creek.

The diatom proportional counts were used to generate an array of diatom association metrics (Table 2). A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999).

Metric values for Mizpah Creek were compared to numeric biocriteria developed for streams in the Great Plains Ecoregions of Montana (Table 3). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993).

The criteria in Table 3 distinguish among four levels of impairment and three levels of aquatic life use support: no impairment or only minor impairment (full support); moderate impairment (partial support); and severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor *biological integrity*, respectively.

Besides the ecoregional biocriteria listed in Table 3, metrics for the lower site on Mizpah Creek (LMC-7) were also compared to metrics generated from an upstream, least-impaired reference site (UMC-1) using Protocol II in Bahls (1993). Protocol II is based on the percentage of change in metric values at the study site(s) from values measured at the local reference stream. Criteria for evaluating biological integrity using Protocol II are given in Table 12 in Bahls (1993).

Protocol II may be used if an upstream reference site is available that fully supports its aquatic life uses, that is, if it has a rating of "good" or "excellent" biological integrity using Protocol I. Mizpah Creek station UMC-1 exhibited only minor impairment using Protocol I and therefore qualifies as a local reference site.

For Protocol I, only periphyton samples collected in summer (June 21-September 21) can be compared with confidence to reference stream samples because metric values change seasonally and summer is the season in which reference streams and impaired streams were sampled for the purpose of biocriteria development. Protocol II can be used at any time of the year.

QUALTIY ASSURANCE

Several steps were taken to assure that the study results are accurate and reproducible.

Upon receipt of the samples, station and sample information were recorded in a laboratory notebook and samples were assigned a unique number compatible with the Montana Diatom Database, e.g., 1860-02. The first part of this number (1860) designates the sampling site (Mizpah Creek one mile south of the Custer County line); the second part of the number (02) designates the number of periphyton samples that have been collected at this site to date for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with station and sample information provided by Patrick Newby of MDEQ. A portion of the raw sample was used to make duplicate diatom slides.

On completion of the project, station information, sample information, and diatom proportional count data will be entered into the Montana Diatom Database. One set of diatom slides will be deposited in the University of Montana Herbarium in Missoula. The other set of slides will be retained by *Hannaea* in Helena.

RESULTS AND DISCUSSION

Results are presented in Tables 4-6, located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species' pollution tolerance classes and percent abundances, are attached as Appendix A.

FIELD AND SAMPLE NOTES

Mizpah Creek UMC-1. The sample from this site contained *Myriophyllum* and bits of terrestrial plants. A small flat piece of a *Nostoc* colony was observed in this sample, as well as isolated filaments. The *Phormidium* species here had very narrow filaments and most of the diatom frustules in this sample were empty.

Mizpah Creek LMC-7. The sample collected here contained bits of aquatic macrophytes. *Monostroma* occurred here as an expanded sheet one cell thick; cells were mutually compressed and not in groups of four. Most of the diatoms in this sample were alive (contained chloroplasts and protoplasm).

NON-DIATOM ALGAE

Cyanobacteria and chrysophytes, including diatoms and *Tribonema*, were the only algae observed in the sample collected at UMC-1 (Table 4). *Tribonema* prefers cool, fresh waters (Smith 1950). Green algae were not present at the upstream site.

Only four genera of non-diatom algae were observed at UMC-1. Least-impaired prairie streams contain an average of 13 genera (Bahls 1993). Although they were only common, diatoms accounted for most of the biomass as UMC-1. The relative abundance of cyanobacteria, particularly the nitrogen-fixer *Nostoc*, the absence of green algae, and the small number of algal genera probably indicate nitrogen deficiency at this site.

In contrast, green algae and diatoms were abundant at LMC-7 (Table 4). This site supported 9 genera of non-diatom algae, including two reliable indicators of organic loading: *Euglena* and *Stigeoclonium*. The most abundant green alga at LMC-7 was *Monostroma*, which is a good indicator of brackish water (Smith 1950). The appearance of *Oedogonium, Anabaena,* and *Nodularia*, and the disappearance of *Nostoc*, may indicate warmer water at LMC-7 than at UMC-1.

DIATOMS

All but one of the major diatom species in Mizpah Creek were either very tolerant or somewhat tolerant of organic pollution (Table 5). The only sensitive species--*Cocconeis placentula*--was much more abundant at the upstream site (UMC-1).

Very tolerant species, especially *Navicula circumtexta* and *Navicula veneta*, were much more abundant at LMC-7, resulting in a very small pollution index (1.36) at this site. These taxa, along with *Nitzschia reversa*, also indicate an increase in dissolved solids between UMC-1 and LMC-7.

Over 80% of the diatom species at LMC-7 were motile and adapted to living on unstable substrates. This resulted in a very high siltation index, even for a prairie stream. LMC-7 also had borderline values for diatom species diversity, percent dominant species, and percent abnormal cells (Table 5).

Diatom association metrics indicated good to excellent water quality and biological integrity at UMC-1. This site proved to be a suitable reference site for use in Protocol II. UMC-1 also supported a significant percentage of diatoms in the family Epithemiaceae, indicating that nitrogen was probably the limiting nutrient here. The two sites had less than a third of their diatom associations in common, indicating that a significant amount of environmental change occurred between them.

BIOASSESSMENT

PROTOCOL I

All diatom association metrics for **UMC-1** indicated full support of aquatic life uses when compared to least-impaired reference streams elsewhere in eastern Montana (Table 5). Minor impairment, but still full support, was indicated by two metrics: Pollution index and percent abnormal cells. Full support of aquatic life uses was also noted at UMC-1 in 1999 (Bahls 2000).

A very low pollution index and an exceptionally large siltation index indicated only partial support of aquatic life uses at **LMC-7** when compared to prairie reference streams in eastern Montana (Table 5). The pollution index was lower and the siltation index was higher in 2000 than they were at this site in 1999. This site also exhibited moderate impairment and partial support of aquatic life uses in 1999 (Bahls 2000).

PROTOCOL II

Metrics at LMC-7 were compared with those at the upstream control site (UMC-1) following Protocol II and using the criteria in Table 12 in Bahls (1993). This comparison also indicated that LMC-7 provided only partial support of aquatic life uses and was moderately impaired. Impairment was due primarily to the very low pollution index, indicating a high level of organic loading, and to the dissimilarity between the two diatom associations. Some of the organic loading here may be internal in origin, i.e., resulting from the breakdown of aquatic plants.

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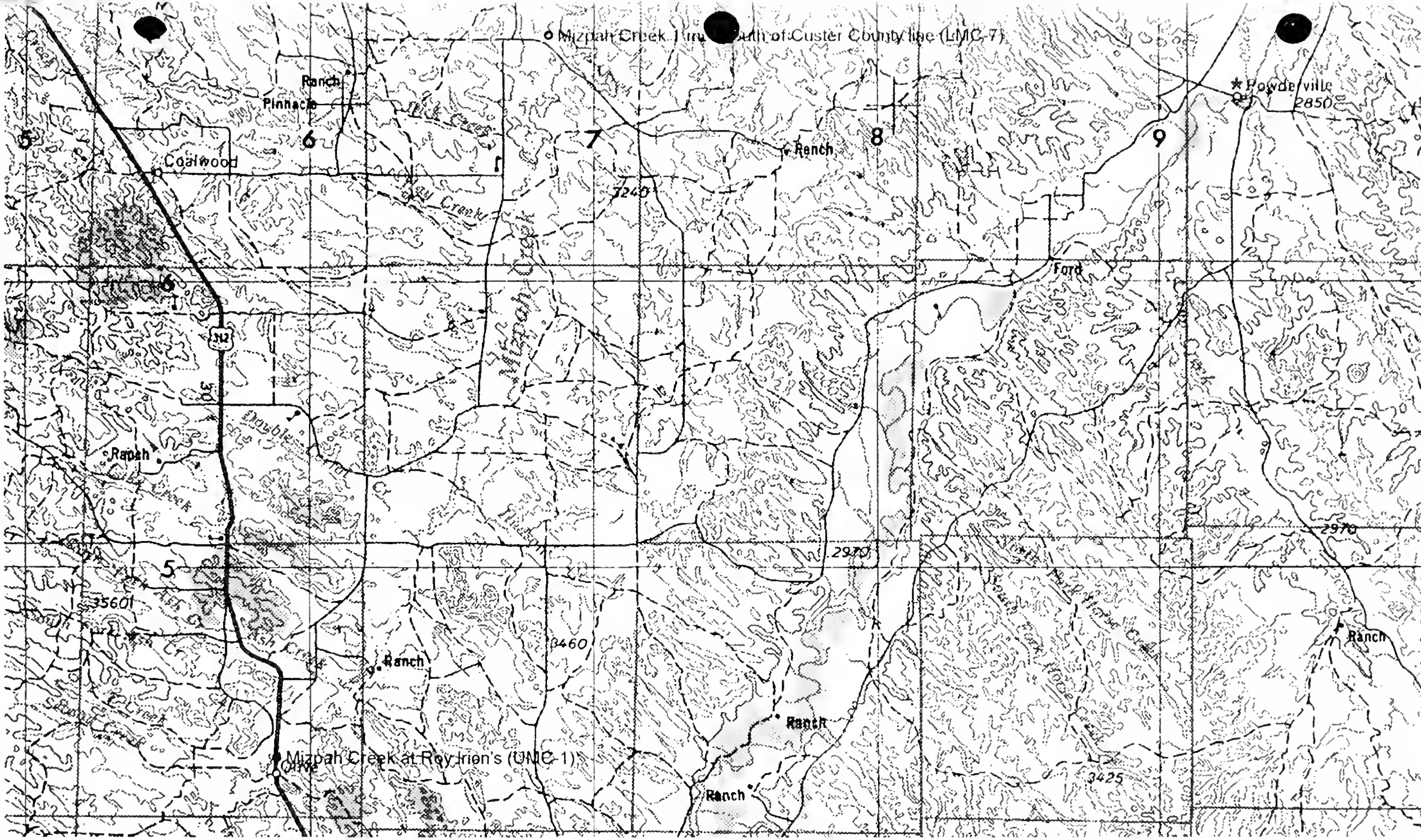
APPENDIX A: DIATOM PROPORTIONAL COUNTS

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
185702	Achnanthes lanceolata	2	11	1.28
185702	Achnanthes minutissima	3	4	0.47
185702	Amphipleura pellucida	2	16	1.86
185702	Amphora coffeaeformis	1	63	7.33
185702	Amphora libyca	3	2	0.23
185702	Aulacoseira distans	3	1	0.12
185702	Aulacoseira granulata	3	0	0.00
185702	Aulacoseira italica	3	0	0.00
185702	Caloneis silicula	2	0	0.00
185702	Cocconeis pediculus	3	2	0.23
185702	Cocconeis placentula	3	206	23.95
185702	Cyclotella meneghiniana	2	9	1.05
185702	Cymbella cymbiformis	3	1	0.12
185702	Cymbella mexicana	3	1	0.12
185702	Cymbella pusilla	1	10	1.16
185702	Cymbella silesiaca	2	0	0.00
185702	Denticula subtilis	2	2	0.23
185702	Entomoneis paludosa	2	1	0.12
185702	Epithemia adnata	2	53	6.16
185702	Epithemia argus	2	2	0.23
185702	Epithemia turgida	3	7	0.81
185702	Fragilaria capucina	2	1	0.12
185702	Fragilaria construens	3	13	1.51
185702	Fragilaria elliptica	2	39	4.53
185702	Gomphonema angustatum	2	2	0.23
185702	Gomphonema clavatum	2	14	1.63
185702	Gomphonema gracile	2	2	0.23
185702	Gomphonema mexicanum	2	2	0.23
185702	Gomphonema parvulum	1	2	0.23
185702	Gyrosigma spencerii	2	1	0.12
185702	Mastogloia elliptica	2	0	0.00
185702	Navicula cuspidata	2	4	0.47
185702	Navicula elginensis	3	2	0.23
185702	Navicula erifuga	2	5	0.58
185702	Navicula gregaria	2	6	0.70
185702	Navicula halophila	2	18	2.09
185702	Navicula oblonga	2	1	0.12
185702	Navicula peregrina	2	10	1.16
185702	Navicula salinarum	1	2	0.23
185702	Navicula veneta	1	132	15.35
185702	Nitzschia amphibia	2	37	4.30
185702	Nitzschia apiculata	2	6	0.70
185702	Nitzschia aurariae	1	6	0.70
185702	Nitzschia capitellata	2	4	0.47
185702	Nitzschia frustulum	2	52	6.05
185702	Nitzschia gracilis	2	1	0.12
185702	Nitzschia hungarica	2	13	1.51

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
185702	Nitzschia liebetruthii	2	14	1.63
185702	Nitzschia microcephala	1	2	0.23
185702	Nitzschia palea	1	9	1.05
185702	Nitzschia pusilla	1	6	0.70
185702	Nitzschia tryblionella	2	1	0.12
185702	Nitzschia valdestriata	2	1	0.12
185702	Nitzschia vermicularis	2	1	0.12
185702	Pinnularia viridis	3	1	0.12
185702	Plagiotropis arizonica	2	1	0.12
185702	Pleurosigma delicatulum	2	1	0.12
185702	Rhoicosphenia curvata	3	2	0.23
185702	Rhopalodia brebissonii	1	2	0.23
185702	Rhopalodia gibba	2	8	0.93
185702	Rhopalodia operculata	1	0	0.00
185702	Stauroneis tackei	2	2	0.23
185702	Stephanodiscus hantzschii	2	3	0.35
185702	Surirella ovalis	2	1	0.12
185702	Synedra delicatissima	2	1	0.12
185702	Synedra famelica	2	7	0.81
185702	Synedra fasciculata	2	30	3.49
185702	Synedra pulchella	2	1	0.12
185702	Synedra ulna	2	0	0.00



MAP 1

'Ekalaka 250K; MT,SD,ND,WY'; Scale: 1" = 2.978Mi 4,792Mt 15,723Ft, 1 Mi = 0.336" , 1 cm = 1,887Mt

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
186002	Amphora coffeaeformis	1	8	0.90
186002	Anomoeoneis sphaerophora	2	3	0.34
186002	Caloneis silicula	2	2	0.22
186002	Cocconeis pediculus	3	0	0.00
186002	Cocconeis placentula	3	38	4.27
186002	Cyclotella meneghiniana	2	3	0.34
186002	Cymatopleura elliptica	2	0	0.00
186002	Cymbella pusilla	1	17	1.91
186002	Diatoma tenue	2	1	0.11
186002	Entomoneis alata	2	4	0.45
186002	Epithemia adnata	2	5	0.56
186002	Gomphonema clavatum	2	1	0.11
186002	Gomphonema gracile	2	49	5.51
186002	Gomphonema parvulum	1	4	0.45
186002	Gyrosigma spencerii	2	4	0.45
186002	Mastogloia smithii	2	0	0.00
186002	Navicula capitata	2	2	0.22
186002	Navicula cincta	1	2	0.22
186002	Navicula circumtexta	1	120	13.48
186002	Navicula erifuga	2	10	1.12
186002	Navicula peregrina	2	5	0.56
186002	Navicula pygmaea	2	5	0.56
186002	Navicula recens	2	5	0.56
186002	Navicula salinarum	1	19	2.13
186002	Navicula sp.	2	1	0.11
186002	Navicula tenelloides	1	3	0.34
186002	Navicula veneta	1	424	47.64
186002	Nitzschia apiculata	2	3	0.34
186002	Nitzschia aurariae	1	2	0.22
186002	Nitzschia calida	2	1	0.11
186002	Nitzschia capitellata	2	0	0.00
186002	Nitzschia frustulum	2	6	0.67
186002	Nitzschia hungarica	2	44	4.94
186002	Nitzschia liebetruthii	2	1	0.11
186002	Nitzschia microcephala	1	3	0.34
186002	Nitzschia obtusa	1	3	0.34
186002	Nitzschia ovalis	1	1	0.11
186002	Nitzschia palea	1	7	0.79
186002	Nitzschia pusilla	1	2	0.22
186002	Nitzschia reversa	2	65	7.30
186002	Nitzschia tryblionella	2	2	0.22
186002	Nitzschia vermicularis	2	1	0.11
186002	Pleurosigma delicatulum	2	0	0.00
186002	Rhoicosphenia curvata	3	6	0.67
186002	Rhopalodia brebissonii	1	1	0.11
186002	Stauroneis tackei	2	2	0.22
186002	Surirella brebissonii	2	1	0.11
186002	Surirella brightwellii	2	1	0.11
186002	Synedra famelica	2	2	0.22
186002	Synedra fasciculata	2	1	0.11
186002	Synedra pulchella	2	0	0.00

Table 1. Location of periphyton stations on Mizpah Creek: Station codes, sample numbers in the Montana Diatom Database, sample dates, and legal descriptions.

Location	Station Code	Sample Number	Legal Description	Latitude/ Longitude
Mizpah Creek at Roy Irion's (below Highway 59)	UMC-1	1857-02	T03SR50E26CC	45 32 34 105 31 39
Mizpah Creek one mile south of Custer County line	LMC-7	1860-02	T01SR51E11BC	45 46 18 105 24 22

Table 2. Diatom association metrics used to evaluate biological integrity in Montana streams: reference, range of values in Montana streams, and expected direction of metric response to increasing anthropogenic perturbation or natural stress.

Metric	Reference	Range of Values	Expected Response
Shannon Species Diversity	Bahls 1979	0.00-5.00+	Decrease[1]
Pollution Index[2]	Bahls 1993	1.00-3.00	Decrease
Siltation Index[3]	Bahls 1993	0.00-90.0+	Increase
Disturbance Index[4]	Barbour *et al.* 1999	0.00-100.0	Increase
No. Species Counted	Bahls 1979, 1993	0-100+	Decrease[1]
Percent Dominant Species	Barbour *et al.* 1999	5.0-100.0	Increase
Percent Abnormal Cells	McFarland *et al.* 1997	0.0-20.0+	Increase
Similarity Index	Whittaker 1952	0.0-80.0+	Decrease
Percent Epithemiaceae	Stevenson & Pan 1999	0.0-80.0+	Decrease
Percent Aerophiles	Johansen 1999	0.0-100	Increase

[1] Shannon diversity and species richness may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increases in nutrients or sediment.

[2] Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

[3] Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*.

[4] Percent abundance of *Achnanthes minutissima*.

Table 3. Criteria for rating levels of biological integrity, environmental impairment or natural stress, and aquatic life use support in wadeable **plains** streams of Montana using selected metrics for benthic diatom associations. The lowest rating for any one metric is the overall rating for the study site.

Biological Integrity/ Impairment or Natural Stress/Use Support	Diversity Index (Shannon)	Pollution Index	Siltation Index	Disturbance Index	Number of Species Counted	Percent Dominant Species	Percent Abnormal Cells	Similarity Index[1]
Excellent None/Full Support	>3.99	>2.25	<50.0	<25.0	>39	<25.0	0.0	>59.9
Good/Minor Full Support	3.00-3.99	1.76-2.25	50.0-69.9	25.0-49.9	30-39	25.0 49.9	>0.0-<1.0	40.0-59.9
Fair/Moderate Partial Support	2.00-2.99	1.25-1.75	70.0-89.9	50.0-74.9	20-29	50.0-74.9	1.0-9.9	20.0-39.9
Poor/Severe Nonsupport	<2.00	<1.25	>89.9	>74.9	<20	>74.9	>9.9	<20.0

[1] The Similarity Index or Percent Community Similarity (Whittaker 1952) may be used to compare a study site to an unimpaired upstream control site on the same stream. This metric measures the degree of floristic similarity between diatom associations at the two sites and is the sum of the smaller of the two percent abundance values for each species that is common to both sites. Adjacent riffles on the same stream, without intervening tributaries or environmental perturbations, will generally have at least 60% of their diatom floras in common (Bahls 1993). PCS may also be used to guage the relative amount of impairment or recovery that occurs between adjacent study sites: >59.9% = very similar floras, no change; 40.0-59.9% = somewhat similar floras, minor change; 20.0-39.9% = somewhat dissimilar floras, moderate change; <20.0% = very dissimilar floras, major change.

Table 4. Relative abundance of cells and rank by biovolume of diatoms and genera of non-diatom algae in periphyton samples collected from Mizpah Creek in August 2000.

Taxa	Relative Abundance and (Rank)	
	UMC-1	LMC-7
Chlorophyta (green algae)		
Monostroma		abundant (2)
Oedogonium		occasional (7)
Stigeoclonium		common (5)
Euglenophyta (euglenoid algae)		
Euglena		rare (10)
Chrysophyta (golden algae)		
Bacillariophyceae	common (1)	abundant (1)
Tribonema	occasional (5)	
Cyanophyta (cyanobacteria)[1]		
Anabaena		occasional (8)
Nodularia		common (6)
Nostoc	occasional (4)	
Oscillatoria	occasional (3)	common (4)
Phormidium	common (2)	frequent (3)
Spirulina		occasional (9)

[1] Formerly known as blue-green algae.

Table 5. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from Mizpah Creek in August 2000.

Species/Metric (Pollution Tolerance Class)[3]	Percent Abundance/Metric Values[2]	
	UMC-1	LMC-7
Amphora coffeaeformis (1)	7.33	0.90
Cocconeis placentula (3)	23.95	4.27
Epithemia adnata (2)	6.16	0.56
Gomphonema gracile (2)	0.23	5.51
Navicula circumtexta (1)		13.48
Navicula veneta (1)	15.35	47.64
Nitzschia frustulum (2)	6.05	0.67
Nitzschia reversa (2)		7.30
Cells Counted	430	445
Total Species	69	51
Species Counted	62	45
Species Diversity	4.24	3.05
Percent Dominant Species	23.95	47.64
Disturbance Index	0.47	0.00
Pollution Index	2.01	**1.36**
Siltation Index	38.84	**83.15**
Percent Abnormal Cells	0.23	0.34
Percent Epithemiaceae	8.60	0.67
Similarity Index	29.33	

[1] A major diatom species is here considered to be one that accounts for 5% or more of the cells in one or more samples of a sample set.

[2] Underlined values indicate good biological integrity, minor impairment, and full support of aquatic life uses; **bold values** indicate fair biological integrity, moderate impairment, and partial support of aquatic life uses; all other values indicate excellent biological integrity, no impairment, and full support of aquatic life uses when compared to diatom criteria for mountain and plains streams in Tables 3 and 4.

[3] 3 = sensitive to pollution; 2 = tolerant of pollution; 1 = most tolerant of pollution.

Table 6. Metric scores and impairment ratings for Mizpah Creek Station LMC-7 based on a comparison with Mizpah Creek Station UMC-1, following Protocol II and Table 12 in Bahls (1993). Underlined values indicate full support of aquatic life uses, minor impairment, and good biological integrity; **bold values** indicate partial support of aquatic life uses, moderate impairment, and fair biological integrity; all other values indicate full support of aquatic life uses, no impairment, and excellent biological integrity.

Metric	Metric Score (%)
Shannon Diversity Index	72
Pollution Index	**68**
Siltation Index	47
Similarity Index	**29**