SUPPORT OF AQUATIC LIFE USES IN THE REDWATER RIVER BASED ON PERIPHYTON COMPOSITION AND COMMUNITY STRUCTURE

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SUMMARY

In late May 1999, composite periphyton samples were collected from natural substrates at 8 sites on the Redwater River and 1 site each on Little Dry Creek and the East Redwater River in eastern Montana. Samples were collected following DEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

The benthic algal flora indicated elevated salinity and organic loading in the headwaters of the **Redwater River**, causing moderate impairment and partial support of aquatic life uses at the uppermost site (**Gackle**). Salinity and organic loading decreased downstream to Circle.. **Below the Circle STP,** an increase in organic and inorganic nutrients (but not salts) again caused moderate impairment with partial support of aquatic life uses. Deformed diatoms **below Circle** also indicated the possible presence of toxins in the water.

Recovery was complete in the next 15 miles of stream. A peak in the number of cells in the diatom family Epithemiaceae indicated a low N:P ratio **below Bluff Creek**. Aquatic life uses were fully supported from **Bluff Creek** downstream to **Nickwall Crossing** near the mouth of the Redwater.

Both **Little Dry Creek** and the **East Redwater River** fully supported aquatic life uses with minor impairment from organic loading and elevated nutrients. All of the sites on the **Redwater River** also exhibited at least minor impairment from organic loading and elevated nutrients. This may be the normal background condition for streams in this area.

INTRODUCTION

This report evaluates the support of aquatic life uses, and probable causes of impairment to those uses, in the Redwater River, the East Redwater River, and Little Dry Creek in eastern Montana. This evaluation is based on species composition and community structure of periphyton (benthic algae) communities at 8 sites on the Redwater River and 1 site each on the East Redwater River and Little Dry Creek that were sampled in May 1999.

Plafkin et al. (1989) list several reasons why biological surveys are superior to water quality analyses for determining use support. The first of these reasons is that biological communities measure our success at protecting the *biological integrity*[1] of waterbodies, which is a goal of the federal Clean Water Act.

The periphyton or phytobenthos community is a basic biological component of all aquatic ecosystems. Collectively, periphyton accounts for much of the primary production and biological diversity of Montana streams.

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;

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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 the natural habitats within a region" (Karr and Dudley 1981).

- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, 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; and

- Excess algae in streams is often correctly perceived as a problem by the public.

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. Most 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 luxuriant growth may be aesthetically undesirable, deplete dissolved oxygen, interfere with fishing and fish spawning, clog irrigation intakes, and cause other problems.

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 purpose of this report is to provide information that will help the State of Montana to determine whether the Redwater River, the East Redwater River, and Little Dry Creek are water-quality limited and in need of TMDLs.

PROJECT AREA AND SAMPLING SITES

The project area is in McCone, Dawson, and Garfield counties in eastern Montana. The Redwater River begins in southern McCone County and flows northeast for about 80 miles, joining the Missouri River south of Poplar, Montana. The East Redwater River, a major tributary, enters the Redwater River about 15 miles upstream from its mouth. Little Dry Creek was included in this study as a least-impaired reference stream against which to compare sites on the Redwater River. Little Dry Creek is a tributary of Big Dry Creek and flows north through Garfield County into Fort Peck Reservoir. Little Dry Creek is the next major drainage to the west of the Redwater River.

The project area is located in the Northwestern Glaciated Plains Ecoregion (Omernik and Gallant 1987). The watersheds of all three streams overlie the Fort Union Formation, a coal-bearing sedimentary deposit of Paleocene age (Taylor and Ashley, undated). Vegetation is primarily grassland and the main land use is cattle grazing with some dryland farming. The town of Circle (pop. 716) is located near the headwaters of the Redwater River and is the only community along the three streams.

Periphyton samples were collected in late May 1999 at 8 sites on the Redwater River, and 1 site each on the East Redwater River and Little Dry Creek (Table 1). Elevations of the sampling sites range from about 3,000 feet near the head of the Redwater River to 2,000 feet near the mouth. All three study streams are classified C-3 in the Montana Surface Water Quality Standards.

METHODS

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, 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.

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 Prescott (1978), Smith (1950), and Whitford and Schumacher (1984). These books also served as the main references on the ecology of the soft algae.

After the identification of soft algae, raw periphyton samples were cleaned of organic matter using sulfuric acid, and permanent diatom slides were prepared in a high refractive index mounting medium following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). For each slide, between 400 and 500 diatom cells (800 to 1,000 valves) were counted at random and identified to species. The following were used as the main taxonomic and autecological references: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975.

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).

One additional metric was calculated for this study:

percent of cells in the diatom family Epithemiaceae. This family is represented in rivers by two genera, *Epithemia* and *Rhopalodia*, that commonly harbor endosymbiotic nitrogen-fixing bluegreen algae (cyanobacteria) within their cells. A diatom association that contains a large percentage of cells in these genera may indicate nitrogen-limiting conditions, that is, low nitrogen to phosphorus ratios (Stevenson and Pan 1999).

Metric values from the Redwater River, East Redwater River, and Little Dry 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.

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. However, summer begins earlier on the plains than it does in the mountains and late spring is often the best time to sample prairie streams because flows often become depleted in the summer.

Quality Assurance. Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample information was recorded in a laboratory notebook and samples were assigned a unique number compatible with the Montana Diatom Database, e.g., 0745-02. The first part of this number (0745) designates the sampling site (Little Dry Creek at Highway 200); the second part of the number (02) designates the number of periphyton 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 recored in a lab notebook along with station and sample information provided by MDEQ. A portion of the raw sample was used to make duplicate diatom slides. A subcontractor (E. Weber of PhycoLogic) selected one sample at random from the sample set and performed a reanalysis of the soft algae and an independent count of diatoms on the duplicate slide for that sample. The reanalysis is a check on taxonomic accuracy and on the reproducibility of the sample processing and analysis methods.

Common algal taxa should be the same for the two analyses of soft algae. The percent community similarity index (Whittaker 1952) calculated from the two diatom counts should exceed 75%. Major diatom taxa (>10% relative abundance) should be identified similarly by both analysts. Synonyms are acceptable. Counts completed on the two duplicate slides, and the resulting metrics and bioassessments, should both yield the same use support category (full support, partial support, nonsupport) for the site in question.

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 and 5, located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species pollution tolerance classes (PTC) and calculated percent abundances, are attached as Appendix A. Results of quality assurance analyses are presented in Appendix B.

SAMPLE OBSERVATIONS

Little Dry Creek at Highway 200. Sample was very silty. The bulk of the sample was a root wad. Branching was observed in the *Rhizoclonium*, but it was rare. About 20% of the diatom frustules were empty. Two species of *Oedogonium* were observed.

Redwater River at Gackle. This sample was relatively free of silt. Two species of *Anabaena* were observed: one with straight filaments and the other with tangled filaments. *Chara* was the visual dominant in this sample.

Redwater River at Kurtz. *Stigeoclonium* consisted of short, tapering but unbranched filaments growing on *Rhizoclonium*.

Redwater River at Union Bridge. Sample was in process of decomposition; general aspect was black; smelled of hydrogen sulfide. Bulk of sample consisted of a root wad and amorphous black organic material. Soft algae were in poor condition, but identifiable.

Redwater River below Circle STP. Sample was very silty. Much of the sample consisted of aquatic macrophytes.

Redwater River below Bluff Creek. Sample was very silty. The bulk of the sample consisted of a root wad and macrophytes (*Myriophyllum*). Algae did not visually dominate this sample.

Redwater River above Pasture Creek. Bulk of sample was a root wad and a small piece of *Myriophyllum*. *Rhizoclonium* was entangled in the root wad and much of it was covered with diatom epiphytes. Less than 10% of the diatom frustules were empty. Sample was not very silty compared to others in this series.

Redwater River at Highway 201. The bulk of this sample consisted of a root wad, bits of grasses and twigs, and a piece of *Myriophyllum*. Algae were significantly less common than at the next upstream site (3A). Sample not very silty compared to others in this series. Although abundant, *Rhizoclonium* was not conspicuous in the root wad.

Redwater River at Nickwall Crossing. Bulk of sample consisted of a few stems and a small root wad, among which were entangled *Rhizoclonium*, *Vaucheria* and tube-dwelling diatoms (*Nitzschia filiformis*?). Sample somewhat silty. *Rhizoclonium* more branched than specimens from other sites.

East Redwater River near mouth. Bulk of sample consisted of a few stems covered with ciliated protozoans on branched stalks. Algae were relatively sparse. Sample not very silty. Sample was collected about 0.25 miles above confluence with the Redwater River. The correct name, according to the USGS hydrologic map, is East Redwater River, not East Fork Redwater River (sample label) or East Redwater Creek (Montana DOT county map book).

NON-DIATOM (SOFT) ALGAE

Little Dry Creek

The periphyton community of Little Dry Creek was dominated by diatoms, with a mix of euglenoid algae and filamentous green and bluegreen algae (Table 4). The soft algal flora indicates moderate nutrient enrichment, warm water, and slow current velocities.

Redwater River

The **upper site** on the Redwater (**RW1-3**) was dominated by the macroscopic green alga *Chara*. This alga is common in standing, alkaline waters. The cyanobacterium *Anabaena*, typically a planktonic alga, also indicated ponding in this reach. The chrysophyte *Tribonema* indicated cool water temperatures and the appearance of the green alga *Stigeoclonium* indicated nutrient enrichment.

Nutrient enrichment appeared to increase downstream at **Kurtz (RW1-9)**, where *Stigeoclonium* became more abundant and the flora was dominated by *Rhizoclonium*. *Rhizoclonium* is a sparsely branched filamentous green alga closely related to *Cladophora*. *Anabaena* and *Tribonema* were also present at this site.

The site **above Circle (RW2-D)** had the lowest genus richness of all the sites--only 2 genera of soft algae were recorded. However, this sample had partially decomposed before it was analyzed and some soft algal taxa may have been lost.

Below the Circle STP (RW2-F), *Enteromorpha* was the most abundant alga, followed by diatoms and *Rhizoclonium* (Table 4). *Enteromorpha* is a green alga of marine origin that prefers constant flows of nutrient-rich water with moderately high conductivity. Free-living bluegreen algae (cyanobacteria) were conspicuously absent here and at the next downstream station **(RW2-B)**, although endophytic cyanobacteria may have been present (see diatom disscussion).

Below Bluff Creek (RW2-B), diatoms were again dominant and the number of soft algal genera increased from 3 to 8 (Table 4), perhaps indicating recovery from disturbances upstream. Diatoms continued as the most abundant algae at sites downstream. An abundance of filamentous green algae indicated moderate nutrient enrichment here.

The site **above Pasture Creek (RW3-A)** supported the largest number of non-diatom algal genera (11) of any study site. Free-living bluegreen algae returned, along with occasional euglenoid algae. These euglenoid algae and an abundance of *Rhizoclonium* and the cyanobacterium *Oscillatoria* indicate moderate nutrient enrichment and some (internal?) organic loading.

Genus richness remained high at **Highway 201 (RW3-F)** with 9 genera of soft algae recorded. *Rhizoclonium* remained abundant and *Stigeoclonium* was common, indicating moderate nutrient enrichment. Free-living cyanobacteria were represented by 5 genera, the most recorded at any site.

Genus richness declined to 4 at **Nickwall Crossing (RW3-D)**. The coenocytic chrysophyte *Vaucheria* appeared here for the first time. This alga is common on moist soil and in springs and seeps in the spring of the year. *Rhizoclonium* continued to be abundant here, indicating moderate nutrient enrichment.

<u>East Redwater River</u>

The East Redwater supported a mix of diatoms, green and euglenoid algae, and cyanobacteria (Table 4). After the diatoms, *Rhizoclonium* and *Stigeoclonium* were the most common algae, indicating moderate nutrient enrichment and some (internal?) organic loading.

DIATOMS

__Little Dry Creek__

Little Dry Creek proved to be a suitable reference site; diatom metrics indicated full support of aquatic life uses. Other than minor impairment from a low pollution index (Table 5), all metrics were normal for prairie streams. All of the sites in this study exhibited at least minor impairment due to a slightly depressed pollution index, leading one to suspect that this is the nominal condition for streams in this part of the state.

__Redwater River__

The upper Redwater River site at **Gackle (RW1-3)** supported a large percentage (58%) of pollution tolerant species. *Amphora delicatissima* and *Cymbella pusilla* were the two most abundant pollution tolerant species (Table 5). These are mesohalobous (brackish water) diatoms (Krammer and Lange-Bertalot 1986). *Amphora delicatissima* is closely related to *Amphora coffeiformis*, which tolerates moderate organic loading (Lowe 1974). Also abundant here were two species of *Synedra*: *Synedra famelica* and *Synedra pulchella*. Both of these species prefer waters with moderately high conductivity (Krammer and Lange-Bertalot 1991a).

The depressed pollution index and small number of species indicate **moderate impairment and partial support of beneficial uses** at the Gackle site. The probable causes of impairment here are elevated salinity and loading by organic nutrients.

Although intended primarily as a measure of organic loading (Lange-Bertalot 1979), in practice the pollution index responds to a variety of disturbances and pollution types, including salts, organics, temperature extremes, toxics, inorganic nutrients, and siltation (Bahls 1993). Taxa that tolerate one of these types of pollution also tend to tolerate one or more of the other types. Knowing the autecology of the dominant species helps to identify which type or types of pollution is the most probable cause of impairment.

The pollution index and the number of diatom species increased at **Kurtz (RW1-9)**, where diatom metrics indicated full support with only minor impairment of beneficial uses. The brackish water taxa recorded at Gackle were much less abundant here, indicating fresher water than upstream. The dominant species at **Kurtz** was *Synedra famelica* (Table 5).

At **Union Bridge (RW2-D)**, *Diatoma tenue* replaced *Synedra famelica* as the dominant diatom species (Table 5). *Diatoma tenue* is halophilous, meaning that it is stimulated by small amounts of salt (Lowe 1974). In a survey of saline seeps in eastern Montana (Bahls and Bahls 1976), *Diatoma tenue* preferred waters with lower conductivities than those preferred by *Synedra famelica*. This indicates that the **Union Bridge** site probably had fresher water than the Kurtz site, which in turn had fresher water than the Gackle site upstream. Diatom metrics indicated full support of uses at **Union Bridge** with minor impairment caused by salts and organic loading.

The site **below Circle (RW2-F)** and the site upstream at Union Bridge had very similar floras (similarity index = 66%), in spite of the intervening presence of the Circle STP. *Diatoma tenue* accounted for almost 70% of the diatom cells **below Circle**. In addition to being stimulated by small amounts of salt, *Diatoma tenue* is typically found in waters where the oxidation of biodegradable compounds is nearly complete, where concentrations of inorganic nutrients are high, and where nitrogen is present in the form of ammonia (Lowe 1974).

Dominance by *Diatoma tenue* and the resulting depressed species diversity index indicated **moderate impairment with partial support of aquatic life uses** below Circle. One may conclude from the autecology of *Diatoma tenue* that the primary cause of impairment here was nutrient, primarily nitrogen, enrichment, with salts playing a minor role. The most likely source of this enrichment is the Circle STP, perhaps exacerbated by background loads of salts and nutrients from upstream.

Deformed valves of *Diatoma tenue* also indicated **moderate impairment and partial support of uses** below Circle (Table 5). Diatom deformities may result from a variety of stressors, including heavy metals (McFarland et al. 1997). Given that *Diatoma tenue* is typically found in waters where ammonia is present, ammonia is a possible cause of the diatom deformities observed **below Circle**.

While Union Bridge and the site below Circle had the largest similarity index, the site below Circle and the next downstream site **below Bluff Creek (RW2-B)** had the smallest similarity index of any pair of adjacent stations on the Redwater River (Table 5). In the 15 miles between these two sites, there was a significant improvement in water quality. The dominant diatom **below Bluff Creek** (*Fragilaria construens*) is a sensitive species and it accounted for less than 10% of the cells at this site, and at other sites, hence it is not listed in Table 5. Another indicator of recovery here is the increase in cells of the family Epithemiaceae (*Epithemia* and *Rhopalodia* spp.), which indicates a decline in available nitrogen relative to phosphorus (Stevenson and Pan 1999). The site **below Bluff Creek** had the largest diversity index and probably the best overall water quality and biological integrity of any of the sites in this study.

Water quality and biological integrity remained good at all of the downstream sites in the **Redwater River**. Minor impairment was indicated by some organic loading and by an occasional deformed cell or a slightly elevated percent dominant species value. Diatom diversity remained high all the way to the mouth of the Redwater and the siltation index was within acceptable limits for prairie streams (Table 5).

East Redwater River

The East Redwater River fully supported its aquatic life uses. Minor impairment was indicated by some organic loading and by a slightly elevated percent dominant species value (34.5%). The dominant diatom species here was *Thalassiosira pseudonana*, a quasi-planktonic centric diatom that is common in eastern Montana streams (Bahls, unpublished data). The East Redwater had slightly more than half of its flora in common with the site on the Redwater below their confluence (RW3-F), indicating that it had a significant influence on the biota and water quality in the main Redwater River.

QUALITY ASSURANCE

Both analysts found four common algal genera in the sample from below the Circle STP (Appendix B-1). Diatoms were rated as very abundant and ranked second in volume by both analysts. The dominant genus in the sample was identified as *Enteromorpha* by *Hannaea* and as *Schizomeris* by PhycoLogic. These two genera are closely related and have similar water quality preferences (Prescott 1978, Smith 1950).

Both analysts identified *Diatoma tenue* as the dominant diatom in replicate slides prepared from the periphyton sample collected below the Circle STP (Appendix B-2). Diatom metrics generated from the replicate counts were very close. However, the slightly larger percent abundance of the dominant diatom in the slide counted by PhycoLogic resulted in a rating of severe and nonsupport of uses at the site below the Circle STP. The similarity index for these two replicate counts was 83.29, which is acceptable.

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Table 1. Location of periphyton sampling stations on Little Dry Creek, the Redwater River, and the East Redwater River, MDEQ station code, sample number in the Montana Diatom Database, legal description, and sample date. Sites on the Redwater River are listed in order from upstream to downstream. The East Redwater River enters the Redwater River just above Highway 201 (Redwater River Station RW3-F).

Location	Station Code (Reach-Site)	Sample Number	Legal Description	Sample Date
Little Dry Creek @ Highway 200	L.Dry	0745-02	T18NR42E09AA	05/27/99
Redwater R. headwaters @ Gackle	RW1-3	1807-01	T16NR46E16CD	05/29/99
Redwater R. near Brockway @ Kurtz	RW1-9	1808-01	T18NR47E30CB	05/26/99
Redwater R. above Circle @ Union Bridge	RW2-D	1809-01	T19NR48E21CC	05/26/99
Redwater R. below Circle STP	RW2-F	1810-01	T19NR48E02DC	05/26/99
Redwater R. below Bluff Creek	RW2-B	1811-01	T21NR50E18CA	05/25/99
Redwater R. above Pasture Creek	RW3-A	1812-01	T23NR50E35DD	05/25/99
Redwater R. at Montana Highway 201	RW3-F	1073-07	T25NR50E23DA	05/26/99
Redwater R. at Nickwall Crossing (ford)	RW3-D	0305-06	T27NR50E35AD	05/25/99
East Redwater River near mouth	ER3-EF	1577-02	T25NR50E24CC	05/26/99

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

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 This is a composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

3 Computed as the sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*. These are common genera of predominantly motile taxa that are able to maintain their positions on the substrate surface in depositional environments.

4 Computed as the percent abundance of *Achnanthes minutissima*. This attached taxon typically dominates early successional stages of benthic diatom associations and resists chemical, physical and biological disturbances in the form of metals toxicity, substrate scour by high flows and fast currents, and grazing by macroinvertebrates.

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. Estimated relative abundance of algal cells and rank by volume of diatoms and genera of non-diatom algae in periphyton samples collected from Little Dry Creek, the Redwater River, and the East Redwater River in May 1999. R = rare, C = common, VC = very common, A = abundant, VA = very abundant.

Taxa	L.Dry	RW1-3	RW1-9	RW2-D	RW2-F	RW2-B	RW3-A	RW3-F	RW3-D	ER3-EF
Chlorophyta										
Ankistrodesmus								C(6)	C(5)	C(4)
Chara		VA(1)				C(3)				
Closterium				C(3)			C(7)			
Cosmarium							R(10)			C(7)
Enteromorpha					VA(1)					
Mougeotia						R(9)				
Oedogonium	VC(3)	VC(7)	C(6)			VC(5)				
Rhizoclonium	A(2)	VA(3)	VA(1)		A(3)	VC(4)	VA(2)	A(2)	A(2)	C(3)
Scenedesmus				VC(2)	C(4)	C(7)	C(8)	C(5)		C(6)
Spirogyra	VC(4)	VA(2)				A(2)	C(5)			
Stigeoclonium		C(10)	VC(3)			VC(6)	C(6)	C(4)		VC(2)
Zygnema						R(8)				
Euglenophyta										
Euglena	R(6)						R(11)			R(8)
Phacus							R(12)			
Chrysophyta										
Diatoms	A(1)	A(4)	A(2)	VA(1)	VA(2)	A(1)	VA(1)	A(1)	A(1)	VC(1)
Tribonema		A(6)	C(4)							
Vaucheria									VC(3)	
Cyanophyta										
Amphithrix										C(5)
Anabaena		VC(8)	C(7)					R(10)		
Merismopedia								C(7)		
Oscillatoria		C(9)					A(3)			
Phormidium	C(5)	A(5)	C(5)				C(9)	C(3)	C(4)	
Rivularia							A(4)	C(8)		
Spirulina								R(9)		

Table 5. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from Little Dry Creek, the Redwater River, and the East Redwater River in May 1999. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support of aquatic life uses with moderate impairment; **underlined and bold values** indicate nonsupport of aquatic life uses and severe impairment based on criteria for wadeable prairie streams in Table 3.

Species/Metric (Pollution Tolerance Class)	Stream (Reach-Station) L.Dry	RW1-3	RW1-9	RW2-D	RW2-F	RW2-B	RW3-A	RW3-F	RW3-D	ER3-EF
Amphora delicatissima (1)		16.30	0.61			0.88		0.70	0.23	0.61
Cymbella pusilla (1)	0.75	15.43	1.60	1.00	0.36	5.75	0.45	1.40		
Diatoma tenue (2)	1.87		5.28	47.66	69.71	3.75	28.40	7.44	3.67	2.93
Diploneis puella (2)	17.71				0.24	1.88	1.00	5.47	5.85	3.29
Fragilaria vaucheriae (2)	4.49						1.22	4.88	22.25	1.34
Nitzschia frustulum (2)	0.62	3.83	14.62	1.67	0.85	3.38	4.12	3.95	0.46	4.51
Synedra famelica (2)		19.38	30.84	8.82	2.43	2.00	10.80	3.95	0.92	1.34
Synedra fasciculata (2)	0.25	0.99	19.53	1.34	5.96	0.38	6.35	0.81	0.11	0.61
Synedra pulchella (2)		14.69	3.07	2.23	1.34	0.50	1.11	1.74	2.87	0.12
Thalassiosira pseudonana (2)				0.22		0.25	0.67	10.23	2.29	34.51
Number of Cells Counted	401	405	407	448	411	400	499	430	436	410
Shannon Species Diversity	4.82	3.41	3.59	3.42	**2.32**	5.44	4.67	5.17	4.67	4.16
Pollution Index	2.01	**1.42**	1.90	2.16	2.03	2.03	2.11	2.07	2.02	2.10
Siltation Index	37.14	28.50	34.55	13.58	10.44	39.56	36.62	30.35	24.30	34.60
Disturbance Index	9.35	0.00	0.25	6.03	2.19	1.63	4.68	5.93	1.15	5.73
Number of Species Counted	66	**27**	48	52	46	82	80	71	64	57
Percent Dominant Species	17.71	19.38	30.84	47.66	**69.71**	9.75	28.40	10.23	22.25	34.51
Percent Abnormal Cells	0.00	0.00	0.00	0.00	**1.58**	0.00	0.00	0.00	0.46	0.00
Percent Epithemiaceae	0.00	0.12	0.61	0.11	0.24	7.00	1.34	3.02	2.29	2.07
Similarity Index[2]		35.98	29.90	66.22	18.48	43.99	51.17	51.57		

[1] A major diatom species is here defined as one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

[2] The similarity index between the East Redwater River site near the mouth (ER3-EF) and the next downstream site on the Redwater River at Highway 201 (RW3-F) was 53.60.

Sample	Genus/Species/Variety	PTC	Count	Percent
074502	Achnanthes minutissima	3	75	9.35
074502	Amphipleura pellucida	2	9	1.12
074502	Amphora dusenii	2	4	0.50
074502	Amphora inariensis	3	2	0.25
074502	Amphora libyca	3	2	0.25
074502	Caloneis bacillum	2	2	0.25
074502	Caloneis schumanniana	2	6	0.75
074502	Cylindrotheca gracilis	2	4	0.50
074502	Cymbella affinis	3	61	7.61
074502	Cymbella cymbiformis	3	10	1.25
074502	Cymbella microcephala	2	27	3.37
074502	Cymbella minuta	2	3	0.37
074502	Cymbella muelleri	2	14	1.75
074502	Cymbella pusilla	1	6	0.75
074502	Cymbella silesiaca	2	1	0.12
074502	Diatoma tenue	2	15	1.87
074502	Diploneis pseudovalis	2	10	1.25
074502	Diploneis puella	2	142	17.71
074502	Entomoneis alata	2	4	0.50
074502	Entomoneis paludosa	2	44	5.49
074502	Fragilaria vaucheriae	2	36	4.49
074502	Gomphonema parvulum	1	2	0.25
074502	Gyrosigma spencerii	2	2	0.25
074502	Navicula accomoda	1	1	0.12
074502	Navicula capitata	2	4	0.50
074502	Navicula capitatoradiata	2	1	0.12
074502	Navicula caterva	2	10	1.25
074502	Navicula cincta	1	5	0.62
074502	Navicula cincta v. rostrata	1	32	3.99
074502	Navicula circumtexta	1	1	0.12
074502	Navicula cryptocephala	3	2	0.25
074502	Navicula cryptotenella	2	16	2.00
074502	Navicula cuspidata	2	4	0.50
074502	Navicula durrenbergiana	1	3	0.37
074502	Navicula erifuga	2	13	1.62
074502	Navicula gregaria	2	5	0.62
074502	Navicula minuscula	1	7	0.87
074502	Navicula notha	2	3	0.37
074502	Navicula odiosa	1	2	0.25
074502	Navicula reichardtiana	2	2	0.25
074502	Navicula veneta	1	5	0.62
074502	Navicula viridula v. rostellata	2	3	0.37
074502	Nitzschia amphibia	2	8	1.00
074502	Nitzschia apiculata	2	10	1.25
074502	Nitzschia bergii	1	8	1.00
074502	Nitzschia filiformis	2	7	0.87
074502	Nitzschia frustulum	2	0	0.00
074502	Nitzschia frustulum v. subsalina	2	5	0.62
074502	Nitzschia gracilis	2	4	0.50
074502	Nitzschia levidensis	2	4	0.50
074502	Nitzschia microcephala	1	6	0.75
074502	Nitzschia palea	1	68	8.48
074502	Nitzschia paleacea	2	21	2.62
074502	Nitzschia perminuta	3	2	0.25
074502	Nitzschia perspicua	1	5	0.62
074502	Nitzschia recta	3	3	0.37
074502	Nitzschia reversa	2	4	0.50
074502	Nitzschia sigma	2	2	0.25
074502	Nitzschia solita	1	0	0.00
074502	Nitzschia valdestriata	2	6	0.75

Sample	Genus/Species/Variety	PTC	Count	Percent
074502	Pinnularia microstauron	2	4	0.50
074502	Rhoicosphenia curvata	3	4	0.50
074502	Simonsenia delognei	2	4	0.50
074502	Stauroneis tackei	2	2	0.25
074502	Stephanodiscus hantzschii	2	6	0.75
074502	Surirella brebissonii	2	16	2.00
074502	Synedra delicatissima v. angustissim	2	1	0.12
074502	Synedra fasciculata	2	2	0.25

APPENDIX A: DIATOM PROPORTIONAL COUNTS

Sample	Genus/Species/Variety	PTC	Count	Percent
180701	Amphora coffeaeformis	1	32	3.95
180701	Amphora delicatissima	1	132	16.30
180701	Amphora holsatica	1	0	0.00
180701	Chaetoceros elmorei	1	2	0.25
180701	Cymbella perpusilla	3	1	0.12
180701	Cymbella pusilla	1	125	15.43
180701	Denticula sp.	3	1	0.12
180701	Entomoneis paludosa	2	1	0.12
180701	Navicula cincta v. rostrata	1	47	5.80
180701	Navicula odiosa	1	17	2.10
180701	Navicula pelliculosa	1	2	0.25
180701	Navicula peregrina	2	4	0.49
180701	Navicula protracta	2	8	0.99
180701	Navicula salinarum	1	34	4.20
180701	Navicula veneta	1	12	1.48
180701	Navicula viridula	2	1	0.12
180701	Nitzschia acicularis	2	4	0.49
180701	Nitzschia aurariae	1	62	7.65
180701	Nitzschia bergii	1	0	0.00
180701	Nitzschia frustulum	2	5	0.62
180701	Nitzschia frustulum v. subsalina	2	26	3.21
180701	Nitzschia liebetruthii	3	1	0.12
180701	Nitzschia obtusa	1	1	0.12
180701	Nitzschia palea	1	4	0.49
180701	Nitzschia reversa	2	3	0.37
180701	Pleurosigma delicatulum	2	1	0.12
180701	Synedra famelica	2	157	19.38
180701	Synedra fasciculata	2	8	0.99
180701	Synedra pulchella	2	119	14.69

Sample	Genus/Species/Variety	PTC	Count	Percent
180801	Achnanthes minutissima	3	2	0.25
180801	Amphora coffeaeformis	1	4	0.49
180801	Amphora delicatissima	1	5	0.61
180801	Amphora holsatica	1	2	0.25
180801	Amphora inariensis	3	0	0.00
180801	Amphora libyca	3	0	0.00
180801	Bacillaria paradoxa	2	1	0.12
180801	Caloneis amphisbaena	2	1	0.12
180801	Cocconeis placentula	3	1	0.12
180801	Cyclotella meneghiniana	2	4	0.49
180801	Cymbella pusilla	1	13	1.60
180801	Diatoma tenue	2	43	5.28
180801	Entomoneis paludosa	2	1	0.12
180801	Epithemia adnata	2	1	0.12
180801	Gyrosigma macrum	2	1	0.12
180801	Gyrosigma peisonis	2	1	0.12
180801	Mastogloia smithii	2	3	0.37
180801	Melosira varians	2	1	0.12
180801	Navicula angusta	2	2	0.25
180801	Navicula capitata	2	6	0.74
180801	Navicula caterva	2	4	0.49
180801	Navicula cincta v. rostrata	1	16	1.97
180801	Navicula circumtexta	1	0	0.00
180801	Navicula erifuga	2	6	0.74
180801	Navicula gregaria	2	10	1.23
180801	Navicula halophila	2	3	0.37
180801	Navicula odiosa	1	5	0.61
180801	Navicula pelliculosa	1	2	0.25
180801	Navicula peregrina	2	2	0.25
180801	Navicula salinarum	1	12	1.47
180801	Navicula slesvicensis	2	2	0.25
180801	Navicula sp.	2	1	0.12
180801	Navicula veneta	1	5	0.61
180801	Navicula viridula v. rostellata	2	2	0.25
180801	Nitzschia amphibia	2	1	0.12
180801	Nitzschia filiformis	2	0	0.00
180801	Nitzschia frustulum	2	8	0.98
180801	Nitzschia frustulum v. subsalina	2	111	13.64
180801	Nitzschia hungarica	2	2	0.25
180801	Nitzschia inconspicua	2	6	0.74
180801	Nitzschia liebetruthii	3	15	1.84
180801	Nitzschia microcephala	1	17	2.09
180801	Nitzschia palea	1	28	3.44
180801	Nitzschia paleacea	2	9	1.11
180801	Nitzschia valdestriata	2	6	0.74
180801	Rhoicosphenia curvata	3	9	1.11
180801	Rhopalodia brebissonii	1	1	0.12
180801	Rhopalodia gibba	2	3	0.37
180801	Rhopalodia operculata	1	0	0.00
180801	Stephanodiscus hantzschii	2	1	0.12
180801	Synedra famelica	2	251	30.84
180801	Synedra fasciculata	2	159	19.53
180801	Synedra pulchella	2	25	3.07

Sample	Genus/Species/Variety	PTC	Count	Percent
180901	Achnanthes hauckiana	2	7	0.78
180901	Achnanthes minutissima	3	54	6.03
180901	Amphipleura pellucida	2	5	0.56
180901	Amphora libyca	3	6	0.67
180901	Amphora pediculus	3	0	0.00
180901	Caloneis bacillum	2	2	0.22
180901	Cocconeis placentula	3	3	0.33
180901	Cyclotella meneghiniana	2	8	0.89
180901	Cymbella affinis	3	10	1.12
180901	Cymbella pusilla	1	9	1.00
180901	Diatoma tenue	2	427	47.66
180901	Diploneis pseudovalis	2	1	0.11
180901	Entomoneis paludosa	2	1	0.11
180901	Fragilaria brevistriata	3	19	2.12
180901	Fragilaria construens v. venter	3	8	0.89
180901	Gomphonema olivaceum	3	60	6.70
180901	Mastogloia smithii	2	1	0.11
180901	Navicula capitata	2	2	0.22
180901	Navicula caterva	2	9	1.00
180901	Navicula cincta v. rostrata	1	6	0.67
180901	Navicula cryptotenella	2	2	0.22
180901	Navicula durrenbergiana	1	1	0.11
180901	Navicula erifuga	2	2	0.22
180901	Navicula goersii	2	2	0.22
180901	Navicula gregaria	2	5	0.56
180901	Navicula halophila	2	1	0.11
180901	Navicula minuscula	1	2	0.22
180901	Navicula peregrina	2	6	0.67
180901	Navicula pygmaea	2	2	0.22
180901	Navicula salinarum	1	0	0.00
180901	Navicula sp.	2	2	0.22
180901	Navicula veneta	1	6	0.67
180901	Nitzschia amphibia	2	1	0.11
180901	Nitzschia apiculata	2	6	0.67
180901	Nitzschia bergii	1	6	0.67
180901	Nitzschia frustulum v. subsalina	2	15	1.67
180901	Nitzschia gracilis	2	4	0.45
180901	Nitzschia liebetruthii	3	12	1.34
180901	Nitzschia microcephala	1	2	0.22
180901	Nitzschia palea	1	14	1.56
180901	Nitzschia paleacea	2	4	0.45
180901	Nitzschia perminuta	3	5	0.56
180901	Nitzschia sp.	2	2	0.22
180901	Nitzschia valdestriata	2	3	0.33
180901	Pinnularia microstauron	2	1	0.11
180901	Pleurosigma delicatulum	2	9	1.00
180901	Rhoicosphenia curvata	3	11	1.23
180901	Rhopalodia gibba	2	1	0.11
180901	Surirella brebissonii	2	0	0.00
180901	Synedra delicatissima v. angustissim	2	15	1.67
180901	Synedra famelica	2	79	8.82
180901	Synedra fasciculata	2	12	1.34
180901	Synedra pulchella	2	20	2.23
180901	Synedra ulna	2	3	0.33
180901	Thalassiosira pseudonana	2	2	0.22

Sample	Genus/Species/Variety	PTC	Count	Percent
181001	Achnanthes minutissima	3	18	2.19
181001	Amphipleura pellucida	2	2	0.24
181001	Amphora inariensis	3	0	0.00
181001	Amphora libyca	3	2	0.24
181001	Amphora pediculus	3	4	0.49
181001	Asterionella formosa	3	1	0.12
181001	Bacillaria paradoxa	2	0	0.00
181001	Caloneis bacillum	2	0	0.00
181001	Cocconeis placentula	3	0	0.00
181001	Cyclotella meneghiniana	2	7	0.85
181001	Cymbella affinis	3	7	0.85
181001	Cymbella cymbiformis	3	0	0.00
181001	Cymbella mexicana	3	0	0.00
181001	Cymbella minuta	2	1	0.12
181001	Cymbella muelleri	2	0	0.00
181001	Cymbella pusilla	1	3	0.36
181001	Cymbella silesiaca	2	2	0.24
181001	Denticula subtilis	2	1	0.12
181001	Diatoma tenue	2	573	69.71
181001	Diploneis pseudovalis	2	4	0.49
181001	Diploneis puella	2	2	0.24
181001	Entomoneis paludosa	2	3	0.36
181001	Epithemia adnata	2	0	0.00
181001	Fragilaria brevistriata	3	5	0.61
181001	Gomphonema olivaceum	3	6	0.73
181001	Mastogloia smithii	2	0	0.00
181001	Navicula arvensis	2	2	0.24
181001	Navicula capitata	2	6	0.73
181001	Navicula caterva	2	6	0.73
181001	Navicula cincta v. rostrata	1	5	0.61
181001	Navicula circumtexta	1	4	0.49
181001	Navicula erifuga	2	11	1.34
181001	Navicula gregaria	2	3	0.36
181001	Navicula odiosa	1	1	0.12
181001	Navicula peregrina	2	0	0.00
181001	Navicula pygmaea	2	0	0.00
181001	Navicula salinarum	1	1	0.12
181001	Navicula slesvicensis	2	2	0.24
181001	Navicula sp.	2	0	0.00
181001	Navicula veneta	1	3	0.36
181001	Nitzschia amphibia	2	5	0.61
181001	Nitzschia apiculata	2	2	0.24
181001	Nitzschia bergii	1	0	0.00
181001	Nitzschia filiformis	2	7	0.85
181001	Nitzschia frustulum	2	2	0.24
181001	Nitzschia frustulum v. subsalina	2	5	0.61
181001	Nitzschia levidensis	2	0	0.00
181001	Nitzschia liebetruthii	3	4	0.49
181001	Nitzschia microcephala	1	0	0.00
181001	Nitzschia obtusa	1	1	0.12
181001	Nitzschia palea	1	6	0.73
181001	Nitzschia paleacea	2	2	0.24
181001	Nitzschia perminuta	3	5	0.61
181001	Pinnularia microstauron	2	2	0.24
181001	Pleurosigma delicatulum	2	2	0.24
181001	Rhoicosphenia curvata	3	0	0.00
181001	Rhopalodia gibba	2	1	0.12
181001	Rhopalodia operculata	1	0	0.00
181001	Surirella brebissonii	2	3	0.36
181001	Synedra delicatissima v. angustissim	2	10	1.22

Sample	Genus/Species/Variety	PTC	Count	Percent
181001	Synedra famelica	2	20	2.43
181001	Synedra fasciculata	2	49	5.96
181001	Synedra pulchella	2	11	1.34

Sample	Genus/Species/Variety	PTC	Count	Percent
181101	Achnanthes minutissima	3	13	1.63
181101	Amphipleura pellucida	2	2	0.25
181101	Amphora coffeaeformis	1	1	0.13
181101	Amphora delicatissima	1	7	0.88
181101	Amphora inariensis	3	0	0.00
181101	Amphora libyca	3	12	1.50
181101	Amphora ovalis	3	2	0.25
181101	Amphora pediculus	3	1	0.13
181101	Caloneis bacillum	2	8	1.00
181101	Caloneis schumanniana	2	1	0.13
181101	Cocconeis placentula	3	4	0.50
181101	Cyclotella atomus	2	2	0.25
181101	Cyclotella meneghiniana	2	16	2.00
181101	Cyclotella sp.	3	0	0.00
181101	Cymatopleura elliptica	2	0	0.00
181101	Cymbella affinis	3	1	0.13
181101	Cymbella cistula	3	0	0.00
181101	Cymbella muelleri	2	8	1.00
181101	Cymbella pusilla	1	46	5.75
181101	Cymbella silesiaca	2	5	0.63
181101	Diatoma tenue	2	30	3.75
181101	Diploneis pseudovalis	2	27	3.38
181101	Diploneis puella	2	15	1.88
181101	Entomoneis alata	2	2	0.25
181101	Entomoneis ornata	1	2	0.25
181101	Entomoneis paludosa	2	10	1.25
181101	Epithemia adnata	2	12	1.50
181101	Epithemia argus	2	8	1.00
181101	Epithemia turgida	3	1	0.13
181101	Fragilaria brevistriata	3	51	6.38
181101	Fragilaria construens v. venter	3	78	9.75
181101	Fragilaria crotonensis	3	2	0.25
181101	Gomphonema olivaceum	3	0	0.00
181101	Mastogloia elliptica	2	12	1.50
181101	Mastogloia smithii	2	23	2.88
181101	Navicula capitata	2	3	0.38
181101	Navicula caterva	2	16	2.00
181101	Navicula cincta v. rostrata	1	56	7.00
181101	Navicula circumtexta	1	6	0.75
181101	Navicula constans	2	2	0.25
181101	Navicula cryptotenella	2	2	0.25
181101	Navicula durrenbergiana	1	2	0.25
181101	Navicula erifuga	2	8	1.00
181101	Navicula goersii	2	2	0.25
181101	Navicula gregaria	2	10	1.25
181101	Navicula halophila	2	2	0.25
181101	Navicula monoculata v. omissa	1	2	0.25
181101	Navicula notha	2	0	0.00
181101	Navicula odiosa	1	2	0.25
181101	Navicula peregrina	2	10	1.25
181101	Navicula pygmaea	2	0	0.00
181101	Navicula reichardtiana	2	2	0.25
181101	Navicula salinarum	1	0	0.00
181101	Navicula sp.	2	3	0.38
181101	Navicula tenera	1	2	0.25
181101	Navicula veneta	1	0	0.00
181101	Nitzschia acicularis	2	4	0.50
181101	Nitzschia amphibia	2	12	1.50
181101	Nitzschia apiculata	2	0	0.00
181101	Nitzschia bergii	1	4	0.50

Sample	Genus/Species/Variety	PTC	Count	Percent
181101	Nitzschia dissipata	3	2	0.25
181101	Nitzschia filiformis	2	8	1.00
181101	Nitzschia frustulum	2	4	0.50
181101	Nitzschia frustulum v. subsalina	2	23	2.88
181101	Nitzschia gracilis	2	14	1.75
181101	Nitzschia hungarica	2	11	1.38
181101	Nitzschia incognita	2	2	0.25
181101	Nitzschia inconspicua	2	0	0.00
181101	Nitzschia liebetruthii	3	32	4.00
181101	Nitzschia linearis	2	1	0.13
181101	Nitzschia microcephala	1	21	2.63
181101	Nitzschia obtusa	1	5	0.63
181101	Nitzschia palea	1	13	1.63
181101	Nitzschia paleacea	2	4	0.50
181101	Nitzschia perminuta	3	1	0.13
181101	Nitzschia recta	3	1	0.13
181101	Nitzschia sigma	2	1	0.13
181101	Nitzschia sociabilis	2	2	0.25
181101	Nitzschia supralitorea	2	10	1.25
181101	Nitzschia valdecostata	2	2	0.25
181101	Nitzschia valdestriata	2	20	2.50
181101	Nitzschia vitrea	1	0	0.00
181101	Pinnularia ignobilis	2	1	0.13
181101	Pleurosigma delicatulum	2	6	0.75
181101	Rhopalodia gibba	2	25	3.13
181101	Rhopalodia musculus	2	4	0.50
181101	Rhopalodia operculata	1	6	0.75
181101	Stephanodiscus hantzschii	2	0	0.00
181101	Surirella brebissonii	2	1	0.13
181101	Surirella brightwellii	2	0	0.00
181101	Surirella sp.	2	0	0.00
181101	Synedra delicatissima v. angustissim	2	1	0.13
181101	Synedra famelica	2	16	2.00
181101	Synedra fasciculata	2	3	0.38
181101	Synedra pulchella	2	4	0.50
181101	Synedra ulna	2	2	0.25
181101	Thalassiosira pseudonana	2	2	0.25

Sample	Genus/Species/Variety	PTC	Count	Percent
181201	Achnanthes minutissima	3	42	4.68
181201	Amphipleura pellucida	2	1	0.11
181201	Amphora coffeaeformis	1	2	0.22
181201	Amphora holsatica	1	2	0.22
181201	Amphora libyca	3	10	1.11
181201	Amphora pediculus	3	4	0.45
181201	Bacillaria paradoxa	2	1	0.11
181201	Caloneis bacillum	2	2	0.22
181201	Caloneis schumanniana	2	4	0.45
181201	Caloneis silicula	2	4	0.45
181201	Cocconeis placentula	3	6	0.67
181201	Cyclotella meneghiniana	2	2	0.22
181201	Cyclotella sp.	3	1	0.11
181201	Cylindrotheca gracilis	2	4	0.45
181201	Cymbella affinis	3	14	1.56
181201	Cymbella cymbiformis	3	0	0.00
181201	Cymbella muelleri	2	2	0.22
181201	Cymbella pusilla	1	4	0.45
181201	Diatoma tenue	2	255	28.40
181201	Diploneis pseudovalis	2	24	2.67
181201	Diploneis puella	2	9	1.00
181201	Entomoneis alata	2	1	0.11
181201	Entomoneis paludosa	2	4	0.45
181201	Epithemia adnata	2	5	0.56
181201	Epithemia argus	2	2	0.22
181201	Fragilaria brevistriata	3	40	4.45
181201	Fragilaria construens v. venter	3	9	1.00
181201	Fragilaria vaucheriae	2	11	1.22
181201	Gomphonema angustatum	2	1	0.11
181201	Gomphonema parvulum	1	2	0.22
181201	Gomphonema subtile	3	2	0.22
181201	Mastogloia smithii	2	2	0.22
181201	Navicula capitata	2	14	1.56
181201	Navicula caterva	2	21	2.34
181201	Navicula cincta	1	2	0.22
181201	Navicula cincta v. rostrata	1	31	3.45
181201	Navicula circumtexta	1	4	0.45
181201	Navicula durrenbergiana	1	1	0.11
181201	Navicula erifuga	2	8	0.89
181201	Navicula goersii	2	0	0.00
181201	Navicula gregaria	2	14	1.56
181201	Navicula halophila	2	1	0.11
181201	Navicula monoculata v. omissa	1	2	0.22
181201	Navicula oblonga	2	0	0.00
181201	Navicula odiosa	1	1	0.11
181201	Navicula peregrina	2	3	0.33
181201	Navicula pupula	2	5	0.56
181201	Navicula pygmaea	2	1	0.11
181201	Navicula salinarum	1	4	0.45
181201	Navicula tenelloides	1	2	0.22
181201	Nitzschia amphibia	2	0	0.00
181201	Nitzschia angustata	2	4	0.45
181201	Nitzschia apiculata	2	5	0.56
181201	Nitzschia bergii	1	2	0.22
181201	Nitzschia dissipata	3	2	0.22
181201	Nitzschia filiformis	2	4	0.45
181201	Nitzschia frustulum	2	1	0.11
181201	Nitzschia frustulum v. subsalina	2	36	4.01
181201	Nitzschia hungarica	2	7	0.78
181201	Nitzschia incognita	2	2	0.22

Sample	Genus/Species/Variety	PTC	Count	Percent
181201	Nitzschia inconspicua	2	1	0.11
181201	Nitzschia levidensis	2	4	0.45
181201	Nitzschia liebetruthii	3	10	1.11
181201	Nitzschia linearis	2	1	0.11
181201	Nitzschia microcephala	1	10	1.11
181201	Nitzschia palea	1	24	2.67
181201	Nitzschia paleacea	2	26	2.90
181201	Nitzschia perminuta	3	59	6.57
181201	Nitzschia perspicua	1	2	0.22
181201	Nitzschia sigma	2	3	0.33
181201	Nitzschia sigmoidea	3	1	0.11
181201	Nitzschia supralitorea	2	8	0.89
181201	Nitzschia valdestriata	2	3	0.33
181201	Plagiotropis lepidoptera v. proboscid	2	0	0.00
181201	Pleurosigma delicatulum	2	5	0.56
181201	Rhoicosphenia curvata	3	5	0.56
181201	Rhopalodia gibba	2	3	0.33
181201	Rhopalodia operculata	1	2	0.22
181201	Stephanodiscus hantzschii	2	7	0.78
181201	Synedra famelica	2	97	10.80
181201	Synedra fasciculata	2	57	6.35
181201	Synedra nana	3	3	0.33
181201	Synedra pulchella	2	10	1.11
181201	Synedra ulna	2	2	0.22
181201	Thalassiosira pseudonana	2	6	0.67

Sample	Genus/Species/Variety	PTC	Count	Percent
107307	Achnanthes lanceolata	2	2	0.23
107307	Achnanthes minutissima	3	51	5.93
107307	Amphipleura pellucida	2	2	0.23
107307	Amphora coffeaeformis	1	0	0.00
107307	Amphora delicatissima	1	6	0.70
107307	Amphora libyca	3	2	0.23
107307	Caloneis silicula	2	6	0.70
107307	Cocconeis placentula	3	1	0.12
107307	Cyclotella atomus	2	1	0.12
107307	Cyclotella meneghiniana	2	5	0.58
107307	Cymatopleura solea	2	2	0.23
107307	Cymbella affinis	3	36	4.19
107307	Cymbella minuta	2	1	0.12
107307	Cymbella muelleri	2	9	1.05
107307	Cymbella pusilla	1	12	1.40
107307	Cymbella silesiaca	2	6	0.70
107307	Diatoma tenue	2	64	7.44
107307	Diploneis pseudovalis	2	51	5.93
107307	Diploneis puella	2	47	5.47
107307	Entomoneis alata	2	2	0.23
107307	Entomoneis ornata	1	1	0.12
107307	Entomoneis paludosa	2	17	1.98
107307	Epithemia turgida	3	2	0.23
107307	Fragilaria brevistriata	3	4	0.47
107307	Fragilaria capucina v. gracilis	2	6	0.70
107307	Fragilaria construens v. venter	3	6	0.70
107307	Fragilaria vaucheriae	2	42	4.88
107307	Frustulia vulgaris	2	2	0.23
107307	Mastogloia elliptica	2	13	1.51
107307	Mastogloia smithii	2	13	1.51
107307	Navicula capitata	2	1	0.12
107307	Navicula caterva	2	19	2.21
107307	Navicula cincta v. rostrata	1	8	0.93
107307	Navicula cryptotenella	2	3	0.35
107307	Navicula durrenbergiana	1	5	0.58
107307	Navicula erifuga	2	4	0.47
107307	Navicula goersii	2	2	0.23
107307	Navicula gregaria	2	19	2.21
107307	Navicula minuscula	1	2	0.23
107307	Navicula notha	2	2	0.23
107307	Navicula pygmaea	2	1	0.12
107307	Navicula salinarum	1	2	0.23
107307	Navicula tenera	1	0	0.00
107307	Nitzschia amphibia	2	0	0.00
107307	Nitzschia angustatula	2	0	0.00
107307	Nitzschia apiculata	2	4	0.47
107307	Nitzschia aurariae	1	2	0.23
107307	Nitzschia bergii	1	4	0.47
107307	Nitzschia dissipata	3	2	0.23
107307	Nitzschia filiformis	2	7	0.81
107307	Nitzschia frustulum v. subsalina	2	34	3.95
107307	Nitzschia gracilis	2	11	1.28
107307	Nitzschia hungarica	2	0	0.00
107307	Nitzschia incognita	2	4	0.47
107307	Nitzschia inconspicua	2	0	0.00
107307	Nitzschia levidensis	2	0	0.00
107307	Nitzschia liebetruthii	3	16	1.86
107307	Nitzschia linearis	2	7	0.81
107307	Nitzschia microcephala	1	8	0.93
107307	Nitzschia palea	1	22	2.56

Sample	Genus/Species/Variety	PTC	Count	Percent
107307	Nitzschia paleacea	2	41	4.77
107307	Nitzschia perminuta	3	12	1.40
107307	Nitzschia reversa	2	2	0.23
107307	Nitzschia supralitorea	2	2	0.23
107307	Nitzschia valdestriata	2	15	1.74
107307	Rhoicosphenia curvata	3	1	0.12
107307	Rhopalodia gibba	2	19	2.21
107307	Rhopalodia operculata	1	5	0.58
107307	Simonsenia delognei	2	3	0.35
107307	Stephanodiscus hantzschii	2	3	0.35
107307	Stephanodiscus minutulus	2	2	0.23
107307	Surirella brebissonii	2	0	0.00
107307	Synedra delicatissima v. angustissim	2	5	0.58
107307	Synedra famelica	2	34	3.95
107307	Synedra fasciculata	2	7	0.81
107307	Synedra nana	3	4	0.47
107307	Synedra pulchella	2	15	1.74
107307	Synedra ulna	2	1	0.12
107307	Thalassiosira pseudonana	2	88	10.23

Sample	Genus/Species/Variety	PTC	Count	Percent
030506	Achnanthes minutissima	3	10	1.15
030506	Amphipleura pellucida	2	51	5.85
030506	Amphora delicatissima	1	2	0.23
030506	Amphora libyca	3	1	0.11
030506	Amphora pediculus	3	2	0.23
030506	Caloneis bacillum	2	4	0.46
030506	Caloneis schumanniana	2	2	0.23
030506	Caloneis silicula	2	4	0.46
030506	Cyclotella atomus	2	2	0.23
030506	Cymbella affinis	3	50	5.73
030506	Cymbella minuta	2	7	0.80
030506	Cymbella muelleri	2	0	0.00
030506	Diatoma tenue	2	32	3.67
030506	Diploneis pseudovalis	2	58	6.65
030506	Diploneis puella	2	51	5.85
030506	Entomoneis alata	2	7	0.80
030506	Entomoneis paludosa	2	48	5.50
030506	Epithemia turgida	3	0	0.00
030506	Fragilaria construens v. venter	3	2	0.23
030506	Fragilaria vaucheriae	2	194	22.25
030506	Gomphonema clavatum	2	1	0.11
030506	Gomphonema olivaceum	3	1	0.11
030506	Gomphonema parvulum	1	16	1.83
030506	Mastogloia smithii	2	2	0.23
030506	Navicula capitata	2	3	0.34
030506	Navicula caterva	2	4	0.46
030506	Navicula cincta v. rostrata	1	13	1.49
030506	Navicula circumtexta	1	2	0.23
030506	Navicula constans	2	2	0.23
030506	Navicula cryptotenella	2	4	0.46
030506	Navicula durrenbergiana	1	3	0.34
030506	Navicula erifuga	2	3	0.34
030506	Navicula goersii	2	2	0.23
030506	Navicula gregaria	2	3	0.34
030506	Navicula monoculata v. omissa	1	4	0.46
030506	Navicula veneta	1	4	0.46
030506	Nitzschia amphibia	2	6	0.69
030506	Nitzschia apiculata	2	8	0.92
030506	Nitzschia aurariae	1	2	0.23
030506	Nitzschia bergii	1	18	2.06
030506	Nitzschia dissipata	3	5	0.57
030506	Nitzschia filiformis	2	33	3.78
030506	Nitzschia frustulum v. subsalina	2	4	0.46
030506	Nitzschia gracilis	2	6	0.69
030506	Nitzschia hungarica	2	2	0.23
030506	Nitzschia incognita	2	6	0.69
030506	Nitzschia linearis	2	4	0.46
030506	Nitzschia microcephala	1	4	0.46
030506	Nitzschia palea	1	5	0.57
030506	Nitzschia paleacea	2	36	4.13
030506	Nitzschia perminuta	3	8	0.92
030506	Nitzschia recta	3	1	0.11
030506	Nitzschia sigma	2	1	0.11
030506	Rhoicosphenia curvata	3	1	0.11
030506	Rhopalodia gibba	2	19	2.18
030506	Rhopalodia operculata	1	1	0.11
030506	Stephanodiscus hantzschii	2	2	0.23
030506	Surirella brebissonii	2	12	1.38
030506	Surirella ovalis	2	4	0.46
030506	Synedra delicatissima v. angustissim	2	21	2.41

Sample	Genus/Species/Variety	PTC	Count	Percent
030506	Synedra famelica	2	8	0.92
030506	Synedra fasciculata	2	1	0.11
030506	Synedra nana	3	6	0.69
030506	Synedra pulchella	2	25	2.87
030506	Synedra ulna	2	9	1.03
030506	Thalassiosira pseudonana	2	20	2.29

Sample	Genus/Species/Variety	PTC	Count	Percent
157702	Achnanthes minutissima	3	47	5.73
157702	Amphipleura pellucida	2	0	0.00
157702	Amphora delicatissima	1	5	0.61
157702	Amphora libyca	3	5	0.61
157702	Amphora pediculus	3	8	0.98
157702	Caloneis bacillum	2	2	0.24
157702	Caloneis schumanniana	2	4	0.49
157702	Cyclotella atomus	2	2	0.24
157702	Cyclotella meneghiniana	2	6	0.73
157702	Cymatopleura elliptica	2	0	0.00
157702	Cymbella affinis	3	8	0.98
157702	Cymbella silesiaca	2	0	0.00
157702	Diatoma tenue	2	24	2.93
157702	Diploneis pseudovalis	2	28	3.41
157702	Diploneis puella	2	27	3.29
157702	Entomoneis paludosa	2	7	0.85
157702	Fragilaria construens v. venter	3	8	0.98
157702	Fragilaria vaucheriae	2	11	1.34
157702	Gomphonema olivaceum	3	2	0.24
157702	Gomphonema parvulum	1	9	1.10
157702	Gyrosigma spencerii	2	1	0.12
157702	Mastogloia elliptica	2	0	0.00
157702	Mastogloia smithii	2	1	0.12
157702	Navicula capitata	2	0	0.00
157702	Navicula caterva	2	23	2.80
157702	Navicula cincta	1	1	0.12
157702	Navicula cincta v. rostrata	1	7	0.85
157702	Navicula circumtexta	1	6	0.73
157702	Navicula cryptotenella	2	0	0.00
157702	Navicula erifuga	2	6	0.73
157702	Navicula goersii	2	2	0.24
157702	Navicula gregaria	2	4	0.49
157702	Navicula monoculata v. omissa	1	14	1.71
157702	Navicula odiosa	1	4	0.49
157702	Navicula peregrina	2	0	0.00
157702	Navicula reichardtiana	2	2	0.24
157702	Navicula salinarum	1	1	0.12
157702	Navicula tenelloides	1	2	0.24
157702	Navicula tripunctata	3	0	0.00
157702	Navicula veneta	1	0	0.00
157702	Nitzschia acicularis	2	0	0.00
157702	Nitzschia amphibia	2	4	0.49
157702	Nitzschia apiculata	2	4	0.49
157702	Nitzschia aurariae	1	2	0.24
157702	Nitzschia filiformis	2	1	0.12
157702	Nitzschia frustulum v. subsalina	2	37	4.51
157702	Nitzschia gracilis	2	0	0.00
157702	Nitzschia incognita	2	0	0.00
157702	Nitzschia inconspicua	2	2	0.24
157702	Nitzschia levidensis	2	0	0.00
157702	Nitzschia liebetruthii	3	22	2.68
157702	Nitzschia microcephala	1	7	0.85
157702	Nitzschia palea	1	31	3.78
157702	Nitzschia paleacea	2	12	1.46
157702	Nitzschia perminuta	3	75	9.15
157702	Nitzschia pusilla	1	4	0.49
157702	Nitzschia supralitorea	2	4	0.49
157702	Nitzschia valdestriata	2	7	0.85
157702	Rhoicosphenia curvata	3	7	0.85
157702	Rhopalodia gibba	2	6	0.73

Sample	Genus/Species/Variety	PTC	Count	Percent
157702	Rhopalodia musculus	2	6	0.73
157702	Rhopalodia operculata	1	4	0.49
157702	Simonsenia delognei	2	2	0.24
157702	Stephanodiscus hantzschii	2	2	0.24
157702	Surirella brebissonii	2	0	0.00
157702	Surirella brightwellii	2	0	0.00
157702	Synedra delicatissima v. angustissim	2	2	0.24
157702	Synedra famelica	2	11	1.34
157702	Synedra fasciculata	2	5	0.61
157702	Synedra pulchella	2	1	0.12
157702	Thalassiosira pseudonana	2	283	34.51
157702	Thalassiosira weissflogii	2	1	0.12

APPENDIX B: QA/QC RESULTS

Appendix B-1. Estimated relative abundance of algal cells and rank by volume of diatoms and genera of non-diatom algae in a periphyton sample collected from the Redwater River below the Circle STP in May 1999. Replicate analyses of the same sample by Loren Bahls, Hannaea, and Erich Weber, PhycoLogic. R = rare, C = common, VC = very common, A = abundant, VA = very abundant.

Taxa	Hannaea	PhycoLogic
Chlorophyta		
Closterium		R
Enteromorpha	VA(1)	
Oedogonium		R
Rhizoclonium	A(3)	A(3)
Scenedesmus	C(4)	
Schizomeris		VA(1)
Chrysophyta		
Diatoms	VA(2)	VA(2)
Vaucheria		C(4)

Appendix B-2. Percent abundance of major diatom species[1] and values of selected diatom association metrics for a periphyton sample collected from the Redwater River below the Circle STP in May 1999. Diatom counts performed on replicate diatom slides by Loren Bahls, Hannaea, and Erich Weber, PhycoLogic. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support of aquatic life uses with moderate impairment; **underlined and bold values** indicate nonsupport of aquatic life uses and severe impairment based on criteria for wadeable prairie streams in Table 3.

Species/Metric	Hannaea	PhycoLogic
Diatoma tenue	69.71	75.83
Number of Cells Counted	411	422
Shannon Species Diversity	**2.32**	**1.95**
Pollution Index	2.03	2.02
Siltation Index	10.44	9.01
Disturbance Index	2.19	1.30
Number of Species Counted	46	45
Percent Dominant Species	**69.71**	**75.83**
Percent Abnormal Cells	**1.58**	[2]
Percent Epithemiaceae	0.24	0.24
Similarity Index	83.29	

[1] A major diatom species is here defined as one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

[2] PhycoLogic did not count abnormal diatom cells, but did observe deformed valves of *Diatoma tenue* in the sample (Erich Weber, personal communication).

Hannaea

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e-mail: lbahls@selway.umt.edu

October 6, 1999

RECEIVED
OCT 07 1999
DEQ / PPA
Monitoring & Data Management Bureau

Ms. Carol Endicott
Monitoring and Data Management Bureau
Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620-0901

Re: Final Redwater River Report and Invoice
MDEQ Contract No. 200012

Dear Carol,

Enclosed is the final Redwater River periphyton report printed on recycled paper per our contract.

Also enclosed is an invoice for this work. I have deducted $25 per sample from the total pending transfer of electronic data files to DEQ. I'm not quite ready to do this and I need to consult with your computer people regarding proper format.

After this deduction I added 4.3% of the total for the 43 days that the final report was submitted in advance of the deadline per the incentive clause in our contract. I picked up the Redwater River samples on July 20, so the contract deadline was November 20.

I am also enclosing a copy of a letter from Leska Fore, who is developing a diatom IBI for Idaho Rivers. I thought you might like to know her opinion of diatoms as indicators of disturbance.

Thanks again for the work. I'll get busy on your remaining samples.

Sincerely,

Loren

Loren L. Bahls, Ph.D.
Phycologist

Enclosures