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THE EFFECTS OF ACID MINE POLLUTION ON THE BENTHIC MACRO-INVERTEBRATES OF THE DRY FORK OF BELT CREEK DRAINAGE

by

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VITA

The author, Raymond James Vandenberg, was born on April 3, 1945 in St. Paul, Minnesota to Raymond T. and Elizabeth L. Vandenberg. He attended public schools in St. Paul, Minnesota and graduated from Central High School in that city in June, 1963. In September, 1963 he entered the University of Minnesota at St. Paul, Minnesota and graduated from there in August, 1967 with a Bachelor of Science degree in Fishery and Wildlife Management. In August of 1967 Raymond married the former Nancy Lou Vong of St. Paul, Minnesota. He began graduate studies at Montana State University in September, 1967 but withdrew in September, 1968 to enlist in the US Air Force. After four years of active duty, he returned to his graduate studies at Montana State University.

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ABSTRACT

The macro-invertebrates and water chemistry of the Dry Fork of Belt Creek drainage were studied from May, 1973 through May, 1974 to determine the degree and extent of acid mine pollution. The numbers of individuals and taxa, compositional balance, and average individual diversity of macro-invertebrates from multi-plate, artificial substrate samplers decreased upon downstream progression on Galena Creek and the Dry Fork of Belt Creek while Tendipedidae increased their dominance. The biotic parameters for collections on Belt Creek showed a slight reduction with downstream progression.

Seepages along Galena Creek increased the specific conductance and concentrations of copper, iron, magnesium, manganese, sulfate, and zinc and decreased the alkalinity and pH in the stream. Water from Galena Creek increased specific conductance and concentrations of calcium, copper, iron, magnesium, manganese, sulfate, and zinc and decreased the alkalinity and pH in the Dry Fork of Belt Creek immediately below their confluence. Further downstream on the Dry Fork of Belt Creek, there was a progressive decrease in the concentrations of iron, magnesium, manganese, sulfate, and zinc and an increase in alkalinity, pH, and the concentration of calcium. Specific conductance and concentrations of copper fluctuated in the lower reaches of the Dry Fork of Belt Creek. Specific conductance and zinc levels increased but copper concentrations decreased in Belt Creek below the entrance of the Dry Fork of Belt Creek.

Of the chemical parameters measured, apparently only copper and zinc had a major effect on the macro-invertebrates. On the Dry Fork of Belt Creek, mats of vegetation, water temperature, and other factors may have contributed to the downstream decrease in biotic parameters since water chemistry generally showed improvement. The acid mine pollution added to Belt Creek by the entrance of the Dry Fork of Belt Creek did not have a discernable negative effect on that stream's macro-invertebrates.

INTRODUCTION

Acidic drainage from idle mines is limiting the biological production in much of Galena Creek and subsequently in the Dry Fork of Belt Creek downstream from its confluence with Galena Creek (Zollman, 1970). Hardrock mining for silver with its accompanying copper, lead, and zinc flourished along Galena Creek from the 1880's until the mid-1890's (Schafer, 1935). Most mines have been inactive since 1900 with the exceptions of the large Block P Mine, which was worked during the periods from 1927 to 1930 and 1941 to 1943, and a few small, sporadically operated mines (Zollman, 1970).

The Montana Department of Health and Department of Fish and Game have conducted (1) chemical analyses of water samples collected from Galena and the Dry Fork of Belt creeks in 1963, 1965, and 1966, (2) short-term, limited surveys of the bottom fauna in the Dry Fork of Belt Creek in 1965 and 1966, and (3) a survey of fish distribution in the Dry Fork of Belt Creek in 1966. Summarizing the results of these investigations, Boland (1966) stated faunal surveys demonstrated a reduction in both numbers and variety of macro-invertebrates and the presence of only one fish in several miles of the Dry Fork of Belt Creek below the entrance of Galena Creek. He further stated chemical analyses indicated high levels of acidity, iron, and zinc and concluded these factors alone or in combination were limiting the biological community. The specific sources of pollution were located on Galena Creek from additional studies of water chemistry in 1968 and 1969. Apparently surface water percolates through mine spoils, infiltrates mine adits, and emerges with acid and heavy metals as seepages (Zollman, 1970), which flow into Galena Creek at several locations upstream from its confluence with the Dry Fork of Belt Creek.

The primary purpose of this study was to determine the severity and extent of the effects of acid mine pollution on the benthic macroinvertebrates of the Dry Fork of Belt Creek drainage. The effects of pollution from the Dry Fork of Belt Creek on Belt Creek were also investigated. I conducted field research from May 4, 1973 through May 17, 1974. In March, 1973 a study was begun by the Montana Department of Natural Resources and Conservation under funding by the Environmental Protection Agency to determine the feasibility of using present methods of mine sealing and water treatment to reduce the acid mine pollution of Galena Creek. The information from my study should also establish biological baselines for the determination of possible improvements in the streams' benthic macro-invertebrate populations resulting from future pollution abatement.

DESCRIPTION OF STUDY AREA

The study area lay principally in Cascade County (T15N, R7E and R8E) on the northern edge of the Little Belt Mountains in central Montana. These mountains form a low, plateau-like range of the Rockies, having a maximum altitude of 2,797 m above mean sea level. They have a base of Pre-Cambrian gneiss and schist progressively covered by Neihart quartzite and several strata of Paleozoic sediments including sandstone, shale, and limestone (Weed, 1899). Igneous intrusions in some instances have formed laccolithic peaks rising up to 300 m above the plateau. The plateau itself is at an elevation of about 2,400 m and has been heavily eroded by the radiating drainages of the Judith, Musselshell, and Smith rivers and Dry Wolf and Belt creeks (Schafer, 1935). This erosion in the absence of glaciation has created narrow, V-shaped valleys occasionally lying 600 m below the rim of the plateau.

The area studied consisted of portions of Galena, the Dry Fork of Belt, and Belt creeks (Figure 1). Galena Creek originates, according to USGS maps, at an altitude of about 2,256 m on the north slope of Mixes Baldy Peak. It flows southwardly, traveling approximately 5.8 km before emptying into the Dry Fork of Belt Creek at an elevation of 1,646 m. Its overall gradient is about 105 meters per stream kilometer, and flows recorded during the study (Table 1) showed the maximum spring discharge at its mouth (Station 3) was

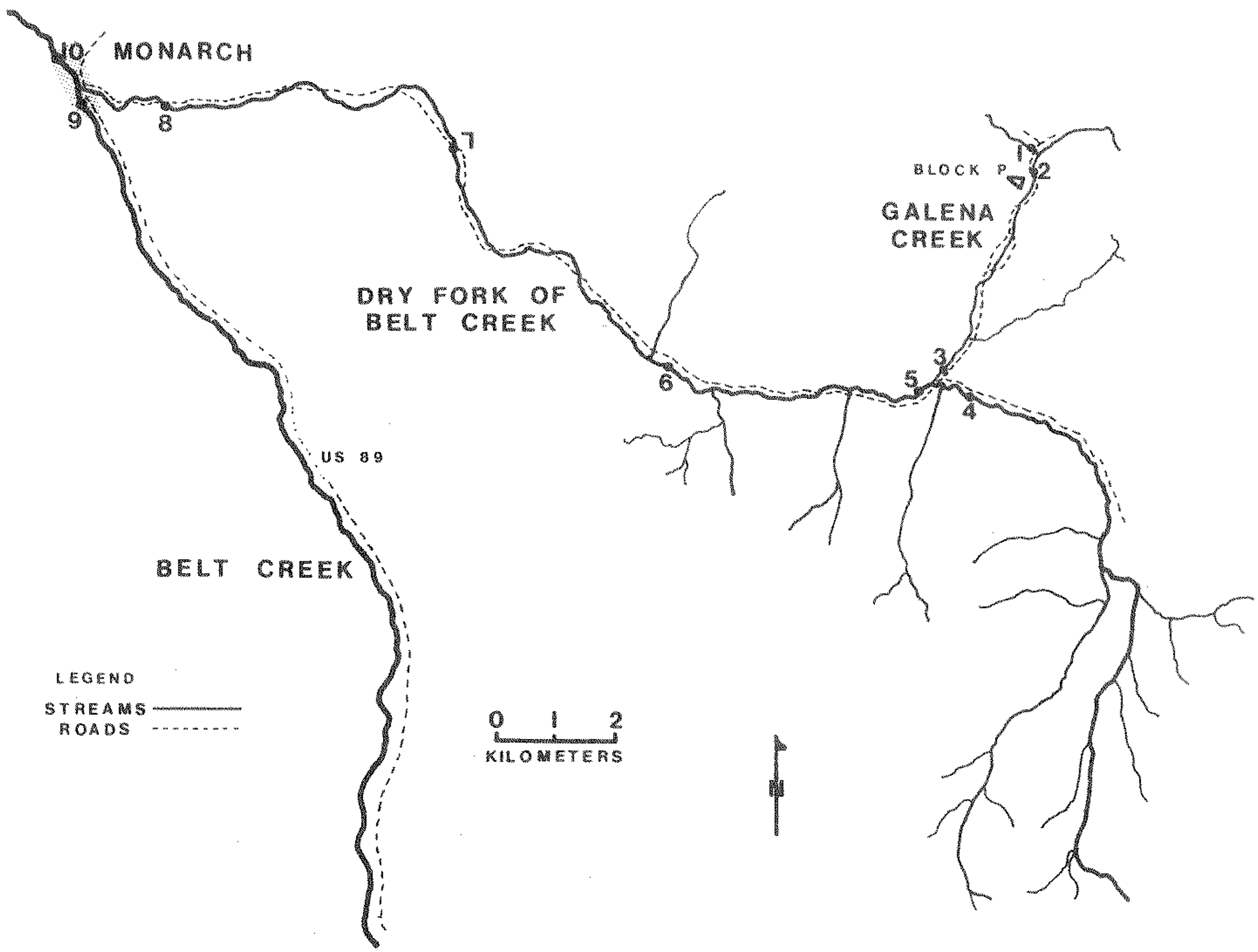

Figure 1. Map showing the location of sampling stations on Galena, the Dry Fork of Belt, and Belt creeks.

TABLE 1. FLOWS (M^3/SEC) MEASURED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date							
	1973						1974	
Station	5/18	6/6	7/5	8/5	9/7	10/8	4/5	5/16
1			0.001	0.003	0.004	0.003		
2			0.016	0.015	0.016	0.014		
3	1.280	0.368	0.148	0.034	0.041	0.029	0.043	0.174
4		1.040	0.492	0.182	0.177	0.100		0.456
5	4.000		0.751	0.222	0.228	0.164	0.151	0.766
6			1.009	0.197	0.286	0.188		0.877
7		2.520	1.241	0.342	0.447	0.233	0.281	1.262
8	5.700	2.427	1.039	0.177	0.206	0.175		1.158

over 44 times as large as its minimum in the fall. The study section on Galena Creek covered the 4.3 km of stream from a point on the Green Creek fork of Galena to its confluence with the Dry Fork of Belt Creek. This section included the major site of acidic mine seepage, the Block P Mine's spoil dump (Montana Department of Natural Resources and Conservation, 1974), which lies between 3.5 and 3.8 km upstream from Galena's mouth. The bottom type of Galena Creek at higher elevations is principally gravel and sand but changes to a semi-fused mixture of boulders and rubble near its mouth.

Aerial photographs by the U. S. Forest Service and USGS maps indicate the Dry Fork of Belt Creek (referred to as the Dry Fork hereafter) originates on the slopes of Big Baldy Mountain at an elevation of about 2,500 m. It flows northwesterly 29.8 km to the town of Monarch where it joins Belt Creek at an altitude of 1,402 m.

The 10.5 km of the Dry Fork lying above 1,707 m in elevation have many small tributaries and an overall gradient of about 76 m/km. The remaining 19.3 km of the stream, lying below 1,707 m and comprising the study section on the Dry Fork, have an overall gradient of 16 m/km and receive five permanent tributaries including Galena Creek, which enters at a point 18.3 km upstream from Belt Creek. The highest recorded discharge near the mouth of the Dry Fork (Station 8) occurred in the spring and was about 33 times greater than that of the lowest fall measurement (Table 1). Weed (1899) reported a water loss in the lower reaches of the Dry Fork and attributed it to the porous limestone stream bed. Flows decreased from Station 7 to Station 8 during this study. The stream bottom of the study section on the Dry Fork is composed largely of boulders and rubble. Konizeski (1970) stated a fishable population of cutthroat trout *(Salmo clarki)* is present in the Dry Fork above Galena Creek.

On USGS maps, Belt Creek begins in the area of King's Hill and flows north out of the Little Belts to join the Missouri River about 20 km east of Great Falls. The discharge just downstream from Monarch averaged 5.1 m^3/sec over a 21-year period and had a 1972 maximum of 34.4 m^3/sec in June and a minimum in December when ice jams blocked all flow (USGS, 1973). The 12.5 km section of Belt Creek upstream from the mouth of the Dry Fork has an overall gradient of 12 m/km. In the study section located just upstream and downstream from this confluence, the bottom type is comprised of boulders and rubble. Rainbow *(Salmo gairdneri)* and brown trout *(Salmo trutta)* populations exist in Belt Creek in fishable numbers (Konizeski, 1970).

Ten stations were established in the study area (Figure 1) as sites for the collection of both aquatic fauna and water samples. Station 1 was located on the Green Creek fork of Galena Creek 4.3 km above the mouth of Galena Creek and served as the control station for Galena Creek. Station 2 was situated on Galena Creek 4.0 km upstream from its mouth and 0.2 km above the Block P spoil dump. Station 3 was on Galena Creek 0.2 km upstream from its mouth. Station 4 was on the Dry Fork 19.3 km upstream from its mouth and 1.0 km up from its confluence with Galena Creek. It served as the control for the Dry Fork. Station 5 was located on the Dry Fork 18.2 km upstream from its mouth and 0.1 km below the entrance of Galena Creek, a distance which should have allowed thorough mixing of the two streams. Stations 6, 7, and 8 were located on the Dry Fork 13.2, 7.2, and 1.4 km upstream from its mouth, respectively, providing approximately equal interstational distances of five to six kilometers between Stations 5 through 8. Station 9 was located on Belt Creek 0.3 km upstream from the entrance of the Dry Fork and served as the control for Belt Creek. Station 10 was on Belt Creek 0.6 km downstream from the mouth of the Dry Fork.

METHODS

Benthic macro-invertebrates were collected using multi-plate, artificial substrate samplers. These samplers were similar to the type described in Standard Methods for the Examination of Water and Wastewater (APHA, 1971), but with the radial dimensions of the large plates uniformly increased to provide a total surface area of approximately 0.2 m^2 for each sampler. Four samplers were used at each station on Galena Creek and the Dry Fork while two were used per station on Belt Creek. All samplers were placed in areas of visually similar current, usually riffles, and were positioned by clamps and anchor rods so they were located just above the substrate with their plates lying parallel to it. An attempt was made to collect samples at four-week intervals, but because of weather and stream conditions, some intervals between sampling dates ranged up to six weeks. However, the colonization period was equal for all samplers collected in a given month.

On each collection date the material from each recovered sampler was scraped into a separate jar, and enough formalin was added to make a 10% concentration for preservation. These samples were taken to Montana State University where they were individually washed on a US Series Number 30 screen. Faunal organisms were then hand picked from the material retained by the screen and preserved in 50% isopropyl alcohol. Benthic macro-invertebrates in each sample were identified to the lowest practical taxon using keys by Usinger (1971) and Ward and Whipple (1959) and counted.

The individual diversity based on Brillouin's interpretation of information theory, maximum individual diversity, and evenness of the collection were calculated for the collection from each sampler using the formulae of Pielou (1969). An average was computed for each of these diversity indices from the individual collection values at each station on a given date, and the resulting averages were used in the inter-stational comparisons. Data were calculated at the Montana State University Computer Center utilizing a computer program written by personnel of the Math Department, M. S. U.

A cage bioassay of 48 hours duration was initiated on September 4, 1973 at Stations 2 through 8 using fingerling rainbow trout obtained from the Fish Cultural Development Center at Bozeman, Montana. Station 1 was not included because its depth was insufficient. Two groups of 10 fish each were held in wire minnow traps and were checked for mortalities every 24 hours. A fish was considered dead when no gilling or other body movement was apparent.

Selected physical and chemical parameters were measured monthly on Galena Creek and the Dry Fork from May, 1973 through May, 1974 except during February and March of 1974. The water chemistry of Belt Creek was studied in September and November of 1973. During months when macro-invertebrates were sampled, physical and chemical measurements or water samples were obtained within 24 hours of the benthos collection.

Stream temperatures were taken with a pocket thermometer usually at 0.3 m. Flows were determined from measurements made approximately every 0.5 m on a transect across the stream. A Scientific Instruments graduated mounting rod and a Gurley Model 622 current meter were used to measure the depth and the velocity at a point lying 60% of the depth below the surface. Dissolved oxygen determinations were made with a Hach Model DR-EL portable water analysis kit following Hach procedures. The pH was measured with an Orion Ionalyzer Model 407 ion meter.

All other tests were conducted at Montana State University from water samples. Determinations of copper, iron, and manganese from acidified water samples and sulfate from filtered samples were made colorimetrically. All colorimetric tests were performed on a Bausch and Lomb Spectronic 20 colorimeter using Hach reagents and procedures (Hach, 1969). Concentrations of total hardness and calcium hardness from unmodified samples and chloride from filtered samples were determined by titrations using Hach reagents and procedures from Standard Methods for the Examination of Water and Wastewater (APHA, 1971). Determinations of total alkalinity, magnesium, specific conductance, sodium, potassium, and zinc were also made using procedures from

Standard Methods (APHA, 1971). Total alkalinity and specific conductance were run from cooled water samples within 24 hours of collection. Alkalinity was done potentiometrically on a Beckman Expandomatic pH meter, and specific conductance was measured with a Y. S. I. Model 31 conductivity bridge. Magnesium was calculated from other determined parameters. Potassium and sodium were determined by flame photometry from acidified water samples using a Beckman Model 2400 DU spectrophotometer. Zinc was determined from acidified water samples by atomic absorption on the spectrophotometer using a Beckman atomic absorption accessory.

RESULTS

Biotic

The numbers of benthic macro-invertebrates collected from each recovered multi-plate sampler are given by taxon, sampling station, and date in Appendix Tables 8 through 16. The total number of invertebrates obtained was 10,548, of which 9% were from Galena Creek, 52% were from the Dry Fork, and 39% were from Belt Creek.

A pattern of declining total numbers of benthic macro-invertebrates with downstream progression was generally present throughout the study. This pattern was best demonstrated on Galena Creek and the Dry Fork during the months of July, August, September, and October when sampling success was uniform. On Galena Creek the numbers of invertebrates collected from Stations 1, 2, and 3 comprised approximately 59%, 38%, and 2%, respectively, of the stream's collection for those months. On the Dry Fork, Stations 4, 5, 6, 7, and 8 had approximately 77%, 9%, 11%, 3%, and 1%, respectively, of that stream's total number for the four-month period. Especially prominent was the large decline that occurred at Station 5 immediately below the confluence of Galena Creek with the Dry Fork. Of the total number of macro-invertebrates collected during August, September, October, and November on Belt Creek, Station 9 had 64% and Station 10 had 36%. However, the greater number of individuals at the upstream station on Belt Creek probably represented sampling error and not an interstational trend since it was primarily caused by an unusually large collection on a single sampler in August (Appendix Table 16) that comprised 32% of the Belt Creek total by itself.

Seasonal trends in the total numbers of individuals collected were not well defined. However, during the July through October period of equal sampling pressure, monthly total numbers collected from Galena Creek increased while those from the Dry Fork generally decreased. From August through November, monthly total numbers on Belt Creek also generally decreased. Seasonal patterns were probably caused by several factors including differences in the life histories of insects, normal sampling variations, and changes in physical and chemical conditions.

Members of the class Insecta comprised 98% of the total number of macro-invertebrates with 10,325 individuals, leaving 223 organisms or 2% of the total not in that class. A total of 50 different taxa was collected during the entire study, of which 46 were insects. Insect taxa were distributed among eight orders, however, the Ephemeroptera, Plecoptera, Trichoptera, and Diptera contained 27%, 8%, 29%, and 36%, respectively, of the total number of insects obtained during the study and accounted for over 99% of the class. Members of each of these four predominant orders were collected in every month sampling was conducted. The largest monthly collection of dipterans, plecopterans, trichopterans, and ephemeropterans occurred in August, September, September, and October, respectively, but these were also the months with the greatest sampler recovery success.

Each of the four major insect orders were dominated by certain genera. *Baetis* and *Ephemerella* accounted for 69% and 13%, respectively, of the total ephemeropteran collection. *Nemoura* made up 53% of the number of plecopterans collected while each of the other taxa in the order represented 10% or less. Trichopterans were dominated by *Brachycentrus* and *Lepidostoma* with 40% and 36%, respectively, of the individuals in the order. The dipteran families Tendipedidae and Simuliidae comprised 57% and 41%, respectively, of the order's total number.

Four of the 50 taxa collected during the study were not insects, and only two of these taxa had more than five members each. The class Turbellaria had 177 individuals or 79% of the non-insect numbers, and the subclass Ostracoda of the class Crustacea had 38 members or 17%. All turbellarians were collected during August, September, and October while all but one of the ostracods were obtained during September and October.

The maximum number of taxa found at any station on a single sampling date was 20. A general pattern of decreasing numbers of taxa upon downstream progression was evident throughout the study. For Galena Creek and the Dry Fork, this trend was best demonstrated during the period of July through October when sampling pressure was equal. For this period, Stations 1, 2, and 3 on Galena Creek had a monthly average of 12, 5, and 2 taxa, respectively, and on the Dry Fork, Stations 4 through 8 had an average of 16, 9, 7, 5, and 2 taxa per month, respectively. On Belt Creek, the total number of taxa at Station 9 exceeded that at Station 10 during three of the four months sampled. However, the difference in the number of taxa between the two stations was never greater than four. For each month from August through October, the total number of taxa at Station 9 was comparable to the respective value at Stations 1 or 4, the other controls.

The community composition of each station's macro-invertebrate collection by major taxonomic groups is presented in Table 2 for the periods of uniform sampling success on each stream. Communities composed of numerous taxonomic groups balanced in their representation are considered indicative of unpolluted conditions while those having only one or two taxa containing large numbers of individuals and a few other taxa with small numbers suggest an effect by pollution, especially if the taxa having large numbers are known to be tolerant of pollution. Ephemeroptera and Plecoptera were considered by Roback and Richardson (1969) and Mackenthum (1969) to be more susceptible to acid mine pollution than the Trichoptera and Diptera. Oliff (1963) found *Centroptilum* more resistant to acid mine pollution than other mayfly nymphs. *Nemoura* have been observed to be tolerant of acid mine

TABLE 2. NUMBERS AND PERCENTAGE COMPOSITION (in parentheses) OF BENTHIC MACRO-INVERTEBRATES BY MAJOR TAXA AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) FOR THE JULY THROUGH OCTOBER COLLECTION PERIOD AND ON BELT CREEK (9 & 10) FOR THE AUGUST THROUGH NOVEMBER COLLECTION PERIOD.

Station	1	2	3	4	5	6	7	8	9	10
Taxa										
Ephemeroptera	77	9	4	1182	30	7	5	0	305	135
	(15)	(3)	(17)	(47)	(10)	(2)	(4)	(0)	(12)	(9)
Plecoptera	164	22	0	233	15	7	7	5	36	23
	(32)	(7)	(0)	(9)	(5)	(2)	(6)	(11)	(1)	(2)
Trichoptera	98	6	2	331	30	98	58	5	1082	1075
	(19)	(2)	(9)	(13)	(10)	(27)	(51)	(11)	(41)	(72)
Diptera	119	145	15	765	206	243	42	34	1199	258
	(23)	(43)	(65)	(30)	(72)	(68)	(37)	(76)	(46)	(17)
Turbellaria	20	153	0	0	2	0	1	1	0	0
	(4)	(46)	(0)	(0)	(1)	(0)	(1)	(2)	(0)	(0)
Ostracoda	37	0	0	0	0	0	0	0	0	0
	(7)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Other	1	1	2	6	3	2	1	0	6	0
	(<1)	(<1)	(9)	(<1)	(1)	(1)	(1)	(0)	(<1)	(0)
Total	516	336	23	2517	286	357	114	45	2628	1491
	(100)	(101)*	(100)	(99)*	(99)*	(100)	(100)	(100)	(100)	(100)

*Rounding gave values unequal to 100%.

pollution in Europe (Koryak *et al.*, 1972). Tendipedidae were found by Roback and Richardson (1969) and Koryak *et al.* (1972) to be unusually resistant to acid mine pollution. Simuliidae, however, have been reported by Mackenthum (1969) to often be absent from areas with acid mine pollution. The compositional trends shown in Table 2 and Appendix Tables 9 through 12 and 16 indicate the severity and extent of the effect of pollution on the biota of the three study streams.

Compositional balance generally decreased upon downstream progression on Galena Creek. Proportions of trichopterans and plecopterans decreased, and the proportion of dipterans increased at both stations downstream from Galena's control. Often the well represented insect genera were the ones of their respective orders known to be tolerant of acid mine pollution. These patterns were best demonstrated in the following analysis of the July through October period of equal sampling success.

At Station 1, the ephemeropterans, plecopterans, trichopterans, and dipterans each contributed 15% or more to the station's collection for the period. Plecopterans had the greatest proportion of the total with 32%. *Nemoura* comprised 52% of the plecopterans, tendipedids made up 95% of the dipterans, and the ephemeropteran genus *Centroptilum* represented 96% of that order for the period. All but one ostracod were found at Station 1 during this period. Their presence probably was due to the small volume of flow (Table 1) and the sand bottom at this station.

At Station 2 only dipterans and turbellarians contributed over 10% of the number of individuals. Dipterans had 43%, and turbellarians had 46%. Tendipedids were the only dipterans at Station 2, and all ephemeropterans were *Baetis*. *Nemoura* comprised 50% of the plecopterans collected at the station during this period. About 86% of the turbellarians obtained during the entire study were from this station. This probably reflects the pool-like nature of the station.

Ephemeropterans with 17% and the dipterans with 65% were the only major groups contributing over 10% of Station 3's number of individuals for the period. All ephemeropterans were *Cinygmula*, and all but one of the dipterans collected during this period were tendipedids.

Data from stations on the Dry Fork showed that with downstream progression the balance initially declined below Galena Creek's entrance, then improved slightly, and declined again at the stream's mouth. All stations downstream from the control had lower compositions of ephemeropterans and higher compositions of dipterans for the July through October period of equal sampling pressure.

The ephemeropterans, plecopterans, trichopterans, and dipterans at Station 4, the Dry Fork control, each contributed 9% or more to the total number of individuals for the period. Ephemeropterans dominated the collection with 47%. Two-thirds of that order were *Baetis* which accounted for 31% of the station's four-month total. *Nemoura* contributed 72% to the plecopteran total, and tendipedids comprised almost 78% of the dipterans while simuliids were 22% of the order.

At Station 5, the first Dry Fork station below the confluence with Galena Creek, ephemeropterans, trichopterans, and dipterans each accounted for 10% or more of the station's collection for the period. Dipterans were decidedly dominant with 72% of the total number, and tendipedids comprised 88% of the order.

Only dipterans with 68% and trichopterans with 27% contributed over 2% of the total number of individuals for the period at Station 6. Tendipedids dominated the dipterans with 93% of the order, and *Brachycentrus* comprised 88% of the trichopterans. All ephemeropterans were *Baetis*.

Trichopterans and dipterans were the only major groups at Station 7 that contributed over 6% to the station's collection for the period. Trichopterans were the most numerous with 51%, and dipterans declined from 68% of the total composition at Station 6 to 37% at this station. The proportions of ephemeropterans and plecopterans were greater than at the previous station, the first such gain observed for these orders and an indication of slight improvement. *Brachycentrus* comprised 97% of the trichopterans, and tendipedids represented 98% of the dipterans.

The plecopterans, trichopterans, and dipterans each contributed over 10% of the total number of individuals collected during the period at Station 8. However, the dipterans clearly dominated with

76% of the total, the highest percentage for any major group observed at any station. The dipterans collected during the period were 97% tendipedids, and the trichopterans were 80% *Brachycentrus*.

The compositional balance of the Belt Creek collections made from August through November had an apparent decline from Station 9 to Station 10. This resulted from an increased proportion of trichopterans and a decreased proportion of dipterans at the downstream station.

At Station 9 ephemeropterans, trichopterans, and dipterans each contributed over 10% to the total number of individuals for the period, and the latter two taxa dominated with 41% and 46%, respectively. *Baetis* comprised 98% of the ephemeropterans collected, and *Brachycentrus* and *Lepidostoma*, respectively, accounted for 54% and 39% of the trichopterans. Six percent of the dipterans were tendipedids while simuliids made up 92% of the order. Egglishaw and Morgan (1965) stated high densities of simuliids are a common occurrence because of their current specificity and recommended they be excluded from sample analysis. One sampler in the August collection (Appendix Table 16) contributed an extraordinarily large number of simuliids which biased the station's compositional balance. If simuliids were excluded, ephemeropterans, trichopterans, and dipterans would have had 20%, 71%, and 6%, respectively, of the total number of individuals at Station 9.

Station 10 had three orders, ephemeropterans, trichopterans, and dipterans, making up 9% or more of its total number of individuals for the period. Trichopterans dominated with 72% of the collection, and *Brachycentrus* and *Lepidostoma* comprised 36% and 57% of that order, respectively. The dipterans had tendipedids and simuliids, respectively, accounting for 33% and 64% of the order. All ephemeropterans were *Baetis*. Exclusion of simuliids from counts at this station would have increased the trichopteran proportion to 82% and reduced the dipteran proportion to 6%, making the adjusted ordinal balances of Stations 9 and 10 more comparable.

The average individual diversity and evenness of the distribution of individuals into the taxa present at each station on each sampling date are given in Table 3. The diversity index typically rises as the wealth of taxa increases. Values theoretically range from zero to any positive number but are usually below 10. The evenness parameter measures the equality of the distribution of individuals into the taxa present and can theoretically range from zero to one with equal distribution of individuals among the taxa being represented by the value of one (Pielou, 1969). A stable, climactic community free of pollution would typically have a large number of taxa with relatively few individuals per taxon, giving it a high diversity and a relatively even distribution. A community subject to pollution would show dominance by resistant taxa and the absence of some more susceptible ones

TABLE 3. THE NUMBER OF SAMPLERS (S) RECOVERED, THE TOTAL NUMBERS OF BENTHIC MACRO-INVERTEBRATES (N) AND OF TAXA (T) FROM THE SAMPLERS, AND THE AVERAGE INDIVIDUAL DIVERSITY ($\tilde{D}$) AND EVENNESS (E) FOR THE STATIONS ON GALENA CREEK (1-3), THE DRY FORK OF BELT CREEK (4-8), AND BELT CREEK (9 & 10) ON EACH SAMPLING DATE.

Date	6/5/73					7/4/73					8/4/73					9/6/73					10/7/73				
Station	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E
1	–	–	–	–	–	4	77	6	1.07	0.72	4	70	9	1.34	0.74	4	245	18	2.42	0.83	4	124	17	2.44	0.88
2	4	17	5	0.53	0.91	4	9	4	0.51	0.93	4	135	4	0.67	0.56	4	35	4	0.64	0.80	4	157	8	1.25	0.68
3	3	5	4	0.29	1.00	4	7	3	0.51	0.89	4	1	1	0.00	*	4	12	2	0.00	*	4	3	2	0.25	1.00
4	4	495	19	1.95	0.60	4	858	15	2.05	0.60	4	505	16	1.80	0.58	4	561	20	2.72	0.80	4	593	15	1.80	0.57
5	4	50	14	1.61	0.83	4	115	16	2.10	0.82	4	61	8	0.83	0.55	4	108	9	0.74	0.42	4	2	1	0.00	*
6	0	–	–	–	–	4	117	5	1.11	0.66	4	79	7	0.51	0.38	4	124	8	0.63	0.40	4	37	7	0.86	0.77
7	4	79	6	0.53	0.60	4	38	4	0.74	0.81	4	17	4	0.35	0.77	4	23	8	1.01	0.90	4	36	4	0.28	0.66
8	2	20	2	0.23	0.55	4	19	2	0.22	1.00	4	11	4	0.45	1.00	4	8	4	0.34	1.00	4	7	2	0.13	1.00
9	–	–	–	–	–	–	–	–	–	–	2	1530	11	1.44	0.48	2	604	17	2.01	0.57	2	452	15	1.66	0.50
10	–	–	–	–	–	–	–	–	–	–	2	598	8	1.95	0.70	2	338	13	1.94	0.63	2	521	15	1.29	0.38

Date	11/3/73					12/14/73					1/16/74					5/17/74				
Station	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E	S	N	T	$\tilde{D}$	E
1	4	43	10	1.14	0.88	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	4	31	5	0.73	0.72	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4	18	5	0.57	0.79
4	4	462	20	2.60	0.75	4	398	17	1.90	0.59	4	292	16	1.76	0.57	2	142	10	2.12	0.76
5	1	0	0	*	–	–	–	–	–	–	–	–	–	–	–	4	27	11	0.87	0.93
6	4	16	6	0.54	0.90	4	19	4	0.62	0.86	0	–	–	–	–	4	51	6	0.55	0.53
7	4	5	4	0.17	1.00	2	1	1	0.00	*	–	–	–	–	–	4	40	5	0.74	0.82
8	4	3	3	0.00	*	0	–	–	–	–	–	–	–	–	–	2	21	5	0.61	0.65
9	2	42	9	1.85	0.86	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	2	34	6	1.01	0.87	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

*Undefined

and consequently would have lower diversity and evenness values.

Based on the numbers of individuals and taxa collected during this study, the maximum individual diversity possible was 3.79. Actual diversity values ranged from 0 to 2.72 during the study, and a pattern of decreasing diversity with downstream progression was generally present on each of the three streams. The most complete documentation of this pattern occurred during the period from July through October for Galena Creek and the Dry Fork and from August through November for Belt Creek when sampler recoveries were equal. Diversity on Galena Creek for the period ranged from 1.07 to 2.44, 0.51 to 1.25, and 0 to 0.51 for Stations 1, 2, and 3, respectively. The average diversity was 1.82, 0.78, and 0.19 for Stations 1, 2, and 3, respectively. Diversities ranged from 1.80 to 2.72, 0 to 2.10, 0.51 to 1.11, 0.28 to 1.01, and 0.13 to 0.45, respectively, during the period for Stations 4 through 8 on the Dry Fork, and the averages for Stations 4 through 8, respectively, were 1.84, 0.92, 0.78, 0.60, and 0.29. On Belt Creek diversities ranged from 1.44 to 2.01 at Station 9 and from 1.01 to 1.95 at Station 10 with an average of 1.74 and 1.55 at Stations 9 and 10, respectively.

Evenness values observed during the study ranged from 0.38 to 1.00 with considerable fluctuation between stations on a specific date and between dates for a particular station. During the months of equal sampling success, a trend of decreasing evenness upon downstream progression was present for Stations 1 and 2 on Galena Creek. On the Dry Fork, Stations 4, 5, and 6 also had a decrease in evenness upon downstream progression during the months of August and September. The evenness values at Station 3 on Galena Creek and Stations 7 and 8 on the Dry Fork usually increased in relation to those at respective upstream stations. Each of these three stations had less than 50 individuals in every month of the period and seemed to show a bias towards high evenness values that may have been due to their small sample sizes. The average of defined evenness values was 0.79, 0.74, and 0.95 at Stations 1, 2, and 3, respectively, for Galena Creek during the period. On the Dry Fork, Stations 4 through 8 averaged 0.64, 0.60, 0.55, 0.79, and 1.00, respectively, for the period. On Belt Creek for the August through November period, Station 9 had an average of 0.60 and Station 10 had 0.65. This increase in average evenness with downstream progression was probably due to the previously noted simuliid dominance at Station 9 in the August collection which would lower that station's evenness.

Fingerling rainbow trout showed increased mortality upon downstream progression for Galena Creek during the 48-hour field bioassay. Station 2 had a total mortality of 75% of the 20 test fish while Station 3 had 100% mortality occurring within the first 24 hours of the test. On the Dry Fork mortality increased from Station 4 to Station 5, below Galena Creek's entrance, and then diminished downstream from there. Station 4 had no mortality. Stations 5 and 6 had 100% mortality, occurring within 24 hours and 48 hours, respectively. The 48-hour mortality at Stations 7 and 8 was 70% and 40%, respectively.

Physical and Chemical

Measurements of pH, temperature, and dissolved oxygen concentration on Galena Creek and the Dry Fork are given in Table 4. Also included in this table for each station and date is the percentage of dissolved oxygen saturation, derived in part from dissolved oxygen concentration and temperature data.

The pH of water in Galena Creek fluctuated slightly between Stations 1 and 2 but always decreased upon downstream progression to Station 3 which had the lowest pH observed at any station on each sampling date. The pH on the Dry Fork decreased between Stations 4 and 5 and generally increased downstream from Station 5 with an eventual partial or full recovery to control levels in four and six months, respectively. The reduction in pH between Stations 4 and 5 was at least one-half unit each month and was the result of the entry of Galena Creek.

The pH measurements ranged from 6.30 to 8.54 with a maximum difference between stations on any one sampling date of 1.96 units. Gaufin (1973) suggested water with a pH range of 6.0 to 8.5 "should protect most cold water lotic insects," indicating that the observed

TABLE 4. THE pH, TEMPERATURE (T) IN °C, DISSOLVED OXYGEN CONCENTRATION (DO) IN MG/1, AND THE PERCENTAGE OF DISSOLVED OXYGEN SATURATION (% DO), ADJUSTED FOR ALTITUDE AND TEMPERATURE, OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date															
	6/6/73				7/5/73				8/5/73				9/7/73			
Station	pH	T	DO	%DO	pH	T	DO	%DO	pH	T	DO	%DO	pH	T	DO	%DO
1	—	—	—	—	7.52	10	9	100	7.22	8	9	94	8.05	9	8	86
2	7.12	5	10	98	7.48	10	9	100	7.48	8	10	105	8.07	10	8	89
3	6.59	8	9	92	6.55	14	7	82	6.51	15	7	85	6.58	15	8	97
4	8.01	7	11	109	8.02	9	9	98	8.14	9	9	98	8.18	11	8	91
5	7.43	8	10	103	7.46	10	9	97	7.62	13	8	91	7.70	12	9	102
6	7.56	9	9	94	7.66	10	10	107	8.00	16	8	100	7.84	12	9	101
7	7.78	11	9	97	7.64	11	9	97	8.21	17	7	88	8.40	15	8	94
8	7.81	12	10	106	7.96	15	7	83	8.00	18	7	86	8.54	18	7	86
	10/8/73				11/4/73				12/14/73				1/16/74			
1	8.14	6	8	80	—	—	—	—	—	—	—	—	—	—	—	—
2	8.26	6	7	70	7.65	—	—	—	—	—	—	—	—	—	—	—
3	6.83	7	9	92	6.97	0	6	50	6.60	0	—	—	6.30	—	—	—
4	8.43	6	6	61	8.01	0	7	60	8.03	1	—	—	7.94	0	—	—
5	7.68	7	8	80	7.13	0	—	—	7.08	—	—	—	7.13	—	—	—
6	7.94	7	7	68	8.20	1	—	—	7.85	—	—	—	8.04	—	—	—
7	8.31	7	7	67	8.10	0	—	—	8.01	0	—	—	7.66	—	—	—
8	8.46	6	6	58	8.40	0	7	57	—	0	—	—	—	—	—	—
	4/5/74				5/16/74											
3	6.31	7	10	102	6.30	2	12	106								
4	7.74	2	—	—	7.95	1	13	113								
5	6.89	6	—	—	7.15	2	12	105								
6	7.60	7	—	—	7.51	4	13	120								
7	7.88	8	9	89	7.80	6	11	106								
8	7.90	7	—	—	7.83	7	10	98								

pH levels were probably not detrimental to the general benthos. Ephemeroptera is the insect order most sensitive to low pH (Bell and Nebeker, 1969; Gaufin, 1973; Kimmel and Hales, 1973). Gaufin (1973) determined that *Rhithrogena robusta* was the most sensitive of the six ephemeropterans he studied with a 96-hour median tolerance limit at the pH of 6.35. This species was found in the study area but not at Station 3, which had pH values below 6.35 in 3 of 10 determinations. This absence could have been caused by the low pH levels.

Water temperatures generally increased with downstream progression on both Galena Creek and the Dry Fork. Exceptions to this pattern occurred from November through January, when the stream had extensive ice cover, and during April and October, when Station 8 had a lower temperature than Station 7. This latter exception was probably due to the occurrence of a considerable degree of evening cooling before the water temperature was determined at Station 8.

Water temperatures ranged from 0° to 18° C during the study with a maximum difference between stations on any one sampling date of 10° C. The highest temperature observed did not exceed the 18.3° C cited by Gaufin (1973) as the upper limit for the maintenance of several of the least temperature tolerant species of Ephemeroptera, Plecoptera, and Trichoptera. However, temperatures occasionally did exceed the 96-hour median tolerance limits he determined for *Cinygmula* (11.70° C), *Ephemerella* (15.45° C), and *Isogenus* (16.15° C) so a temperature-related limitation during three of the four months of uniform sampling success was still possible. On one occasion during this study, *Cinygmula* was found at 14° C.

No inter-stational trends were present for dissolved oxygen concentrations or percentages of dissolved oxygen saturation observed during the study. Dissolved oxygen concentrations ranged from 6 to 13 mg/l with a maximum variation between stations on any one sampling date of 3 mg/l. Six milligrams per liter is the minimum that Gaufin (1973) considered conducive to long-term survival of aquatic insects. The minimum level of 6 mg/l measured in this study was apparently adequate for the benthos since one collection made at this concentration had the greatest number of individuals and the second largest number of taxa for that sampling date.

Of the 50 dissolved oxygen saturation determinations, all were at 50% saturation or above, 40 were above 80% saturation, and 16 were supersaturated. Gaufin (1973) cited work by Per Brink on Swedish streams showing saturation values below 40% brought serious population reductions for Plecoptera so they were probably not seriously affected by the saturation levels present. Ephemeropterans have been found to be more sensitive to low oxygen saturations than plecopterans (Gaufin, 1973), but it is also unlikely they were adversely affected since they were found to be numerous at some of the lowest dissolved oxygen saturation levels observed.

The concentrations of chloride, potassium, and sodium determined for water samples from stations on Galena Creek and the Dry Fork are presented in Appendix Table 17. The only evident pattern for these three parameters was one of higher sodium concentrations in Galena Creek than in the Dry Fork. This may have been due to the weathering of more feldspar along Galena Creek because of the syenetic geological formations there.

Chloride, potassium, and sodium concentrations ranged from 0.3 to 1.7 mg/l, 0.4 to 1.0 mg/l, and 1.6 to 4.0 mg/l, respectively. The maximum differences in chloride, potassium, and sodium concentrations between stations on any one sampling date were only 1.3, 0.5, and 2.2 mg/l, respectively, and the maximum combined concentration of potassium and sodium was 4.6 mg/l. The concentrations for all three parameters were considerably below toxic levels found in studies cited by McKee and Wolf (1963) in Water Quality Criteria.

The total alkalinity, as $CaCO_3$, and specific conductance determinations for samples from Galena Creek and the Dry Fork are given by station and sampling date in Appendix Table 18. On Galena Creek, the total alkalinity, a measure of the water's hydrogen ion buffering capacity, generally decreased upon downstream progression, indicating an increased acid load in the stream. On the Dry Fork, total alkalinity decreased from Station 4 to Station 5 and then usually increased with downstream progression to levels that exceeded the control. The reduction at Station 5 was probably due to the influence of water from Galena Creek, entering the Dry Fork just upstream. The downstream recovery was due to the replacement of bicarbonate from the limestone ($CaCO_3$) that largely comprised the drainage.

Total alkalinity ranged from 10.5 to 116.0 mg/l with a maximum difference between stations on any one sampling date of 98.5 mg/l. Station 3 had the lowest total alkalinity of all stations on 9 of 10 sampling dates, and 7 of its 10 measurements were below the 20 mg/l level established by the NTAC (1968) as a minimum for satisfactory buffering capacity. Other stations were generally well above that level.

Specific conductance, an estimation of the total dissolved ionizable solids present, increased on Galena Creek upon downstream progression, showing the addition of acid mine drainage. The highest determinations of any station occurred at Station 3 during 9 of 10 months sampled, an indication of the large effect the pollution had on the stream in that area. On the Dry Fork, specific conductance increased between Stations 4 and 5 and became variable downstream from Station 5. Station 4 had the lowest measured specific conductance for each of the 10 samples with water from Galena Creek always increasing the conductance at Station 5.

The range of specific conductance encountered was 148.5 to 502.1 μmhos/cm at 25° C, which approximated the normal range for US waters

(Ellis, 1937). The maximum difference between stations on any one sampling date was 294.6 μmhos/cm. Between Stations 5 and 8, the maximum monthly difference did not exceed 40 μmhos/cm, indicating a retention of total dissolved ionizable solids. In addition, an estimation of the concentration of total dissolved ionizable solids from the specific conductance showed that the study area had hard water as defined by Reid (1961), since all values were above the 50 mg/l minimum concentration.

Neither total alkalinity nor specific conductance are specific toxic factors that would have adversely affected the benthos. Rather they indicated the quality of the water and the degree and distribution of pollution.

Total hardness and calcium hardness determinations, each as $CaCO_3$, for stations on Galena Creek and the Dry Fork are presented in Appendix Table 19. Total hardness increased in a downstream direction on Galena Creek on five of the six sampling dates when all its stations were sampled. The highest monthly total hardness was recorded at Station 3 on 9 of 10 sampling dates. On the Dry Fork, concentrations progressively increased from Stations 4 through 7 during 6 of 10 months. The lowest total hardness occurred at Station 4 on every sampling date. Consequently, part of the increase observed on the Dry Fork between Stations 4 and 5 was due to the entrance of water from Galena Creek. Total hardness ranged from 54.4 to 233.4 mg/l, and the maximum difference between stations on any one sampling date was 127.4 mg/l.

Total hardness minus total alkalinity (Appendix Table 18) equals the non-carbonate hardness. The calculation of this parameter, under the observed pH levels, indicated the presence of substantial amounts of anions other than bicarbonates and carbonates in the water at all stations but Station 4. Non-carbonate hardness ranged from 30.0 to 215.9 mg/l at Galena Creek stations. At Station 4 it had a maximum value of 6.8 mg/l and was not definable (when total alkalinity exceeded total hardness) on 5 of the 10 sampling dates, so this station generally had a carbonate-bicarbonate type of water. The non-carbonate hardness ranged from 12.1 to 86.5 mg/l at Stations 5 through 8 on the Dry Fork with the increase from the level at Station 4 due to acid mine pollution entering from Galena Creek.

Calcium hardness increased upon downstream progression in four of six samples on Galena Creek and in 9 of 10 samples for Stations 4 through 7 on the Dry Fork. It ranged from 38.6 to 126.4 mg/l, and the maximum difference between stations on any one sampling date was 56.0 mg/l.

The concentrations of calcium and magnesium present at the Galena Creek and Dry Fork stations were calculated in part from the hardness determinations and are given in Table 5. Because calcium levels were obtained directly from calcium hardness values, their trends were

TABLE 5. THE CALCIUM (Ca) AND MAGNESIUM (Mg) CONCENTRATIONS IN MG/1 OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date									
	6/6/73		7/5/73		8/5/73		9/7/73		10/8/73	
Station	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
1	--	--	23.7	7.8	30.6	12.0	31.0	15.3	39.4	11.4
2	25.0	8.2	31.8	9.3	48.2	6.4	45.4	13.0	46.8	10.5
3	22.0	7.3	37.6	13.4	46.9	16.3	46.3	15.6	50.6	13.8
4	15.4	3.7	18.6	4.6	25.8	6.0	30.6	3.6	28.7	5.8
5	17.0	4.6	22.8	9.7	30.8	8.8	31.4	8.8	34.1	10.0
6	17.8	4.3	25.4	6.9	35.2	8.5	35.8	8.5	38.8	8.9
7	19.4	4.8	28.0	6.9	37.8	9.0	40.0	8.1	43.7	8.7
8	19.4	4.5	27.2	6.6	39.2	8.8	39.8	8.1	42.1	9.9
	11/4/73		12/14/73		1/16/74		4/5/74		5/16/74	
1	40.6	8.1	--	--	--	--	--	--	--	--
2	45.8	10.6	--	--	--	--	--	--	--	--
3	50.5	21.1	48.3	18.2	40.8	16.0	43.5	18.3	32.5	10.9
4	33.4	5.4	29.6	5.7	28.6	6.1	33.6	6.2	25.0	2.6
5	39.0	12.2	34.9	11.2	35.2	10.1	38.8	12.7	23.0	7.3
6	46.8	9.7	41.2	10.2	36.5	8.7	42.2	10.0	25.9	6.5
7	50.3	6.6	46.0	9.8	38.2	7.9	45.6	9.0	28.4	6.9
8	59.2	10.0	--	--	--	--	42.6	9.0	29.0	6.2

identical. Station 3 had the highest monthly concentration observed on 7 of 10 samples, showing again that water from Galena Creek was in part responsible for the increase in concentration observed between Stations 4 and 5 in 9 of the 10 samples. However, in the case of calcium, the influence of Galena Creek on the Dry Fork was probably not as direct as with some other parameters because the limestone basin of the Dry Fork also caused the increase in calcium at Stations 5, 6, and 7.

Observed calcium concentrations ranged from 15.4 to 59.2 mg/l, and the maximum difference between stations on any one sampling date was 25.8 mg/l. In low flow periods, Stations 6 and 7 reached or exceeded saturation levels for calcite, and all other stations except Station 3 approached saturation. Although Station 3 had high concentrations of calcium, it remained far below calcite saturation because its high concentrations of other dissolved ionizable solids resulted in low ionic activity. None of the observed levels of calcium approached the 300 mg/l minimum concentration found to be toxic to fish in research cited by McKee and Wolf (1963). Because calcium has an antagonistic action towards the toxic effects of heavy metals (Lloyd, 1962; McKee and Wolf, 1963), it was probably beneficial to the benthic macro-invertebrates instead of detrimental.

Levels of magnesium did not have consistent downstream pattern between the three stations on Galena Creek, but Station 3 had the highest monthly concentration in 9 of 10 samples. On the Dry Fork, concentrations increased from Station 4 to Station 5 with a progressive downstream decrease below Station 5 occurring on 7 of the 10 sampling dates. Station 4 had the lowest concentration each of the 10 months so water from Galena Creek always increased the level of magnesium at Station 5.

Magnesium concentrations ranged from 3.7 to 21.1 mg/l, and the maximum difference between stations on any one sampling date was 15.7 mg/l. Magnesium levels were below the 100 mg/l concentration found toxic to fish and probably had a beneficial effect on the benthos because of its antagonistic action towards heavy metal toxicity (McKee and Wolf, 1963).

The selected physical and chemical determinations made on Belt Creek in November, 1973 are presented in Appendix Table 20. There were no essential differences between Stations 9 and 10 in the levels of pH, specific conductance, total alkalinity, total hardness, calcium hardness, calcium, magnesium, and sodium, and all were well within the respective ranges previously presented for Galena Creek and the Dry Fork. However, specific conductance increased slightly upon downstream progression, indicating an addition of dissolved ionizable solids from the Dry Fork. The volume of water in Belt Creek apparently minimized the influence of water from the Dry Fork.

The concentrations of total iron and manganese determined during the study are given in Table 6. Total iron concentrations on Galena Creek generally increased with downstream progression. On 10 of 11 sampling dates, Station 3 had the highest monthly iron level. On the Dry Fork, concentrations increased from Station 4 to Station 5 and then generally decreased with downstream progression. Station 4 had the lowest concentrations of total iron on 10 of the 11 dates so water from Galena Creek consequently increased the concentrations at Station 5 during all but one month of the study. There was no difference between the two Belt Creek stations in their iron concentrations.

For all stations on Galena Creek and the Dry Fork, there apparently was a relation between high total iron concentrations and high stream flows (Table 1). The highest levels of total iron recorded at Stations 2 through 6 occurred during May, 1973, coinciding with the peak of spring runoff that year. This relationship was probably due to the increased suspension and downstream transportation of previously deposited ferric hydroxide (or ferric oxide hydroxide) precipitate from upstream areas. Chadwick (1974) reported a similar increase in total iron concentrations during high flows at two of his stations.

Concentrations of total iron ranged from 0.02 to 1.64 mg/l with a maximum difference between stations on any one sampling date of 1.54 mg/l. On Galena Creek, iron levels at Stations 1 and 2 did not exceed 0.13 mg/l and 0.33 mg/l, respectively, and Station 3 had iron values

TABLE 6. THE TOTAL IRON (Fe) AND MANGANESE (Mn) CONCENTRATIONS IN MG/1 OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date											
	5/18/73		6/6/73		7/5/73		8/5/73		9/7/73		10/8/73	
Station	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn	Fe	Mn
1	——	——	0.13	0.30	0.10	0.25	0.08	0.40	0.06	0.35	0.03	0.25
2	0.33	——	0.31	0.40	0.08	0.30	0.08	0.30	0.10	0.35	0.06	0.30
3	1.64	——	1.12	0.46	0.60	0.68	0.58	0.68	0.60	0.80	0.91	0.58
4	0.10	——	0.08	0.25	0.08	0.25	0.06	0.35	0.06	0.46	0.03	0.30
5	1.22	——	0.22	0.40	0.20	0.46	0.27	0.51	0.29	0.51	0.31	0.51
6	0.71	——	0.24	0.35	0.13	0.35	0.10	0.51	0.29	0.40	0.06	0.51
7	0.24	——	0.10	0.35	0.13	0.35	0.08	0.40	0.10	0.35	0.06	0.30
8	0.31	——	0.16	0.25	0.06	0.35	0.08	0.20	0.06	0.35	0.03	0.25
9	——	——	——	——	——	——	——	——	0.06	0.30	——	——
10	——	——	——	——	——	——	——	——	0.06	0.25	——	——
	11/4/73		12/14/73		1/16/74		4/5/74		5/16/74			
1	0.08	0.35	——	——	——	——	——	——	——	——		
2	0.12	0.30	——	——	——	——	——	——	——	——		
3	1.08	0.35	0.13	0.35	0.55	0.63	0.40	0.51	0.31	0.30		
4	0.02	0.25	0.03	0.20	0.03	0.25	0.02	0.20	0.03	0.30		
5	0.35	0.30	0.10	0.35	0.91	0.46	0.13	0.46	0.20	0.35		
6	0.12	0.30	0.06	0.25	0.20	0.30	0.13	0.40	0.18	0.40		
7	0.06	0.20	0.06	0.30	1.08	0.30	0.10	0.25	0.08	0.58		
8	0.03	0.35	——	——	0.71	0.40	0.08	0.30	0.12	0.51		
9	0.03	0.20	——	——	——	——	——	——	——	——		
10	0.03	0.30	——	——	——	——	——	——	——	——		

of 0.60 mg/l or below on 7 of the 11 sampling dates. On the Dry Fork, Station 4 did not have iron present in excess of 0.10 mg/l. On 11 sampling dates, an iron concentration of 0.35 mg/l was exceeded twice at Stations 5 and 8 and once at Stations 6 and 7. Levels in Belt Creek were below 0.06 mg/l. Roback and Richardson (1969) found a well developed insect fauna with a balanced assemblage of species in each order in an area having iron concentrations usually ranging between 0.60 and 0.83 mg/l but once having a measurement of 4.97 mg/l. Chadwick (1974) had similar results, detecting no effect on benthic macro-invertebrates by total iron concentrations of approximately 0.80 mg/l with one determination of 1.70 mg/l. Consequently, iron concentrations in the range observed in this study should not have been detrimental to benthic macro-invertebrates present.

Manganese increased in concentration upon downstream progression on Galena Creek on three of the six sampling dates all three stations were sampled, and the highest monthly concentrations occurred at Station 3 on 9 of 10 sampling dates. Water from Galena Creek increased the manganese concentration of the Dry Fork from Station 4 to Station 5 during all 10 months of sampling. At Stations 5 through 8, manganese concentrations decreased with downstream progression on 5 of the 10 sampling dates but fluctuated without pattern between those stations during the other five months. Stations 9 and 10 on Belt Creek also had no consistent pattern.

Manganese concentrations ranged from 0.20 to 0.80 mg/l, and the maximum difference between stations on any one date was 0.55 mg/l. Roback and Richardson (1969) reported a manganese level of 1.12 to 2.73 mg/l at a station that had 65 taxa and was "reasonably diverse and well balanced". Levels as high as 15 mg/l were found harmless to insect larvae over a 7-day exposure in work cited by McKee and Wolf (1963). Since concentrations of manganese in this study did not approach these levels, they should not have been toxic to the benthos.

The determinations of copper, sulfate, and zinc concentrations are given in Table 7. Copper increased on Galena Creek in a downstream progression during three of the six months when all three stations were sampled. On 9 of 10 sampling dates, Station 3 had the highest observed monthly level of any station in the study. For the Dry Fork, values of copper increased with downstream progression between Stations 4 and 5 during all months due to the entrance of Galena Creek. Concentrations at Stations 6 through 8 usually fluctuated without pattern at levels somewhat lower than observed at Station 5. Belt Creek had a reduction in copper concentrations with downstream progression, evidently due to dilution by the Dry Fork.

Concentrations of copper ranged from 0.08 to 0.79 mg/l, and the maximum difference between stations on any one sampling date was 0.64 mg/l. Station 3 had concentrations over 0.60 mg/l in 7 of 10 samples. No other station had a level greater than 0.42 mg/l.

TABLE 7. THE COPPER (Cu), SULFATE (SO_4), AND ZINC (Zn) CONCENTRATIONS IN MG/1 OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date														
	6/6/73			7/5/73			8/5/73			9/7/73			10/8/73		
Station	Cu	SO_4	Zn	Cu	SO_4	Zn	Cu	SO_4	Zn	Cu	SO_4	Zn	Cu	SO_4	Zn
1	0.15	--	0.13	0.17	44	0.09	0.15	62	0.13	0.24	72	0.07	0.11	72	0.10
2	0.36	100	0.68	0.20	106	0.50	0.15	87	0.32	0.17	152	0.32	0.17	--	0.24
3	0.34	91	3.40	0.63	112	6.25	0.79	267	8.70	0.79	228	9.20	0.72	236	9.85
4	0.17	9	0.04	0.17	9	0.07	0.15	11	0.05	0.20	9	0.02	0.11	9	0.04
5	0.20	23	0.73	0.34	31	1.23	0.21	53	1.69	0.29	54	1.75	0.29	69	1.90
6	0.17	22	0.54	0.17	29	0.88	0.24	43	0.63	0.20	51	0.87	0.17	54	0.94
7	0.27	19	0.45	0.17	28	0.70	0.20	43	0.32	0.15	47	0.36	0.15	51	0.38
8	0.21	19	0.45	0.15	28	0.43	0.27	40	0.13	0.15	51	0.15	0.17	51	0.25
9	--	--	--	--	--	--	--	--	--	0.27	--	0.09	--	--	--
10	--	--	--	--	--	--	--	--	--	0.24	--	0.10	--	--	--
	11/4/73			12/14/73			1/16/74			4/5/74			5/16/74		
1	0.13	67	0.10	--	--	--	--	--	--	--	--	--	--	--	--
2	0.29	159	0.41	--	--	--	--	--	--	--	--	--	--	--	--
3	0.72	270	11.75	0.20	200	9.80	0.32	200	6.70	0.61	228	8.55	0.75	165	5.80
4	0.11	10	0.01	0.13	9	0.02	0.15	10	0.03	0.13	7	0.03	0.17	7	0.02
5	0.29	112	3.46	0.20	87	2.15	0.17	87	2.42	0.17	132	2.59	0.42	40	1.26
6	0.20	62	1.09	0.20	67	1.28	0.17	61	2.07	0.17	87	1.71	0.21	32	0.93
7	0.13	54	0.53	0.15	58	0.60	0.15	51	0.97	0.20	51	1.10	0.24	30	0.71
8	0.08	54	0.32	--	--	--	0.15	40	0.26	0.17	43	0.54	0.29	34	0.65
9	0.15	--	0.01	--	--	--	--	--	--	--	--	--	--	--	--
10	0.11	--	0.06	--	--	--	--	--	--	--	--	--	--	--	--

Research results on the toxicity of copper are variable. Warnick and Bell (1969) found median tolerance limits at copper concentrations of 0.32 mg/l for ephemeropterans in 48 hours, 8.3 mg/l for plecopterans in 96 hours, and 32 mg/l for trichopterans in 14 days. However, Sprague *et al.* (1965) concluded that all macro-invertebrates would be absent from water having copper concentrations of 0.19 mg/l. Vivier and Nisbet (1962) reported that a 6-day exposure to 0.05 mg/l of copper resulted in 100% mortality for ephemeropterans although trichopterans were still active. Other research on the toxicity of copper to aquatic organisms including insects demonstrated effects at concentrations as low as 0.015 mg/l (McKee and Wolf, 1963). Variability of test results was probably due to the use of different taxa and test conditions. Copper toxicity is modified by changes in water temperature, hardness, dissolved oxygen concentration, and the presence of other heavy metals (Lloyd, 1962). In this study the magnitude of the influence of copper on the benthos was difficult to isolate, especially from the effect of zinc. However, I feel that copper had some effect at all stations except possibly Stations 1 and 4.

Sulfate concentrations increased in a downstream direction on Galena Creek during the four months all three stations were sampled. Station 3 had the highest observed monthly level on 9 of 10 sampling dates. With downstream progression, the sulfate levels on the Dry Fork increased between Stations 4 and 5 but decreased from Station 5 to Station 7 on each of 10 sampling dates. Station 4 had the lowest level each month so the entrance of Galena Creek probably caused the increase observed at Station 5. Concentrations of sulfate were generally highest during the months having low flows (Table 1), which was the opposite of the trend noted for iron concentrations.

Sulfate ranged from 7 to 270 mg/l during the study, and the maximum difference between stations on a given sampling date was 260 mg/l. Sulfate probably originated from the oxidation of various sulfides and constituted the major anion indicated by the non-carbonate hardness. Station 2 had levels usually above 90 mg/l, and Station 3 had values above 200 mg/l on 7 of 10 sampling dates. All other stations generally were below 90 mg/l.

Little has apparently been published about the toxicity of sulfate to benthic macro-invertebrates. Roback and Richardson (1969) recorded sulfate levels of 236 to 330 mg/l at a station having good benthic representation and balance. Using these levels as a guide, only benthos at Station 3 might have been affected by sulfate. This effect would have been minor since Warnick and Bell (1969) felt the effects of sulfate anions were not as detrimental as those of the associated heavy metal cations of copper and zinc.

Zinc concentrations in Galena Creek increased with downstream progression with Station 3 having the highest observed level during each of the 10 months sampled. Concentrations increased on the Dry

Fork from Station 4 to Station 5 on every sampling date and then progressively decreased downstream from Station 5. Station 4 had the lowest values each sampling date so the entrance of Galena Creek probably caused the increases at Station 5. Belt Creek had a downstream increase in zinc concentrations between Stations 9 and 10, probably due to the entrance of the Dry Fork. During the months of high flows (May, June, and July in Table 1), Stations 3 and 5 had their lowest observed concentrations of zinc while Stations 2, 7, and 8 usually had high concentrations. The latter seasonal pattern of zinc levels was similar to that of iron and probably was also due to the increased transportation of precipitated materials.

Zinc concentrations ranged from 0.01 to 11.75 mg/l during the study, and the difference between these two levels was also the maximum observed difference between stations on any given sampling date. Station 3 did not have a concentration below 3.40 mg/l on any sampling date while Stations 1 and 4 and the Belt Creek stations did not exceed 0.13 mg/l any month. Specific levels of toxicity for zinc could not be determined from the literature because of varied test results. Wurtz and Bridges (1961) found a 96-hour median tolerance limit of 1.46 mg/l for tendipedids, and Sprague *et al.* (1965) considered 2.4 mg/l of zinc sufficient to eliminate all macro-invertebrates. However, Warnick and Bell (1969) had a 10-day median tolerance limit for trichopterans at 32 mg/l. The reduced numbers and diversity of macro-invertebrates and the high zinc concentrations at Station 3 suggest zinc had a major influence on the benthos there. Zinc also could have caused the reductions in benthos and compositional balance at Station 5 and may have been partly responsible for the depressed biotic parameters at stations further downstream on the Dry Fork.

SUMMARY AND DISCUSSION

Depressed communities of macro-invertebrates were found to extend at least 4.0 km on Galena Creek and 18.3 km on the Dry Fork. A severe reduction in total number of individuals, total number of taxa, and diversity of benthos and increased domination by pollution tolerant forms, particularly Tendipedidae, were evident in collections from these areas. The biotic parameters on Belt Creek below the entrance of the Dry Fork were slightly reduced from those observed above the entrance.

The changes observed in the biotic parameters for stations on Galena Creek and the Dry Fork were similar to those found by Dombach and Olive (1969) in acidic streams and by Chadwick (1974) in areas having high concentrations of sulfate and iron, ferric hydroxide deposition, but pH values usually above 7. In this study, acidity (as measured by pH) may have been a problem in Galena Creek adjacent to the seepages, but it was well neutralized before reaching any sampling station. Consequently, its effect on benthos collections should have been negligible, supporting statements by Koryak *et al.* (1972) and Kimmel and Hales (1973) that many biological problems associated with acid mine pollution are not caused by acidity alone.

Because a complex series of physical and chemical changes occurred over the affected areas, it was impossible to specifically identify any one factor in the acid mine drainage as the cause of the biotic changes. However, copper and zinc with their additive or possibly synergistic interactions (Lloyd, 1962; McKee and Wolf, 1963) seemed to be the major toxicants to the benthos. The levels of either copper or zinc at Station 3 were probably sufficient to have caused the observed benthic reductions although deposition of ferric hydroxide, and other materials may also have been detrimental at that station. At Station 5, the parameters for the benthos decreased as flows dropped and concentrations of copper and zinc increased. A dramatic reduction in benthos occurred in October at Station 5, possibly indicating copper and zinc concentrations had achieved a lethal threshold. Lloyd (1962) has shown a lethal threshold exists for these heavy metals with regard to rainbow trout. Areas downstream from Station 5 on the Dry Fork showed progressively reduced concentrations of zinc and several other measured chemical parameters. The downstream decrease in mortality of rainbow trout fingerlings indicated an improvement in water quality along the Dry Fork below the entrance of Galena Creek. This improvement, however, was not observed to a similar degree in the parameters of the benthic macro-invertebrates, which usually continued to decrease.

The persistence of detrimental levels of copper may account for the lack of improvement in invertebrate numbers, taxa, and diversity below Station 5, but that alone does not explain the progressive downstream decreased in these parameters. Extensive, thick mats of vegetation comprised of various bacteria and algae formed on the stream bottom at Stations 5 through 8 after spring runoff and may have reduced the diversity of the habitat and brought other detrimental changes. These mats could not be directly related to the acid mine drainage but may result from an input of nutrients. Increased water temperatures and reduced flows probably further accounted for the reductions in benthos, especially at Station 8 from July through October.

On Belt Creek the inter-stational differences in total number of individuals and community composition were largely attributable to sampling bias and not to persistent acid mine pollutants entering from the Dry Fork. Pollution from the town of Monarch may also have contributed to the remaining biological differences between Stations 9 and 10.

The reduction or elimination of copper and zinc concentrations entering Galena Creek should be a principal consideration of future pollution abatement projects. While this may not mitigate all detrimental factors, it should bring improvement to the benthic macroinvertebrate communities in the Dry Fork drainage.

APPENDIX

TABLE 8. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON JUNE 5, 1973. Hyphens indicate zero counts.

Station	2				3			4				5				7				8	
Sampler	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2
Taxa																					
Ephemeroptera																					
Ephemerella	-	-	-	-	-	-	-	23	11	18	20	-	2	-	1	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	2	4	8	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	25	1	12	6	-	-	-	-	-	-	-	-	-	-
Baetis	-	-	-	-	-	-	-	1	-	1	2	-	1	-	-	-	-	-	-	-	-
Plecoptera																					
Nemoura	-	-	-	3	1	-	-	7	2	3	-	1	1	1	1	-	3	-	-	-	2
Capniinae	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	1	1	2	1	-	-	-	-	-	-	-	-	-	-
Arcynopteryx	1	1	-	-	-	-	-	4	1	3	8	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraperlinae	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	-	-	-	-	-	1	-	1	-	-	-	1	1	-	-	1	-	-	-	-	-
Coleoptera																					
Elmidae	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera																					
Parapsyche	-	-	-	-	-	-	-	1	-	1	3	-	1	-	2	-	-	-	-	-	-
Rhyacophila	-	3	-	1	-	-	-	6	7	2	8	-	1	2	1	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1	2	1	-	-
Lepidostoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Neothremma	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Oligophebodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Diptera																					
Dicranota	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-
Pericoma	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Tendipedidae	-	1	4	2	-	1	1	32	93	121	33	7	6	7	1	34	28	5	2	6	12
Simuliidae	-	-	-	-	-	-	-	1	3	5	-	1	1	-	1	-	-	-	-	-	-
Collembola	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Nemata (Nematoda)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-
Total	1	5	4	7	1	3	1	110	125	178	82	11	20	11	8	35	34	7	3	6	14

TABLE 9. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON JULY 4, 1973. Hyphens indicate zero counts.

Station	1				2				3				4				5				6				7				8			
Sampler	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Taxa																																
Ephemeroptera																																
Ephemerella	-	-	-	-	-	-	-	-	-	-	-	-	26	46	40	31	1	3	3	3	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	-	-	-	-	-	23	12	7	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	-	-	3	1	-	9	12	20	33	2	6	3	1	-	-	-	-	-	-	-	-	-	-	-	-
Baetis	-	-	-	-	-	-	-	-	-	-	-	-	3	2	1	2	-	1	1	-	2	1	1	1	-	-	1	2	-	-	-	-
Centroptilum	9	5	3	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera																																
Peltoperla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	-	-	-	1	-	-	-	-	-	-	-	-	7	1	8	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcynopteryx	2	2	3	3	-	-	1	-	-	-	-	-	-	1	-	3	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	5	1	4	-	1	-	-	-	-	-	1	-	-	-	-	-	-
Isoperla	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera																																
Elmidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera																																
Parapsyche	-	-	-	-	-	-	-	-	-	-	-	-	2	2	3	3	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	-	-	-	-	-	-	-	-	12	5	5	1	3	3	1	1	1	-	1	-	-	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	1	3	4	1	5	25	11	9	15	-	1	4	12	-	-	2	-
Oligophebodes	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imania	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ecclisomyia	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera																																
Tendipedidae	2	5	26	12	2	1	3	-	-	-	2	-	85	113	85	162	8	14	7	16	7	7	6	28	3	4	4	6	-	2	3	12
Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-	6	60	1	1	-	1	1	8	-	-	-	-	-	-	-	-	-	-	-	-
Nemata (Nematoda)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Total	13	12	32	20	3	2	4	0	0	4	3	0	168	263	173	254	19	40	20	36	35	21	16	45	3	6	9	20	0	2	5	12

TABLE 10. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON AUGUST 4, 1973. Hyphens indicate zero counts.

Station	1				2				3				4				5				6				7				8			
Sampler	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
<u>Taxa</u>																																
Ephemeroptera																																
Ephemerella	-	-	-	-	-	-	-	-	-	-	-	-	26	16	9	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	-	-	-	-	-	6	3	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	-	-	-	-	-	1	3	5	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis	1	1	1	-	-	-	-	-	-	-	-	-	84	119	33	62	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Centroptilum	-	1	2	4	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera																																
Brachyptera	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	10	3	1	2	-	-	-	-	-	-	-	-	2	5	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Arcynopteryx	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	1	-	-	-	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	1	1	1	1	-	1	1	-	-	-	1	-	1	1	1	2	-
Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera																																
Parapsyche	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-	-	1	-	-
Oligophebodes	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imania	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnephilus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera																																
Heleinae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-	-	-	1	-	-
Tendipedidae	6	6	7	17	31	19	28	30	-	-	-	-	26	20	7	28	11	9	8	19	12	14	25	18	6	-	4	3	-	1	2	2
Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	1	2	1	-	1	-	-	-	-	-	1	-	-	-	-	-	-
Turbellaria	-	-	1	1	3	9	7	6	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-
Total	18	12	12	28	34	29	36	36	0	0	0	1	151	177	63	114	15	11	12	23	15	15	27	22	7	2	4	4	1	4	4	2

TABLE 11. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON CALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON SEPTEMBER 6, 1973. Hyphens indicate zero counts.

Station	1				2				3				4				5				6				7				8			
Sampler	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Taxa																																
Ephemeroptera																																
Ephemerella	-	-	-	-	-	-	-	-	-	-	-	-	4	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Speorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	-	-	-	-	-	4	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis	-	-	-	-	-	-	-	-	-	-	-	-	33	26	15	37	-	1	1	-	-	-	-	-	1	-	-	1	-	-	-	-
Centroptilum	4	12	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera																																
Peltoperla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachyptera	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	17	26	13	10	1	-	-	-	-	-	-	-	16	35	16	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capniinae	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3	4	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-
Arcynopteryx	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla	-	1	-	5	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Paraperlinae	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	10	5	5	3	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera																																
Dytiscidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Elmidae	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera																																
Parapsyche	-	-	-	-	-	-	-	-	-	-	-	-	9	35	7	28	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Arctopsyche	-	-	-	-	-	-	-	-	-	-	-	-	11	45	21	54	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	-	-	-	-	-	-	-	5	12	3	11	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Agapetus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	1	4	-	-	-	1	-	1	5	6	3	-	1	-	1	-	-
Lepidostoma	3	5	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnephilidae	-	2	2	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Neothremma	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imania	10	11	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera																																
Dicranota	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexatoma	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heleinae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	1	2	-	-	-	1	2	-	-	-	-	-	-	-	-
Tendipedidae	2	4	2	3	1	2	4	1	2	3	6	-	8	19	9	16	13	25	16	36	33	9	32	26	1	2	1	2	1	1	1	2
Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-	3	5	1	5	2	1	-	1	1	-	1	8	-	-	-	-	-	-	-	-
Empididae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Turbellaria	-	12	-	1	15	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Ostracoda	25	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acari	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	80	90	30	45	19	3	8	5	2	3	6	1	97	190	86	188	21	28	19	40	36	9	37	42	9	6	4	4	1	2	3	2

TABLE 12. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON OCTOBER 7, 1973. Hyphens indicate zero counts.

Station	1				2				3				4				5				6				7				8			
Sampler	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Taxa																																
Ephemeroptera																																
Ephemerella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	-	-	-	-	-	5	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis	-	-	-	-	-	-	2	7	-	-	-	-	170	76	79	45	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-
Centroptilum	3	7	5	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera																																
Brachyptera	-	-	-	-	-	-	-	-	-	-	-	-	4	3	1	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	1	-	1	1	7	-	1	2	-	-	-	-	16	20	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capniinae	5	-	1	2	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	3	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Arcynopteryx	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	3	5	-	3	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-
Trichoptera																																
Parapsyche	-	-	-	-	-	-	-	-	-	-	-	-	4	3	7	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctopsyche	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-
Rhyacophila	-	1	-	-	-	-	-	-	-	-	-	-	13	2	2	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Brachycentrus	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	1	8	-	6	4	-	27	-	1	-	-	-	-
Lepidostoma	2	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Limnephilidae	1	-	-	3	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neothremma	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligophebodes	3	-	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Imania	2	3	2	1	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ecclisomyia	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera																																
Pericoma	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tendipedidae	9	8	2	2	2	8	5	8	-	1	-	-	4	3	7	1	-	-	-	-	5	-	5	-	1	2	2	-	3	1	1	1
Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-	32	19	20	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Collembola	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbellaria	2	2	-	1	14	27	48	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracoda	1	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acari	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-
Total	36	37	16	35	25	35	62	35	0	2	0	1	255	131	125	82	1	0	0	1	15	2	14	6	1	30	4	1	3	1	2	1

TABLE 13. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON NOVEMBER 3, 1973. Hyphens indicate zero counts.

Station	1				2				4				5	6				7				8			
Sampler	1	2	3	4	1	2	3	4	1	2	3	4	1	1	2	3	4	1	2	3	4	1	2	3	4
Taxa																									
Ephemeroptera																									
Ephemerella	-	-	-	-	-	-	-	-	6	1	8	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Epeorus	-	-	-	-	-	-	-	-	1	6	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	-	-	-	-	-	-	-	-	2	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	-	-	-	-	-	-	-	-	5	7	6	5	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis	-	-	3	1	1	-	-	-	76	21	41	44	-	1	-	-	-	-	-	-	-	1	-	-	-
Centroptilum	-	1	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Plecoptera																									
Brachyptera	-	-	-	-	-	-	-	-	5	2	2	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	-	-	1	-	6	2	6	8	17	10	20	14	-	-	-	-	-	-	-	-	-	-	-	-	-
Capniinae	-	4	9	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Acroneuria	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcynopteryx	-	-	-	1	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoperla	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	1	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-
Trichoptera																									
Parapsyche	-	-	-	-	-	-	-	1	3	2	7	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Arctopsyche	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	-	-	-	4	5	13	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	1	1	-	-	-	2	-	3	5	-	2	-	-	-	-	-	-
Lepidostoma	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
Oligophebodes	7	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diptera																									
Antocha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Tendipedidae	-	2	2	1	3	1	1	1	10	6	12	28	-	-	-	-	-	-	-	-	-	-	1	-	-
Simuliidae	-	-	-	-	-	-	-	-	11	14	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-
Empididae	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Collembola	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Acari	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	7	8	21	7	10	4	7	10	152	79	115	116	0	4	2	3	7	0	2	1	2	1	1	1	0

TABLE 14. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON THE DRY FORK OF BELT CREEK ON DECEMBER 14, 1973. Hypens indicate zero counts.

Station	4				6				7	
Sampler	1	2	3	4	1	2	3	4	1	2
Taxa										
Ephemeroptera										
Ephemerella	1	-	1	-	-	-	-	-	-	-
Epeorus	1	4	4	1	-	-	-	-	-	-
Rhithrogena	2	2	4	4	-	-	-	-	-	-
Cinygmula	5	10	7	9	-	-	-	-	-	-
Baetis	67	94	67	21	-	4	-	-	-	1
Plecoptera										
Brachyptera	5	4	3	2	-	-	-	-	-	-
Nemoura	13	10	6	1	-	-	-	-	-	-
Capniinae	-	1	2	-	-	-	-	-	-	-
Acroneuria	-	-	1	-	-	-	-	-	-	-
Arcynopteryx	-	1	3	1	-	-	-	-	-	-
Isogenus	1	1	-	-	-	-	-	-	-	-
Isoperla	-	1	-	-	-	-	-	-	-	-
Alloperla	-	-	-	-	-	-	-	2	-	-
Trichoptera										
Parapsyche	2	-	2	2	-	-	-	-	-	-
Rhyacophila	2	1	3	-	-	-	-	-	-	-
Brachycentrus	-	-	-	-	-	1	1	1	-	-
Lepidostoma	2	-	2	2	-	-	-	-	-	-
Diptera										
Tendipedidae	7	7	4	-	1	3	4	2	-	-
Simuliidae	-	-	2	-	-	-	-	-	-	-
Total	108	136	111	43	1	8	5	5	0	1

TABLE 15. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8) ON JANUARY 16, 1974 AND MAY 17, 1974. Hyphens indicate zero counts.

Date	1/16/74				5/17/74																			
Station	4				3				4		5				6				7				8	
Sampler	1	2	3	4	1	2	3	4	1	2	1	2	3	4	1	2	3	4	1	2	3	4	1	2
<u>Taxa</u>																								
Ephemeroptera																								
Ephemerella	4	1	3	2	-	-	-	-	9	4	-	1	-	1	-	-	-	-	-	-	-	-	-	-
Epeorus	-	3	4	2	-	-	-	-	37	12	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena	2	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cinygmula	1	2	1	3	-	-	-	-	3	1	-	1	-	2	-	-	-	-	-	-	-	-	-	-
Baetis	21	80	51	41	-	-	-	-	9	3	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Plecoptera																								
Brachyptera	1	9	5	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nemoura	3	6	2	1	1	-	-	-	1	2	-	-	-	2	-	-	1	-	-	-	1	-	-	-
Acroneuria	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arcynopteryx	3	3	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isogenus	-	-	-	1	-	-	-	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Isoperla	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Paraperlinae	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alloperla	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Trichoptera																								
Parapsyche	2	3	1	-	-	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Rhyacophila	1	3	2	2	-	1	1	-	3	-	-	-	-	1	-	-	-	1	1	-	-	-	-	-
Brachycentrus	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	1	1	3	3	-	4
Lepidostoma	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Diptera																								
Tendipedidae	2	3	4	-	3	4	1	5	13	18	1	1	-	8	2	9	14	19	2	2	14	11	2	12
Simuliidae	-	2	-	-	-	-	-	-	3	21	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Atherix	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Collembola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	1
Ostracoda	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Total	40	117	76	59	5	5	2	6	81	61	1	5	1	20	4	11	15	21	4	3	19	14	2	19

TABLE 16. NUMBERS AND TAXA OF BENTHIC MACRO-INVERTEBRATES OBTAINED FROM EACH 0.2 M^2 SAMPLER RECOVERED AT STATIONS ON BELT CREEK. Hyphens indicate zero counts.

Date	8/4/73				9/6/73				10/7/73				11/3/73			
Station	9		10		9		10		9		10		9		10	
Sampler	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Taxa																
Ephemeroptera																
Epeorus	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-
Baetis	56	29	8	68	16	54	4	-	11	117	9	31	11	6	-	15
Plecoptera																
Pteronarcella	3	7	-	-	1	3	-	-	-	1	-	1	-	-	-	-
Nemoura	-	-	-	-	-	4	-	2	1	-	1	-	1	-	-	-
Capniinae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Acroneuria	-	2	-	-	1	2	-	1	-	1	-	-	-	-	-	-
Arcynopteryx	-	-	-	-	1	-	3	4	2	3	1	2	-	-	-	-
Isogenus	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
Isoperla	-	-	-	-	-	1	-	-	1	-	-	1	-	-	-	1
Alloperla	-	1	-	2	-	-	-	-	-	-	-	1	-	-	-	-
Coleoptera	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Dytiscidae	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Elmidae	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Curculionidae	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
Trichoptera																
Arctopsyche	-	10	2	9	13	38	41	15	1	4	-	1	1	-	-	-
Hydroptilidae	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	1	-	-	-	4	-	-	-	-	-	-
Agapetus	-	-	-	-	-	-	-	1	-	-	2	-	-	-	1	-
Brachycentrus	20	200	76	185	156	130	59	24	28	42	6	38	2	3	-	4
Lepidostoma	109	4	32	31	102	17	76	71	175	12	290	96	3	5	2	10
Limnephilidae	-	-	-	-	-	1	1	2	-	-	-	-	-	-	-	-
Diptera																
Antocha	-	-	-	-	-	-	1	-	5	3	1	1	1	-	-	-
Tendipedidae	3	22	7	12	5	7	27	4	11	25	3	31	1	2	-	-
Simuliidae	12	1042	26	136	-	42	1	-	-	3	-	2	-	-	-	-
Atherix	6	3	3	1	3	2	-	-	-	-	1	1	-	-	-	-
Empididae	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Nemata (Nematoda)	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Total	210	1320	154	444	299	305	214	124	235	217	315	206	22	20	3	31

TABLE 17. THE CHLORIDE (Cl), POTASSIUM (K), AND SODIUM (Na) CONCENTRATIONS IN MG/1 OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date														
	6/6/73			7/5/73			8/5/73			9/7/73			10/8/73		
Station	Cl	K	Na	Cl	K	Na	Cl	K	Na	Cl	K	Na	Cl	K	Na
1	--	0.5	3.5	1.7	0.4	3.0	0.8	0.6	3.0	0.5	0.4	2.9	0.8	0.5	3.3
2	0.5	0.6	3.0	0.4	0.6	3.5	0.3	0.7	3.1	0.5	0.4	2.9	0.6	0.7	3.2
3	0.6	0.5	2.4	0.4	0.6	3.2	0.8	0.7	3.2	0.7	0.4	3.3	0.6	0.6	3.8
4	1.1	0.6	1.6	0.8	0.6	1.9	0.4	0.7	1.8	0.4	0.6	1.7	0.6	0.4	1.7
5	1.3	0.6	1.8	0.4	0.6	1.8	0.4	0.9	2.1	0.5	0.5	1.9	0.6	0.6	2.3
6	0.5	0.6	1.8	0.5	0.6	1.9	0.8	0.9	2.1	0.5	0.6	1.9	0.6	0.6	2.1
7	0.7	0.5	1.8	0.5	0.6	1.8	0.3	0.9	2.0	0.5	0.6	1.9	0.6	0.9	2.1
8	0.6	0.5	2.0	0.6	0.6	1.8	0.8	0.9	2.0	0.4	0.6	1.9	0.7	0.6	2.1
	11/4/73			12/14/73			1/16/74			4/5/74			5/16/74		
1	0.4	0.4	3.7	--	--	--	--	--	--	--	--	--	--	--	--
2	0.7	0.5	3.6	--	--	--	--	--	--	--	--	--	--	--	--
3	0.8	0.6	4.0	1.0	0.5	4.0	0.4	0.6	3.3	0.5	1.0	3.2	0.4	0.5	2.9
4	0.5	0.5	1.8	0.7	0.6	1.8	0.2	0.6	1.8	0.6	0.7	1.8	0.4	0.6	2.0
5	0.9	0.5	2.8	0.5	0.5	2.5	0.3	0.5	2.5	0.8	0.9	2.2	0.3	0.6	2.3
6	0.4	0.6	2.7	0.4	0.6	2.3	0.2	0.6	2.1	0.7	0.7	2.0	0.3	0.6	2.1
7	0.6	0.5	2.5	0.8	0.7	2.1	0.4	0.5	2.0	0.4	0.7	2.0	0.4	0.6	2.2
8	0.5	0.6	2.5	--	--	--	--	0.7	2.1	0.6	0.7	1.9	0.4	0.6	2.0

TABLE 18. THE TOTAL ALKALINITY (T A), AS $CaCO_3$, IN MG/1 AND THE SPECIFIC CONDUCTANCE (Cond.) IN µmhos/cm AT 25° C OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date									
	6/6/73		7/5/73		8/5/73		9/7/73		10/8/73	
Station	T A	Cond.	T A	Cond.	T A	Cond.	T A	Cond.	T A	Cond.
1	--	--	62.0	214.5	88.5	299.5	92.5	302.6	96.0	297.2
2	16.0	332.2	43.5	307.1	64.5	355.3	57.5	362.0	90.0	306.4
3	19.0	304.5	12.5	392.2	15.0	496.0	10.5	429.5	25.5	455.9
4	57.5	152.2	70.0	148.5	94.0	201.4	92.0	181.1	94.5	170.4
5	51.5	193.8	64.0	200.7	83.5	277.0	82.0	248.3	80.5	272.3
6	47.0	193.8	74.0	212.6	97.0	287.8	92.0	263.8	96.0	269.4
7	57.5	193.8	82.0	225.7	105.0	305.1	102.5	285.2	109.5	278.8
8	58.0	207.6	80.0	221.8	110.5	299.5	100.0	266.4	108.0	284.0
	11/4/73		12/14/73		1/16/74		4/5/74		5/16/74	
1	100.5	302.4	--	--	--	--	--	--	--	--
2	53.0	372.0	--	--	--	--	--	--	--	--
3	17.5	502.1	24.5	470.3	30.0	379.6	17.5	457.2	13.0	326.0
4	107.0	219.4	98.0	208.4	93.0	183.6	103.0	225.4	70.5	150.5
5	73.5	316.8	79.0	295.5	66.5	271.5	69.5	343.7	56.5	192.3
6	96.0	303.4	98.0	312.3	81.0	247.4	84.0	324.3	62.5	198.3
7	116.0	307.9	112.0	311.9	89.5	259.8	100.0	322.8	73.5	206.9
8	103.5	313.5	--	--	--	--	99.5	315.8	72.0	209.1

TABLE 19. THE TOTAL HARDNESS (T H) AND CALCIUM HARDNESS (C H), AS $CaCO_3$, IN MG/1 OF WATER SAMPLES TAKEN FROM STATIONS ON GALENA CREEK (1-3) AND THE DRY FORK OF BELT CREEK (4-8).

	Date									
	6/6/73		7/5/73		8/5/73		9/7/73		10/8/73	
Station	T H	C H	T H	C H	T H	C H	T H	C H	T H	C H
1	--	--	92.0	59.2	126.8	76.4	141.4	77.4	146.0	98.6
2	98.4	62.6	119.0	79.4	148.0	120.6	168.0	113.6	161.0	117.0
3	93.2	55.0	161.0	94.0	199.8	117.2	196.4	115.8	201.1	126.4
4	54.4	38.6	66.0	46.4	90.0	64.6	92.2	76.4	96.0	71.8
5	63.6	42.4	100.6	57.0	117.0	77.0	118.8	78.6	130.8	85.2
6	64.0	44.4	94.0	63.6	124.8	88.0	127.0	89.6	136.0	97.0
7	69.8	48.6	100.4	70.0	132.8	94.4	134.6	100.0	146.0	109.2
8	68.4	48.6	96.6	68.0	134.8	98.0	133.6	99.6	146.8	105.2
	11/4/73		12/14/73		1/16/74		4/5/74		5/16/74	
1	135.8	101.4	--	--	--	--	--	--	--	--
2	159.2	114.4	--	--	--	--	--	--	--	--
3	233.4	126.2	211.4	120.8	180.0	102.0	198.6	108.8	136.0	81.2
4	106.0	83.4	98.0	74.0	97.2	71.6	109.8	84.0	73.8	62.6
5	154.0	97.4	137.4	87.2	135.6	88.0	154.2	97.0	90.6	57.6
6	159.2	117.0	147.2	103.0	131.2	91.2	150.0	105.6	93.8	64.8
7	154.0	125.8	156.8	115.0	132.0	95.4	153.2	114.0	101.6	71.0
8	190.0	148.0	--	--	--	--	145.0	106.4	100.0	72.4

TABLE 20. SELECTED PHYSICAL-CHEMICAL DETERMINATIONS MADE AT BELT CREEK STATIONS ON NOVEMBER 4, 1973.

Determination	Units	Station 9	Station 10
pH	--	8.10	7.99
Specific Conductance	µmhos/cm at 25° C	204.1	211.7
Total Alkalinity	mg/l as $CaCO_3$	89.0	88.5
Total Hardness	mg/l as $CaCO_3$	99.4	102.2
Calcium Hardness	mg/l as $CaCO_3$	76.0	74.8
Calcium	mg/l	30.4	29.9
Magnesium	mg/l	5.7	6.7
Sodium	mg/l	2.4	2.5

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