ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC AND YUKON REGION

BENTHIC INVERTEBRATE DATA COLLECTED BY THE ENVIRONMENTAL PROTECTION SERVICE JULY 1982 AND 1983 RELATIVE TO EQUITY SILVER MINE, HOUSTON, B.C.

86-06

Regional Program Report No. 86-06

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JANUARY, 1986

ABSTRACT

Benthic invertebrate samples were collected from three creeks associated with the Equity Mine property. One creek reflected a community subjected to acid mine drainage (low pH, high metal content) and/or sedimentation stress. The two other creeks didn't indicate any obvious impact due to the mine.

RÉSUMÉ

Des échantillons d'invertébrés benthiques ont été obtenus à partir de trois ruisseaux adjacents à la propriété de la mine Equity. Un des ruisseaux montra une communauté assujetti au drainage minier acide (faible pH, contenu métallique élevé et/ou au stress de sedimentation. Les deux autres ruisseaux n'ont pas indiqués d'impact évidents due à la mine.

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SUMMARY

The benthic invertebrate composition for Bessemer Creek in 1982 and 1983, compared to 1973, reflected a community subjected to acid mine drainage (low pH, high metal content) and/or sedimentation stress. The results for Foxy Creek upstream and downstream of the mine site and Buck Creek upstream and downstream (at least during high spring runoff) of Bessemer Creek did not indicate any obvious impact due to the mine operation. Without species specific information on the tolerance of various aquatic insects to low pH and metal toxicity (primarily copper and zinc), benthic invertebrates can only be expected to indicate major impacts. The differences between stations in terms of abiotic conditions (flow, substrate particle size and sediment detritus content) should be given more attention in invertebrate programs of this nature.

1. INTRODUCTION

Equity Silver Mines is located approximately 33 km southeast of Houston, B.C. (Figure 1). The mine began production in September 1980. In November 1981 it was determined that waste rock at the mine site was generating acid and acid mine drainage was entering Bessemer Creek. The company constructed a temporary acid mine drainage collection system in Spring 1982 and has continued to make improvements to the collection and treatment system since then.

The Environmental Protection Service (EPS) collected pre-mine operation benthic invertebrate samples from streams adjacent to the proposed Equity Mine site in July, 1973 (Hallam and Kussat 1974). EPS conducted post-mine operation benthic invertebrate surveys in July 1982 and July 1983. This report presents the data collected in July 1982 and July 1983 and comparisons are made to the July 1973 data. Water quality data collected on the July 1982 and 1983 surveys has been reported on by Derksen et al 1985.

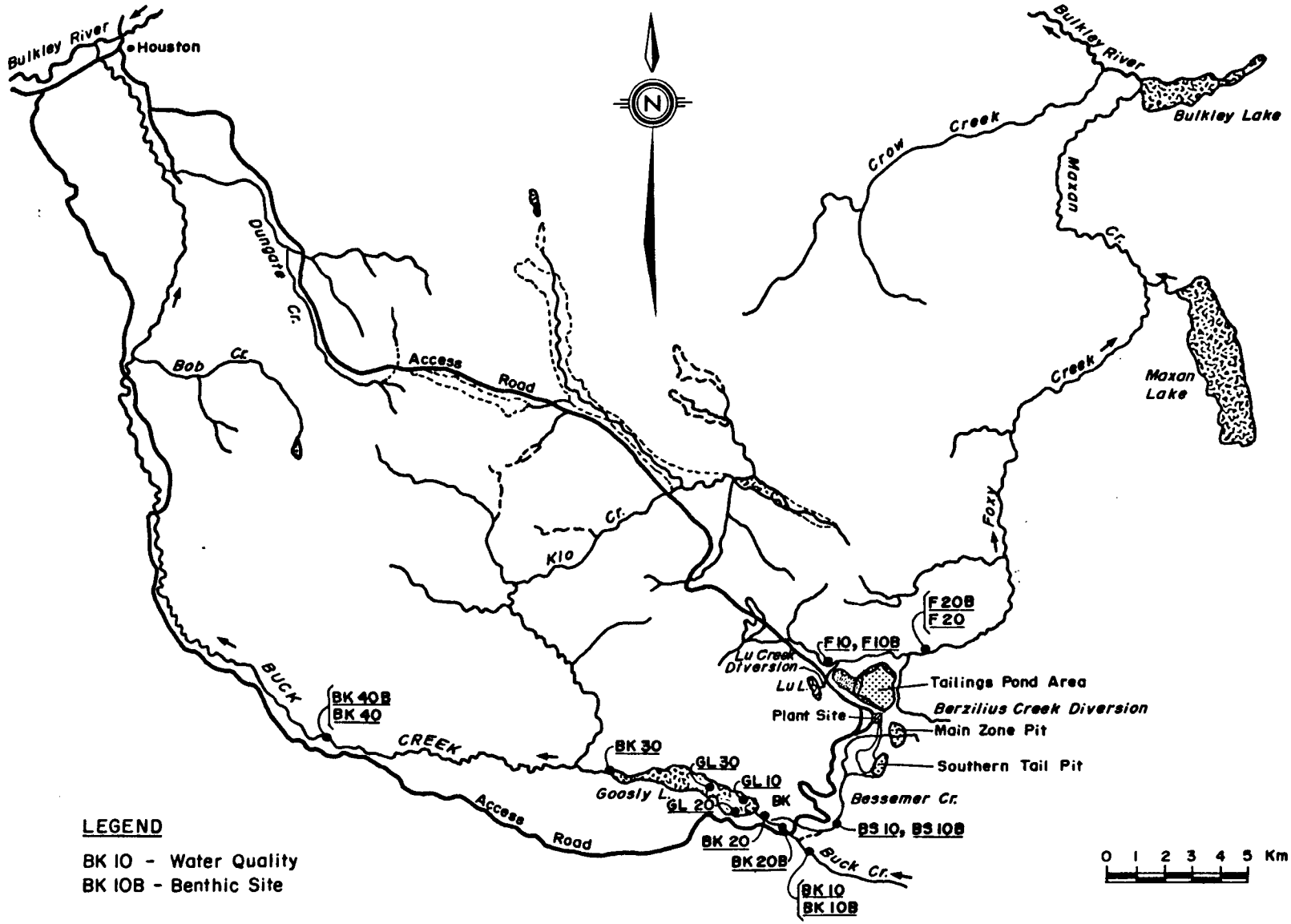

FIGURE 1 EQUITY SILVER MINE - EPS WATER QUALITY AND BENTHIC INVERTEBRATE MONITORING STATIONS

2. DESCRIPTION OF STUDY AREA

The Equity Mine site is centered on the Foxy Creek and Bessemer Creek watersheds. Foxy Creek is a tributary of Maxan Creek which flows into Bulkley Lake. Bessemer Creek is a tributary of Buck Creek upstream of Goosly Lake. Buck Creek downstream of Goosly Lake flows into the Bulkley River at Houston (Figure 1).

Six creek stations were sampled during the 1982 and 1983 surveys. The sample stations are described in Table 1 and are shown in Figure 1.

Buck creek station BK20-B during 1982 and 1983 was considered to be downstream of Bessemer Creek. However, Bustard 1984 reported that this station location was actually upstream of Bessemer Creek. During high runoff periods in the spring Bessemer Creek is thought to enter Buck Creek upstream of site BK20-B.

3. MATERIALS AND METHODS

At each station, creek velocity was measured with a Mead Model HP-302 velocity meter.

Three benthic invertebrate samples were collected at each site using a modified Hess circular sampler (0.093 m^2) with a 351 um Nitex cloth. The samples were preseved with 70% ethyl alcohol. Although not reported by Hallam and Kussat 1974, their 1973 samples were also collected with a circular sampler with a 351 um Nitex net. A Wild M20 microscope was used for identification.

TABLE 1 DESCRIPTION OF EPS BENTHIC INVERTEBRATE SAMPLE LOCATIONS - July 14, 1973; July 21/22, 1982; July 18/19, 1983

STATION		LOCATION	VELOCITY (cm/s)			SUBSTRATE		
1982, 1983	1973	1982, 1983	1982	1983	1973	1982	1983	1973
Foxy Creek								
F10-B	2	- approx. 40 m u/s of Lu Cr. confluence - south side of midstream, 1.5 m from S. side - 1973 likely a comparable site	[3-67]	15 [3-24]	-	- jagged rocks, large aggregate	-	- large aggregate bottom substrate interdispersed with sandy patches
F20-B	-	- approx. 40 m d/s of lowest possible drainage from Berzilius Cr. - approx. 300 m d/s of main Berzilius Cr. input - mid stream, 1.5 m from S. side - 1973 no comparable site	[52-122]	- [3-67]	-	- jagged rocks, large aggregate	- large pebble aggregate	-
Bessemer Creek								
BS10-B	9	- lower Bessemer Cr. u/s of Buck Cr. confluence - midstream - 1973 likely a comparable site	15	40	-	- small to medium aggregate interdispersed with sand	- small pebble aggregate, sand/gravel below aggregate	- large aggregate bottom substrate interdispersed with sandy patches

CONTINUED...

TABLE 1 (Continued)

STATION		LOCATION	VELOCITY (cmis)			SUBSTRATE		
1982, 1983	1973	1982, 1983	1982	1983	1973	1982	1983	1973
Buck Creek								
BK10-B	10	- u/s of Bessemer Cr. approx. 540 m u/s of the road bridge - 1 m from S. side 1973 - comparable site	[3-37]	3 [3-27]	-	- small to medium aggregate inter-dispersed with sand	- small to medium sized pebble aggregate, sand/ gravel underlay	- large aggregate bottom substrate interdispersed with sandy patches
BK20-B	-	- approx. 2 km u/s of Goosly L. inlet, and d/s of the road bridge - 1.2 m from N. side - 1973 no comparable site	[12-49]	55 [1.5-73]	-	- medium aggregate	- small to medium sized pebble aggregate, sand/ gravel underlay	
BK40-B	11	- at Ferris Property, approx. 11 km d/s of Goosly L. outlet - 2 m from S. side - 1973 was not at same site and was approx. 1 km d/s of Goosly Lake outlet	[27-70]	37 [3-131]	-	- medium aggregate	- sandy gravel substrate	- as above

[ ] = range across creek channel, otherwise velocity at point samples collected

4. RESULTS AND DISCUSSION

4.1 Aquatic Insects as Indicators of Stressed Receiving Waters

Basically, three components (pH, heavy metals and sediment) of the Equity mine operation, if not controlled, could be expected to influence benthic invertebrate community structure.

Field studies on the affects of acid mine drainage (low pH) on benthic invertebrates have generally indicated that as a group, Ephemeroptera and Plecoptera are less tolerant of low pH conditions (pH < 4.5) then Trichoptera or Diptera (Tomkiewiez and Dunson 1977, Warner 1971, Weed and Rutschky 1972, Roback and Richardson 1969). Certainly, even within these groups different species have different tolerances to low pH (Bell 1971, Bell and Nebeker 1969, Gaufin 1973) (Appendix Ia).

It is generally recognized that stoneflies (Plecoptera), mayflies (Ephemeroptera) and caddisflies (Trichoptera) represent a group that is quite sensitive to environmental change. Such organisms have complex appendages and external respiratory structures which must be kept free from particulate matter in the stream (Weed and Rutschky 1972). NCASI 1984, summarizing the work of others, reported that sediments can have a major influence on benthic species composition as well as microdistribution. In one example, cobble that was completely embedded with fine sand was proven to be unacceptable to most species. In another case, it was reported that increased sedimentation of a sand/silt/clay mixture caused a negative response and all species preferred unsedimented over heavily sedimented substrates. High levels of sediment appeared to form a surface seal preventing non-burrowing insects from gaining access to the underside of cobbles. China-clay deposition was reported to result in the elimination of several sensitive species and typical river fauna were replaced by burrowing or tube-building forms of macroinvertebrates including chironomidae (midges). Benthic invertebrate communities will respond differently, depending on the degree of sedimentation and the nature of the sediment.

Winner et al 1980 reported that insect community structure exhibits a predictable, graded response to heavy metal pollution. In heavily

stressed sections, macroinvertebrates other than tubificid worms and chironomids were virtually eliminated from rock-rubble, riffle habitats. Mayflies occured only at the least polluted stations. They hypothesized that heavily polluted habitats are dominated by midges, moderately polluted habitats by midges and caddisflies and minimally polluted or unpolluted habitats by caddisflies and mayflies. Nehring 1976 reported that the insects he tested (mayfly, stonefly) were more tolerant of heavy metals than most fish but that they concentrated the metals in relative proportion to the occurrence of metals in the stream. The tolerance of various benthic insects to metal levels (Cu, Zn) is not as well documented as for fish and is quite variable (Spear 1981, Spear and Pierce 1979, Gauss et al 1985, Nehring 1976) (Appendix Ib).

4.2 Bessemer Creek, Foxy Creek and Buck Creek Invertebrates

The detailed benthic invertebrate analysis for each creek is reported in Appendix II(a-c). Hallam and Kussat 1974 reported their results as the combined count of three samples and identifications were generally taken to the family level. For comparative purposes the 1982 and 1983 data have been reduced to a similar level (Appendix IIIa and b).

Ephemeroptera and Plecoptera, Trichoptera and Diptera as groups appear to generally indicate the affects of acid mine drainage (low pH and or high metal content) or sedimentation stressed streams. As such, the 1982 and 1983 results have been compared to the 1973 results at the order level of identification. Without specific information on the sensitivity of individual species or genera to low pH or metal concentrations, identification difficulties to determine species, sampling variability in obtaining density estimates, and lack of measurement of abiotic features (sediment particle size, velocity, organic/detritus content etc.) it is difficult to assess anything more than the obvious affects. Indeed, many of those requirements can only be fulfilled in highly controlled research studies.

Of the stations sampled by EPS in 1982 and 1983, only Bessemer Creek has been both continuously exposed to mine effluents and has a

historical data base to compare to. The Foxy Creek control site area (1982, 1983) was monitored in 1973 but there hasn't been any activity upstream of that area from which to evaluate an impact. Treated acid mine drainage was not discharged to the Foxy Creek system until 1984. Thus, the lower Foxy Creek benthic site results primarily form a data base for possible future assessments. Any differences between the two Foxy stations may or may not reflect the impact of the Equity development (construction, creek diversions, flow changes etc.) up to 1983. For Buck Creek, the control site area was sampled in 1973 but the downstream site was not. There is also some question as to the extent of exposure to mine discharge (Bessemer Creek) at the downstream Buck Creek site. This and the low gradient nature (beaver dams) of Buck Creek makes assessing station differences and the impact of the mine difficult.

The effect of the mine operation on the benthic invertebrates community of Bessemer Creek can be seen in Table 2. The reduction and/or elimination of Ephemeroptera and Plecoptera in 1982 plus a reduced Diptera fauna in 1982 reflect the acid conditions of the mine discharge (low pH, high metal content) plus any sedimentation affects (Table 3). In 1983, there were no Ephemeroptera or Plecoptera but the Diptera density was comparable to 1973. While the pH levels in 1983 were not low (pH > 6.15) and extreme heavy metal levels were not detected, the habitat was unsuitable for Ephemeroptera and Plecoptera. Subsequent to the 1982/83 benthic studies, the mines silt check dam was relocated to the area of benthic sampling.

For the two control areas, which were sampled in 1973, Foxy Creek station F10-B and Buck Creek station BK10-B, the results were not unlike the 1973 results (Table 2). There were more Ephemeroptera recorded in 1982 and 1983 at both sites. Results for Foxy Creek upstream and downstream of the mine operation and Buck Creek upstream and downstream (at least during high runoff) of Bessemer Creek are shown in Table 4. There is nothing in the results to suggest any obvious impact from the mine on the invertebrate community.

TABLE 2 DENSITY AND PERCENT COMPOSITION OF SOME MAJOR INVERTEBRATE ORDERS FOR 1973, 1982 AND 1983

DENSITY (#/m^2)									
GROUP (Order)	FOXY CREEK			BESSEMER CREEK			BUCK CREEK		
Station:	1973 (2)	1982 (F10-B)	1983 (F10-B)	1973 (9)	1982 (BS10-B)	1983 (BS10-B)	1973 (10)	1982 (BK10-B)	1983 (BK10-B)
Ephemeroptera	179	348	883	200	4	0	86	568	286
(F)	(2)	(5)	(5)	(3)	(1)	(0)	(2)	(5)	(5)
Plecoptera	62	180	218	18	0	0	64	45	44
(F)	(3)	(3)	(4)	(2)	(0)	(0)	(1)	(3)	(2)
Trichoptera	62	15	18	0	0	0	0	4	0
(F)	(3)	(2)	(1)	(0)	(0)	(0)	(0)	(1)	(0)
Diptera	694	514	811	144	11	176	343	660	304
(F)	(5)	(5)	(5)	(2)	(2)	(1)	(4)	(3)	(2)
TOTAL SAMPLE	1174	1093	2084	469	15	242	695	1886	920

PERCENT COMPOSITION									
GROUP (Order)	FOXY CREEK			BESSEMER CREEK			BUCK CREEK		
	1973	1982	1983	1973	1982	1983	1973	1982	1983
Ephemeroptera	15	32	42	43	27	0	12	30	31
Plecoptera	5	17	10	4	0	0	9	2	5
Trichoptera	5	1	1	0	0	0	0	< 1	0
Diptera	59	47	39	31	73	73	49	35	33
Combined % of Total Sample	84	97	92	78	100	73	70	68	69

(F) = Number of families, total sample from Appendix III(b)

TABLE 3 SUMMARY OF WMB WATER QUALITY DATA FOR 1982 AND 1983 - LOWER BESSEMER CREEK (0700081) AND UPPER SILT CHECK (0400762)

0700081*											
1982						1983					
TIME PERIOD	pH	d Cu (mg/l)		d Zn (mg/l)		TIME PERIOD	pH	d Cu (mg/l)		d Zn (mg/l)	
		$\bar{x}$	range	$\bar{x}$	range			$\bar{x}$	range	$\bar{x}$	range
WMB											
Apr. 20 - Jun. 15	3.4-5.3		.07 - 7.8		.05 - 4.53	Jan. 4 - Jul. 26	6.15 - 7.75	.057	.003 - .32	.162	.022 - .53
n =	4		5		5		29		29		29

0400762* 1982					
TIME PERIOD	pH	d Cu (mg/l)		d Zn (mg/l)	
		$\bar{x}$	range	$\bar{x}$	range
Jan. 18 - May 11	2.9 - 5.2	6.7	1.63 - 30.1	4.8	2 - 18
n =	16		14		15

* Waste Management Branch data on file at EPS

TABLE 4 MEAN DENSITY AND PERCENT COMPOSITION OF MAJOR INVERTEBRATE ORDERS FOR 1982 AND 1983 - FOXY CREEK AND BUCK CREEK

MEAN DENSITY (#/m^2)								
	FOXY CREEK				BUCK CREEK			
	1982		1983		1982		1983	
	F10-B	F20-B	F10-B	F20-B	BK10-B	BK20-B	BK10-B	BK20-B
Ephemeroptera	348 198-499	99 4-194	883 75-1692	374 - to 923	568 197-939	264 - to 549	286 - to 669	81 - to 313
Plecoptera	180 13-347	73 - to 202	220 - to 528	103 - to 213	44 - to 91	84 - to 172	44 - to 91	15 - to 30
Trichoptera	15 -* to 30	- -	54 - to 626	18 - to 175	242 - to 485	4 - to 19	- -	- -
Diptera	513 259-767	114 - to 346	810 247-1373	297 - to 607	660 489-831	1342 165-2518	304 17-591	441 - to 1514
SAMPLE TOTAL 95% LIMITS	1089 994-1184	348 151-546	2086 424-3748	1129 91-2168	1876 1150-2600	2082 935-3230	920 370-1470	547 - to 1884

PERCENT COMPOSITION								
	FOXY CREEK				BUCK CREEK			
	1982		1983		1982		1983	
	F10-B	F20-B	F10-B	F20-B	BK10-B	BK20-B	BK10-B	BK20-B
Ephemeroptera	32	28	42	33	30	13	31	15
(F)	(5)	(5)	(5)	(4)	(5)	(5)	(5)	(2)
Plecoptera	17	21	11	9	2	6	5	3
(F)	(3)	(3)	(4)	(3)	(3)	(3)	(2)	(1)
Trichoptera	1	-	3	2	13	1	-	-
(F)	(2)	(0)	(1)	(2)	(1)	(1)	(0)	(0)
Diptera	47	33	39	26	35	64	33	81
(F)	(5)	(4)	(5)	(4)	(3)	(5)	(2)	(2)
COMBINED % OF TOTAL SAMPLE	97	82	95	70	80	84	69	99

(F) = Number of Families
-* = negative value for 95% limits

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ACKNOWLEDGEMENTS

The invertebrate samples were identified by Mr. John Keays, Powell River, B.C. Thanks are extended to Mr. B. Kelso for reviewing this report.

APPENDIX I(a) SUMMARY OF INVERTEBRATE TOXICITY DATA - pH

INVERTEBRATE GROUP	$\bar{x}$ 96-h LC_{50}		LC_{50}				50 % EMERGENCE SUCCESS
	$\bar{x}$	single	30-d	48-d	68-d	90-d	
Stoneflies (Plecoptera)							
Taeniopteryx maura	3.25		3.71				5.0
Acroneuria lycorias	3.32		3.85				5.0
Acroneuria parallela	5.33						
Acroneuria pacifica						5.8	
Isogenus frontalis	3.68		4.50				6.6
Isogenus aestivalis	5.15						
Pteronarcys dorsata	4.25		5.00				5.8
Pteronarcys californica	4.60					4.95	
Pteronarcella badia	4.37					4.52	
Mayflies (Ephemeroptera)							
Stenonema rubium	3.32						
Ephemerella subvaria	4.65		5.38				5.9
Ephemerella doddsi	5.13						
Ephemerella grandis				5.8			
Leptophlebia sp.	5.21						
Hexagenia limbata	5.90						
Cinygmula par	6.04						
Rithrogena robusta	6.35						
Heptagenia sp.	6.18						
Caddisflies (Trichoptera)							
Brachycentrus americanus	1.5		2.45				4.0
Hydropsyche betteni	3.15		3.38				4.7
Hydropsyche sp.	3.34						
Limnephilus ornatus	2.83						
Brachycentrus occidentalis						4.3	
Cheumatopsyche sp.						4.52	
Dragonflies (Odonata)							
Ophiogomphus rupinsulensis	3.5		4.30				5.2
Boyeria vinosa	3.25		4.42				5.2
Trueflies (Diptera)							
Simulium vittatum	3.64						
Atherix variegata					4.2		

(summarized from Gaufin 1973, Bell 1971 and Bell and Nebaker 1969)

APPENDIX I(b) SUMMARY OF INVERTEBRATE TOXICITY DATA - Copper and Zinc

INVERTEBRATE GROUP	LC_{50}** (mg/l)		REFERENCE
	Cu	Zn	
Stoneflies			
Pteronarcys californica	10.1-13.9 (96-h)	> 13.9 (96-h)	Nehring 1976
Acroneuria lycorias		32 (14-d)	Spear 1981
Acroneuria lycorias	8.3 (96-h)		Spear and Pierce 1979
Mayflies			
Ephemerella grandis	.18-.20 (96-h)	> 9.2 (96-h)	Nehring 1976
Ephemerella subvaria		16 (10-d)	Spear 1981
Ephemerella subvaria	.32 (96-h)		
Caddisflies			
Hydropsyche betteni	-	32 (11-d)	Spear 1981
	96-h EC_{50}* (ug/l)		
Dipteran			
Chironomus tentans			Gauss et al 1985
1st instar (soft water)	16.7	-	
(medium water)	36.5	-	
(hard water)	98.2	-	
4th instar (soft water)	211	-	
(medium water)	977	-	
(hard water)	1184	-	

*effective concentration when 50% of organisms immobilized
**lethal concentration to 50% of organisms (h = hour, d = day)

APPENDIX II(a) DETAILED BENTHIC INVERTEBRATE COMPOSITION FOR FOXY CREEK (#/m^2)

Class / Order / Family / Genera	1982						1983					
	F10-B			F20-B			F10-B			F20-B		
	1	2	3	1	2	3	1	2	3	1	2	3
Phylum Invertebrata												
Insecta												
UID (larvae)												
COLEOPTERA												
Dytiscidae												
Agabus												
Coptotomus												
Hydroporus												
Staphylinidae				0	0	11						
Elmidae												
Heterlimnius	11	11	11	0	0	11	11	11	110	110	110	77
COLLEMBOLLA	0	0	11									
Smynthuridae	11	11	11									
EPHEMEROPTERA												
Baetidae												
Baetis				22	11	22						
Baetis bi-tricaudatus	0	0	22				11	11	0	33	396	231
Ephemerellidae							11	0	33	121	132	33
Ephemerella	0	11	22	11	0	0						
Ephemerella coloradensis	11	0	22									
Ephemerella doddsi				0	11	0						
Ephemerella inermis-infrequens	0	22	33									
Drunella												
Serratella tibialis							110	55	11	11	0	0
Heptageniidae	22	11	33				0	33	11	11	22	11
Cinygmula	55	66	143	11	33	22	77	187	209	0	11	0
Epeorus (Iron)	0	0	11							11	11	0
Leptophlebiidae												
Paraleptophlebia debilis												
Paraleptophlebia temporalis	66	44	44	22	0	0	132	363	506			
Siphlonuridae												
Ameletus	198	132	77	44	66	11	209	253	429	33	55	0
Siphlonurus				11	0	0						

CONTINUED...

APPENDIX II(a) (Continued)

Class / Order / Family / Genera	1982						1983					
	F10-B			F20-B			F10-B			F20-B		
	1	2	3	1	2	3	1	2	3	1	2	3
PLECOPTERA												
UID (larvae)	0	11	0									
Chloroperlidae	11	0	0	0	22	11	22	11	22	11	22	11
Sweltsa	121	66	77	22	88	44	77	66	297	33	99	66
Nemouridae	11	22	11									
Visoka cataractae	0	22	55	11	0	0	11	22	0			
Zapada	11	0	66				44	11	22	22	33	0
Amphinemura												
Perlidae	0	0	11	0	22	0						
Doroneuria	11	0	33									
?Doroneuria							0	11	0	11	0	0
Perlodidae							0	22	22			
Kogotus												
TRICHOPTERA												
UID (pupa)	11	11	0									
Glossosomatidae										264	198	33
Rhyacophilidae												
Rhyacophila	11	0	0							11	11	0
Rhyacophila ?vepulsa												
Rhyacophila acropedes-vao	0	0	11				0	44	11	44	66	99
Limnephilidae												
Dicosmoecus	0	11	0									
Ecclisomyia bilera												
DIPTERA												
Ceratopogonidae	0	11	11	0	11	0	44	143	143	88	77	11
Chironomidae												
UID (larvae)				11	0	0	132	165	110			
UID (pupa)	0	22	0				22	0	11			
?Cryptochironomus							0	11	0			
Micropsectra	11	22	165	33	0	0	55	11	11	0	0	11
Polypedilum (Fallax)	0	0	11	0	0	11				11	11	0
Polypedilum (Pentapedilum)												
Tanytarsus				11	0	11						
T. pupa												
Zavrelia	374	297	88	33	11	22	88	264	352	187	198	22
Z. pupa	22	0	0							11	0	0
Diamesa												

CONTINUED...

APPENDIX II(a) (Continued)

Class / Order / Family / Genera	1982						1983					
	F10-B			F20-B			F10-B			F20-B		
	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA												
Prodiamesa							11	22	0			
Corynoneura										0	11	0
Corynoneura (Corynoneura)	22	33	22	22	0	0						
C. pupa	11	121	11									
Thienemanniella										0	0	11
Cricotopus							0	11	0			
C. pupa							0	11	22			
Cricotopus ?trifasciatus							11	11	11	0	22	11
C. ?trifasciatus pupa												
Cricotopus ?bicinctus												
Cricotopus (Isocladius)												
C. (Isocladius) pupa												
Eukiefferiella							0	11	11	11	0	88
Heterotrissocladius marcidus							11	22	11			
?Heterotrissocladius							11	0	11			
Metriocnemus							11	0	0			
Orthocladius (Orthocladius)	11	22	33	11	0	0	121	187	44			
O. (Orthocladius) pupa							11	11	11			
Psectrocladius												
Thienemannemyia	77	33	11	11	0	22	0	11	11			
T. pupa				22	0	11						
Culicidae												
Culicoides pupa												
Empididae												
?Weidemannia	0	11	0	0	0	22						
Hemerodromia							11	22	66	33	0	0
Psychodidae												
Pericoma												
Ephydridae												
Hydrellia												
Simuliidae	0	0	44				33	33	0	0	11	0
UID (pupa)							0	11	0	22	0	0
Prosimulium onychodactylum												
P. onychodactylum pupa										22	22	0
Tipulidae	22	11	0	55	0	11						
Dicranota												
Eriocera sp.							0	66	11			

CONTINUED...

APPENDIX II(a) (Continued)

Class Order Family Genera	1982						1983					
	F10-B			F20-B			F10-B			F20-B		
	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA												
Eriocera fultonensis												
Tipula	11	0	0									
Acari				11	0	0	22	11	11	0	11	0
Sperchon							0	33	22	11	0	0
Unionicola							0	11	0			
Crustacea												
CLADOCERA				11	22	22						
COPEPODA				11	0	0						
OSTRACODA				22	0	11	0	55	77	0	22	0
Phylum Annelida												
Oligochaeta												
Enchytraeidae												
Tubificidae												
Naididae												
Naidium breviseta												
Nais communis				22	11	22						
Phylum Nematoda	0	11	11				44	0	11			
Phylum Mollusca												
Pelecypoda	11	0	0									
Bivalvia							0	11	22			
Phylum Coelenterata												
Hydra												

APPENDIX II(b) DETAILED BENTHIC INVERTEBRATE COMPOSITION FOR BESSEMER CREEK (#/m^2)

Class Order Family Genera	1982			1983		
	BS10-B			BS10-B		
	1	2	3	1	2	3
Phylum Invertebrata						
Insecta						
UID (larvae)						
COLEOPTERA						
Dytiscidae						
Agabus						
Coptotomus						
Hydroporus						
Staphylinidae						
Elmidae						
Heterlimnius						
COLLEMBOLLA						
Smynthuridae						
EPHEMEROPTERA						
Baetidae						
Baetis						
Baetis bi-tricaudatus						
Ephemerellidae						
Ephemerella						
Ephemerella coloradensis						
Ephemerella doddsi						
Ephemerella inermis-infrequens						
Drunella						
Serratella tibialis						
Heptageniidae						
Cinygmula						
Epeorus (Iron)						
Leptophlebiidae						
Paraleptophlebia debilis						
Paraleptophlebia temporalis	11	0	0			
Siphlonuridae						
Ameletus						
Siphlonurus						

CONTINUED...

APPENDIX II(b) (Continued)

Class Order Family Genera	1982			1983		
	BS10-B			BS10-B		
	1	2	3	1	2	3
PLECOPTERA						
UID (larvae)						
Chloroperlidae						
Sweltsa						
Nemouridae						
Visoka cataractae						
Zapada						
Amphinemura						
Perlidae						
Doroneuria						
?*Doroneuria*						
Perlodidae						
Kogotus						
TRICHOPTERA						
UID (pupa)						
Glossosomatidae						
Rhyacophilidae						
Rhyacophila						
Rhyacophila ?*vepulsa*						
Rhyacophila acropedes-vao						
Limnephilidae						
Dicosmoecus						
Ecclisomyia bilera						
DIPTERA						
Ceratopogonidae						
Chironomidae						
UID (larvae)	11	11	0	33	22	22
UID (pupa)						
?*Cryptochironomus*						
Micropsectra						
Polypedilum (*Fallax*)						
Polypedilum (*Pentapedilum*)						
Tanytarsus						
T. pupa						
Zavrelia						
Z. pupa				22	0	0
Diamesa				11	0	0

CONTINUED...

APPENDIX II(b) (Continued)

Class Order Family Genera	1982			1983		
	BS10-B			BS10-B		
	1	2	3	1	2	3
DIPTERA						
Chironomidae						
Prodiamesa						
Corynoneura						
Corynomeura (Corynoneura)						
C. pupa						
Thienemanniella						
Cricotopus						
C. pupa						
Cricotopus ?trifasciatus						
C. ?trifasciatus pupa						
Cricotopus ?bicinctus						
Cricotopus (Isocladius)				231	33	88
C. (Isocladius) pupa						
Eukiefferiella				55	0	0
Heterotrissocladius marcidus						
?Heterotrissocladius						
Metriocnemus						
Orthocladius (Orthocladius)				0	11	0
O. (Orthocladius) pupa						
Psectrocladius						
Thienemannemyia						
T. pupa						
Culicidae	0	11	0			
Culicoides pupa						
Empididae						
?Weidemannia						
Hemerodromia						
Psychodidae						
Pericoma						
Ephydridae						
Hydrellia						
Simuliidae						
UID (pupa)						
Prosimulium onychodactylum						
P. onychodactylum pupa						
Tipulidae						
Dicranota						
Eriocera sp.						

CONTINUED...

APPENDIX II(b) (Continued)

Class Order Family Genera	1982			1983		
	BS10-B			BS10-B		
	1	2	3	1	2	3
DIPTERA *Eriocera fultonensis* *Tipula*						
Acari *Sperchon* *Unionicola*						
Crustacea CLADOCERA COPEPODA OSTRACODA						
Phylum Annelida Oligochaeta Enchytraeidae Tubificidae Naididae *Naidium breviseta* *Nais communis*				0	22	176
Phylum Nematoda						
Phylum Mollusca Pelecypoda Bivalvia						
Phylum Coelenterata *Hydra*						

APPENDIX II(c) DETAILED BENTHIC INVERTEBRATE COMPOSITION FOR BUCK CREEK (#/m^2)

Class / Order / Family / Genera	1982									1983								
	BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Phylum Invertebrata																		
Insecta																		
UID (larvae)							0	11	11									
COLEOPTERA							0	11	0									
Dytiscidae	0	11	0				11	0	0									
Agabus				0	0	11												
Coptotomus				11	0	0												
Hydroporus							11	22	0									
Staphylinidae							88	0	0									
Elmidae	77	88	231	11	11	0												
Heterlimnius																0	33	0
COLLEMBOLLA																		
Smynthuridae																		
EPHEMEROPTERA																		
Baetidae																		
Baetis	44	22	0	0	66	66	0	44	11							0	0	11
Baetis bi-tricaudatus	0	0	11							22	55	33	11	99	0	0	187	242
Ephemerellidae										11	0	0				0	22	33
Ephemerella	33	33	0	11	22	33	0	22	0									
Ephemerella coloradensis																		
Ephemerella doddsi																		
Ephemerella inermis-infrequens																		
Drunella																		
Serratella tibialis	132	55	110	22	33	121							0	88	44	0	77	0
Heptageniidae	22	0	11	11	11	33				0	22	0				0	22	11
Cinygmula				11	11	11												
Epeorus (Iron)																		
Leptophlebiidae										33	22	55						
Paraleptophlebia debilis																		
Paraleptophlebia temporalis	33	11	11	77	22	22				0	11	0						
Siphlonuridae																		
Ameletus	385	275	517	55	44	110	88	44	0	66	330	198						
Siphlonurus																		

CONTINUED...

APPENDIX II(c) (Continued)

Class / Order / Family / Genera	1982									1983								
	BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
PLECOPTERA																		
UID (larvae)				0	22	0												
Chloroperlidae	11	0	0	33	0	11												
Sweltsa	22	22	22	66	77	22				11	11	33	11	22	11	0	44	22
Nemouridae																		
Visoka cataractae																		
Zapada																		
Amphinemura	0	11	0	0	11	0												
Perlidae																		
Doroneuria																		
?Doroneuria																		
Perlodidae	22	0	0	0	0	11				22	55	0				0	0	22
Kogotus	0	22	0															
TRICHOPTERA																		
UID (pupa)																		
Glossosomatidae																		
Rhyacophilidae																		
Rhyacophila																		
Rhyacophila ?vepulsa																		
Rhyacophila acropedes-vao																		
Limnephilidae																		
Dicosmoecus	0	11	0	0	0	11												
Ecclisomyia bilera				121	88	11												
DIPTERA																		
Ceratopogonidae	22	11	121	11	11	11												
Chironomidae																		
UID (larvae)	198	143	286	396	407	132	44	22	11	33	44	33	0	55	11	22	22	44
UID (pupa)				0	11	0				11	11	0				0	11	0
?Cryptochironomus																		
Micropsectra	308	374	209	308	187	154	0	11	11	275	77	88	0	0	11	0	11	0
Polypedilum (Fallax)	0	0	22															
Polypedilum (Pentapedilum)				22	0	33				33	22	11	0	33	11	0	11	0
Tanytarsus	11	0	22				0	11	0	0	11	0						
T. pupa										0	11	0						
Zavrelia	0	22	11	0	0	11	0	11	0	22	22	11						
Z. pupa							0	11	0									
Diamesa																		

CONTINUED...

APPENDIX II(c) (Continued)

Class / Order / Family / Genera	1982									1983								
	BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA																		
Prodiamesa													0	0	11			
Corynoneura	0	0	11							0	11	0				11	11	0
Corynomeura (Corynoneura)				11	0	0												
C. pupa				11	0	0												
Thienemanniella										0	11	11				11	55	33
Cricotopus	22	55	11							0	11	0	0	11	0	0	33	11
C. pupa													0	11	0			
Cricotopus ?trifasciatus													22	11	66			
C. ?trifasciatus pupa													0	11	11			
Cricotopus ?bicinctus													0	22	33	0	11	0
Cricotopus (Isocladius)										0	11	0	11	77	44	11	22	11
C. (Isocladius) pupa													0	22	0	0	0	11
Eukiefferiella				0	11	0				0	11	11	0	88	66	11	44	55
Heterotrissocladius marcidus				33	44	0				11	11	0						
?Heterotrissocladius										11	0	11						
Metriocnemus																		
Orthocladius (Orthocladius)	0	0	11	891	473	484				0	11	0	0	22	44			
O. (Orthocladius) pupa																		
Psectrocladius										0	11	0						
Thienemannemyia	11	0	22	55	110	0	22	0	0	11	11	0				0	11	0
T. pupa										0	0	11						
Culicidae																		
Culicoides pupa				0	55	0												
Empididae																		
?Weidemannia																		
Hemerodromia																		
Psychodidae																		
Pericoma				22	0	0												
Ephydridae																		
Hydrellia																0	0	308
Simuliidae													33	539	33			
UID (pupa)													0	11	0			
Prosimulium onychodactylum																		
P. onychodactylum pupa																		
Tipulidae	11	0	11				11	11	0									
Dicranota	44	0	0	44	55	33				11	11	0						
Eriocera sp.																0	0	11

CONTINUED...

APPENDIX II(c) (Continued)

Class / Order / Family / Genera	1982									1983								
	BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA																		
Eriocera fultonensis	11	0	0															
Tipula																		
Acari	11	0	99	33	11	55												
Sperchon										11	0	11	0	22	0			
Unionicola										0	22	0						
Crustacea																		
CLADOCERA	0	11	0															
COPEPODA				22	0	0												
OSTRACODA	220	253	231	44	44	55				55	165	77						
Phylum Annelida																		
Oligochaeta																		
Enchytraeidae																		
Tubificidae				0	0	22				165	121	55						
Naididae																		
Naidium breviseta	11	33	88	253	55	341												
Nais communis	11	11	0															
Phylum Nematoda	11	0	0	11	11	33	11	0	0	0	0	55	11	0	0			
Phylum Mollusca																		
Pelecypoda	110	160	121	11	0	0	11	0	0									
Bivalvia										77	33	11						
Phylum Coelenterata																		
Hydra	0	0	11															

APPENDIX III(a) BENTHIC INVERTEBRATE COMPOSITION AT FAMILY LEVEL (#/m²) - Individual Sample Analysis

	FOXY CREEK												BESSEMER CREEK						BUCK CREEK																	
	1982						1983						1982			1983			1982									1983								
	F10-B			F20-B			F10-B			F20-B			BS10-B			BS10-B			BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Invertebrata (Insecta) UID																									-	11	11									
COLEOPTERA																									-	11	-									
Dytiscidae	-	-	-																-	11	-	11	-	11	22	22	-									
Staphylinidae	-	-	-	-	-	11																			88	-	-									
Elmidae	11	11	11	-	-	11	11	11	110	110	110	77							77	88	231	11	11	-												
TOTAL	11	11	11	-	-	22	11	11	110	110	110	77							77	99	231	22	11	11	110	33	-									
COLLEMBOLLA	-	-	11																																	
Symnthuridae	-	11	11																																	
TOTAL	-	11	22																																	
EPHEMEROPTERA																																				
Baetidae	-	-	22	22	11	22	11	11	-	33	396	231							44	22	11	-	66	66	-	44	11	22	55	33	11	99	-	-	187	253
Ephemerellidae	11	33	77	11	11	-	120	55	44	132	132	33							165	88	110	33	55	154	-	22	-	11	-	-	-	88	44	-	99	33
Heptageniidae	77	77	187	11	33	22	77	220	220	22	44	11							22	-	11	22	22	44				-	22	-				-	22	11
Leptophlebiidae	66	44	44	22	-	-	132	363	506	-	-	-	11	-	-				33	11	11	77	22	22				33	33	55						
Siphlonuridae	198	132	77	55	66	11	209	253	429	33	55	-							385	275	517	55	44	110	88	44	-	66	330	198						
TOTAL	352	286	407	121	121	55	549	902	1199	220	627	275	11	-	-				649	396	660	187	209	396	88	110	11	132	440	286	11	187	44	-	308	297
PLECOPTERA	-	11	-																			-	22	-												
Chloroperlidae	132	66	77	22	110	55	99	77	319	44	121	77							33	22	22	99	77	33				11	11	33	11	22	11	-	44	22
Nemouridae	22	44	132	11	-	-	55	33	22	22	33	-							-	11	-	-	11	-												
Perlidae	11	-	44	-	22	-	-	11	-	11	-	-																								
Perlodidae							-	22	22										22	22	-	-	-	11				22	55	-				-	-	22
TOTAL	165	121	253	33	132	55	154	143	363	77	154	77							55	55	22	99	110	44				33	66	33	11	22	11	-	44	44
TRICHOPTERA	11	11	-																																	
Glossosomatidae										264	198	33																								
Rhyacophilidae	-	-	11				-	44	11	55	77	99																								
Limnephilidae	-	11	-																-	11	-	121	88	22												
TOTAL	11	22	11				-	44	11	319	275	132							-	11	-	121	88	22												

CONTINUED...

APPENDIX III(a) (Continued)

	FOXY CREEK												BESSEMER CREEK						BUCK CREEK																	
	1982						1983						1982			1983			1982									1983								
	F10-B			F20-B			F10-B			F20-B			BS10-B			BS10-B			BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DIPTERA																																				
Ceratopogonidae	-	11	11	-	11	-	44	143	143	88	77	11							22	11	121	11	11	11												
Chironomidae	528	550	341	154	11	77	484	748	616	220	242	143	11	11	-	352	66	110	550	594	605	1727	1243	814	66	66	22	407	297	187	33	363	308	66	242	165
Culicidae													-	11	-							-	55	-												
Empididae	-	11	-	-	-	22	11	22	66	33	-	-																								
Psychodidae																						22	-	-												
Ephydridae																																		-	-	308
Simuliidae	-	-	44				33	44	-	44	33	-																			33	550	33			
Tipulidae	33	11	-	55	-	11	-	66	11										66	-	11	44	55	33	11	11	-	11	11	-				-	-	11
TOTAL	561	583	396	209	22	110	572	1023	836	385	352	154	11	22	-	352	66	110	638	605	737	1804	1364	858	77	77	22	418	308	187	66	913	341	66	242	484
(Acari)				11	-	-	22	55	33	11	11	-																								
TOTAL				11	-	-	22	55	33	11	11	-																								
(Crustacea)																																				
CLADOCERA				11	22	22													-	11	-															
COPEPODA				11	-	-																22	-	-												
OSTRACODA				22	-	11	-	55	77	-	22	-							220	253	231	44	44	55				55	165	77						
TOTAL				44	22	33	-	55	77	-	22	-							220	264	231	66	44	55				55	165	77						
Annelida (Oligochaeta)				22	11	22										-	22	176	22	44	88	253	55	363				165	121	55						
TOTAL				22	11	22										-	22	176	22	44	88	253	55	363				165	121	55						
Nematoda	-	11	11				44	-	11										11	-	-	11	11	33	11	-	-	-	-	55	11	-	-			
TOTAL	-	11	11				44	-	11										11	-	-	11	11	33	11	-	-	-	-	55	11	-	-			

CONTINUED...

APPENDIX III(a) (Continued)

	FOXY CREEK												BESSEMER CREEK						BUCK CREEK																	
	1982						1983						1982			1983			1982									1983								
	F10-B			F20-B			F10-B			F20-B			BS10-B			BS10-B			BK10-B			BK20-B			BK40-B			BK10-B			BK20-B			BK40-B		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Mollusca	11	-	-				-	11	22										110	160	121	11	-	-	11	-	-	77	33	11						
TOTAL	11	-	-				-	11	22										110	160	121	11	-	-	11	-	-	77	33	11						
Coelenterata																			-	-	11															
TOTAL																			-	-	11															
GRAND TOTAL	1111	1045	1111	440	308	297	1352	2244	2662	1122	1551	715	22	22	-	352	88	286	1793	1634	2200	2607	1903	1737	297	220	33	891	1155	715	99	1144	399	66	594	825
$\bar{x}$ TOTAL	1089			348			2086			1129			15			242			1876			2082			183			920			547			495		

APPENDIX III(b) BENTHIC INVERTEBRATE COMPOSITION AT FAMILY LEVEL (#/m^2) - Combined Count of Three Samples

	FOXY CREEK				BESSEMER CREEK		BUCK CREEK					
	1982		1983		1982	1983	1982			1983		
	F10-B	F20-B	F10-B	F20-B	BS10-B	BS10-B	BK10-B	BK20-B	BK40-B	BK10-B	BK20-B	BK40-B
Invertebrata (Insecta)									7			
COLEOPTERA									4			
Dytiscidae							4	7	15			
Staphylinidae		4							29			
Elmidae	11	4	44	99			132	7				
TOTAL	11	8	44	99			136	14	55			
COLLEMBOLLA	4											
Symnthuridae	7											
TOTAL	11											
EPHEMEROPTERA												
Baetidae	7	18	7	220			26	44	18	37	37	147
Ephemerellidae	40	7	73	99			121	81	7	4	44	44
Heptageniidae	114	22	172	26			11	29		7		11
Leptophlebiidae	51	7	334		4		18	40		40		
Siphlonuridae	136	44	297	29			392	70	44	198		
TOTAL	348	98	883	374	4		568	264	69	286	81	202
PLECOPTERA	4							7				
Chloroperlidae	92	62	165	81			26	70		18	15	22
Nemouridae	66	4	34	18			4	4				
Perlidae	18	7	4	4								
Perlodidae			15				15	4		26		7
TOTAL	180	73	218	103			45	85		44	15	29

CONTINUED...

APPENDIX III(b) BENTHIC INVERTEBRATE COMPOSITION AT FAMILY LEVEL (#/m^2) - Combined Count of Three Samples

	FOXY CREEK				BESSEMER CREEK		BUCK CREEK					
	1982		1983		1982	1983	1982			1983		
	F10-B	F20-B	F10-B	F20-B	BS10-B	BS10-B	BK10-B	BK20-B	BK40-B	BK10-B	BK20-B	BK40-B
TRICHOPTERA	7											
Glossosomatidae				165								
Rhyaophilidae	4		18	77								
Limnephilidae	4						4	77				
TOTAL	15		18	242			4	77				
DIPTERA												
Ceratopogonidae	7	4	110	59			51	11				
Chironomidae	473	81	616	202	7	176	583	1261	51	297	235	158
Culicidae					4			18				
Empididae	4	7	33	11								
Psychodidae								7				
Ephydridae												103
Simuliidae	15		26	26							205	
Tipulidae	15	22	26				26	44	7	7		4
TOTAL	514	114	811	298	11	176	660	1341	58	304	440	265
(Acari)		4	37	7			37	33		15	7	
TOTAL		4	37	7			37	33		15	7	
(Crustacea)												
CLADOCERA		18					4					
COPEPODA		4						7				
OSTRACODA		11	44	7			235	48		99		
TOTAL		33	44	7			239	55		99		

CONTINUED...

APPENDIX III(b) BENTHIC INVERTEBRATE COMPOSITION AT FAMILY LEVEL (#/m^2) - Combined Count of Three Samples

	FOXY CREEK				BESSEMER CREEK		BUCK CREEK					
	1982		1983		1982	1983	1982			1983		
	F10-B	F20-B	F10-B	F20-B	BS10-B	BS10-B	BK10-B	BK20-B	BK40-B	BK10-B	BK20-B	BK40-B
Annelida (Oligochaeta)		18				66	51	224		114		
TOTAL		18				66	51	224		114		
Nematoda	7		18				4	18	4	18	4	
TOTAL	7		18				4	18	4	18	4	
Mollusca	7		11				130	4	4	40		
TOTAL	7		11				130	4	4	40		
Coelenterata							7					
TOTAL							7					
GRAND TOTAL	1093	348	2084	1130	15	242	1881	2115	190	920	547	496

*Note: #/m^2 determined from total #per 3 m^2 divided by 3.