Benthic Invertebrates, Periphyton, and Bottom Material and their Trace-Metal Concentrations in Salmon Creek Basin, Clark County, Washington

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Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

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By Amy C. White and Stuart W. McKenzie

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UNITED STATES DEPARTMENT OF THE INTERIOR
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Conversion factors for inch-pound system and International System Units (SI)

[For use of those readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:]

Multiply inch-pound units	By	To obtain metric unit
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
	Area	
$inch^2$ ($in.^2$)	6.452	$centimeter^2$ (m^2)
$foot^2$ (ft^2)	0.09290	$meter^2$ (m^2)
$mile^2$ (mi^2)	2.590	$kilometer^2$ (km^2)
	Specific combinations	
$foot^3$ per second (ft^3/s)	0.02832	$meter^3$ per second (m^3/s)

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ABSTRACT

In 1978, data were collected for identification and quantification of benthic invertebrates, periphyton, and bottom material and their trace-metals concentrations from three sites in Salmon Creek basin. Metal analyses included arsenic, cadmium, chromium, copper, lead, zinc, selenium, and mercury. Physical data collected included water temperature, dissolved oxygen, pH, discharge, and size of cobbles and fine stream-bottom material. Additional chemical analyses included major constituents. Benthic invertebrate identifications were generally taken to the generic level, with a total of 49 taxons identified and quantified. A total of 36 periphyton taxons were quantified and identified, generally at the species level.

INTRODUCTION

Analyses of samples collected in the Salmon Creek basin, Clark County, Wash., are given in tables 2-8. The study resulted from concern expressed by the Clark County 208 study group that toxic metals may be killing benthic invertebrates. The group had previously collected benthic invertebrate samples and water samples in the Burnt Bridge Creek basin (south of Salmon Creek basin) that showed low counts of benthic invertebrates and the presence of mercury in the water.

The objectives of this study were to (1) collect additional data on trace-metal concentrations in the water and bed sediment, (2) collect benthic invertebrate and periphyton samples in order to describe community structure, and (3) analyze benthic invertebrates and periphyton for their trace-metal content. Field data were obtained between September 14 and November 30, 1978.

DESCRIPTION OF SAMPLING SITES

Salmon Creek, north of Vancouver, Wash., which flows southwestward through Clark County into Vancouver Lake (see fig. 1) was sampled at two points. The upper basin, sampled at Brush Prairie, has a drainage area of 48.7 mi^2. Land use in the upper basin is primarily agricultural, with some logging. The lower basin, sampled at Salmon Creek County Park, has a drainage area of 81.3 mi^2. Land use is mostly light residential, with other areas used for dense residential, commercial, forest, and parks.

Cougar Creek enters Salmon Creek from the southwest. The drainage area includes a 2.88-mi^2 area, of which 45 percent is parks, forests, and vacant lots; 5 percent agricultural; 40 percent light residential; 2 percent dense residential; and 8 percent commercial (Laenen and Solin, 1978).

The locations of the three sampling sites are shown in figure 1. Table 1 gives the site numbers, names, and locations, as determined from U.S. Geological Survey 7½-minute series topographic maps, and the types of land use upstream from each site.

Table 1.--Locations of sampling sites

Site number	Station identification	Location	Land use upstream from sampling site
1	Salmon Creek at Brush Prairie	Lat 45°44'08", long 122°34'00", in NE¼ sec.21, T.3 N., R.2 E.	Agricultural and forest.
2	Salmon Creek at Salmon Creek County Park	Lat 45°42'23", long 122°39'17", in NW¼ sec.35, T.3 N., R.1 E.	Agricultural, forest, and urban.
3	Cougar Creek at mouth	Lat 45°42'43", long 122°41'11", in SE¼ sec.28, T.3 N., R.1 E.	Urban and parks.

During sampling in September and October, sampling site 1 on Salmon Creek at Brush Prairie was a riffle area ranging from 20 to 30 ft in width, approximately 25 ft in length, and less than 1 ft in depth. The site was about 200 ft upstream from the bridge where the road from Brush Prairie crosses Salmon Creek. A reference point was established with a nail in an ash tree on the left bank (looking downstream) about 150 ft upstream from the bridge. The storm of November 30, 1978, was sampled at the bridge.

During sampling in September and October, sampling site 2 on Salmon Creek at Salmon Creek County Park was a riffle area ranging from 30 to 40 ft in width and less than 1 ft in depth. Except for storm samples, which were collected near the bridge in November, samples were collected about 300 ft upstream from the park bridge. Between the bridge and Interstate Highway 5, an urban storm sewer empties into the creek.

During September, sampling site 3 on Cougar Creek at mouth (upstream from a culvert at the mouth of Cougar Creek) was a riffle area about 8 ft in width and 6 in. or less in depth. A nail, painted red, in an alder seedling on the left bank approximately 60 ft above the culvert, was established as the reference point. Storm sampling on November 30, 1978, was done at gaging station 14213040, approximately 1,000 ft upstream from the culvert.

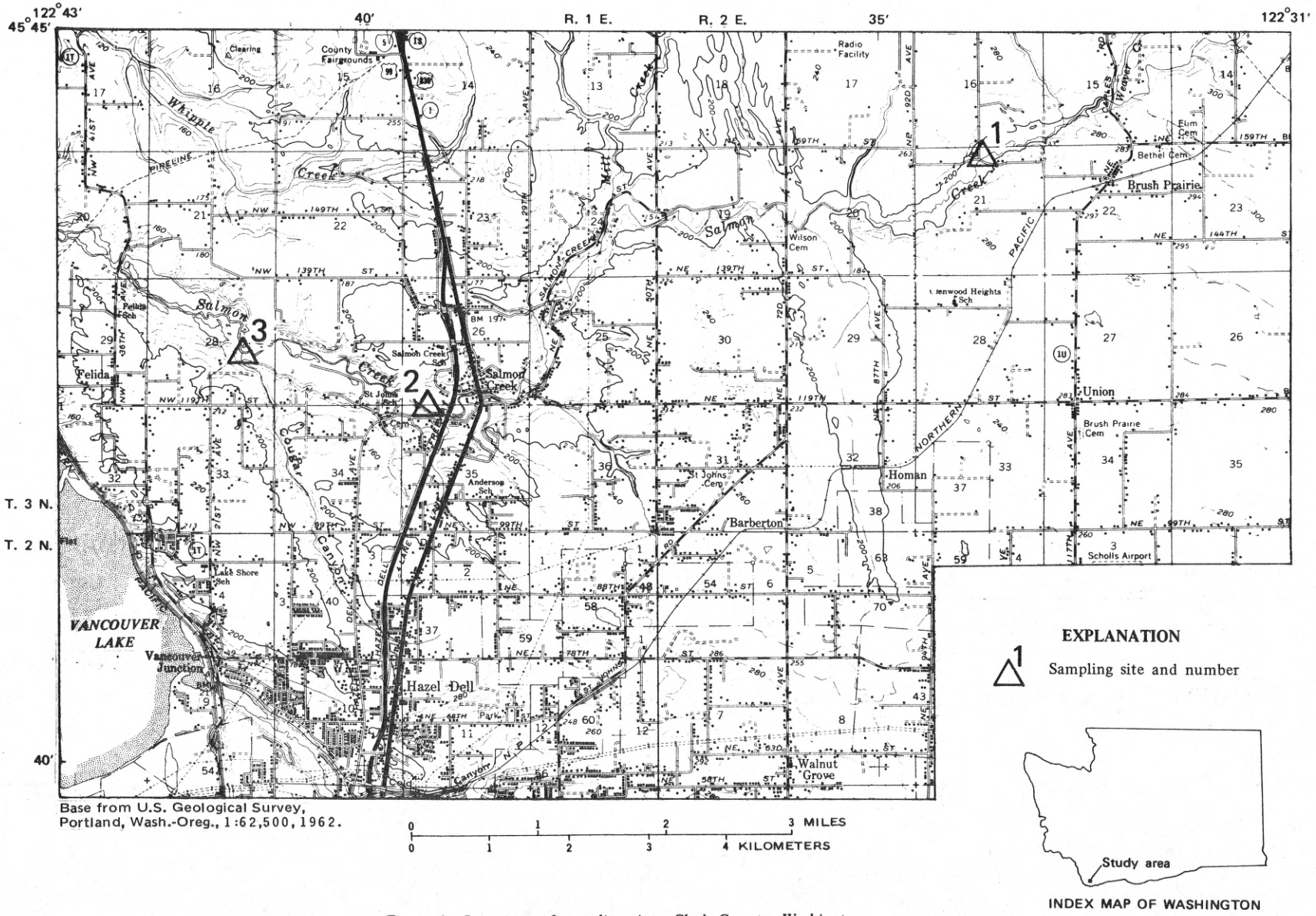

Figure 1.–Locations of sampling sites, Clark County, Washington.

SAMPLING GUIDELINES AND LABORATORY METHODS

Water

All sampling, excluding that done during the storm event, included field measurements of water temperature and dissolved oxygen. Specific conductance and pH were measured in the laboratory.

Sample bottles were hand filled from the riffle area. Samples for dissolved constituents were filtered, and acidified with concentrated nitric acid. Discharge was measured using U.S. Geological Survey standard techniques (Buchanan and Somers, 1969).

Storm samples were collected using a depth-integrating US DH-48 suspended-sediment sampler. At both Salmon Creek sites 1 and 2, the current was too strong during the November 30 storm sampling to permit wading across the creek. Therefore, several samples were collected from both left and right banks, moving toward the middle of the creek. Upon return to the laboratory, samples were mixed in a water-sediment sample splitter and subsampled. Suspended-sediment concentrations were determined as described by Guy (1969).

Base-flow water samples were analyzed for major constituents and for total and dissolved concentrations of arsenic, cadmium, chromium, copper, lead, zinc, selenium, and mercury, in accordance with procedures described by Skougstad and others (1978) (table 2). Additional samples were collected, including the storm samples, and were analyzed for total and dissolved trace metals. With the exception of storm samples, a dissolved metal was determined only if detected in the total concentration analysis. Table 3 lists the trace-metal-concentration and physical data for low-flow and storm conditions.

Table 2.--Major constituents in base flow

Site no.	Station identification	Sampling		Discharge (ft^3/s)	Milligrams per liter										
		Date	Time		Dissolved silica (SiO_2)	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Dissolved sodium (Na)	Dissolved potassium (K)	Dissolved sulfate (SO_4)	Dissolved chloride (Cl)	Dissolved fluoride (F)	Dissolved nitrite plus nitrate (N)	Hardness (Ca, Mg)	Alkalinity as $CaCO_3$
1	Salmon Creek at Brush Prairie	9-14-78	1500	30	21	8.0	2.4	4.7	1.3	1.9	4.0	0.1	0.02	30	31
2	Salmon Creek at Salmon Creek County Park	9-20-78	1100	40	33	15	4.6	6.1	2.0	4.3	5.1	.1	3.1	56	50
3	Cougar Creek at mouth	9-27-78	1100	2	55	24	8.7	8.3	2.5	8.8	6.3	.1	2.1	96	85

Table 3.--Trace-metal concentrations and physical data

[--, not determined; E, estimated]

Site no.	Station identification	Date (1978)	Time (2400 hours)	Stage (ft)	Discharge (ft^3/s)	Specific conductance (microhos/cm at 25°C)	Temperature (°C)	pH (units)	Dissolved oxygen (mg/L)	Micrograms per liter: Total Arsenic (As)	Micrograms per liter: Dissolved Arsenic (As)	Micrograms per liter: Total Cadmium (Cd)	Micrograms per liter: Dissolved Cadmium (Cd)	Micrograms per liter: Total Chromium (Cr)1/	Micrograms per liter: Dissolved Chromium (Cr)1/	Micrograms per liter: Total Copper (Cu)	Micrograms per liter: Dissolved Copper (Cu)	Micrograms per liter: Total Lead (Pb)1/	Micrograms per liter: Dissolved Lead (Pb)1/	Micrograms per liter: Total Zinc (Zn)	Micrograms per liter: Dissolved Zinc (Zn)	Micrograms per liter: Total Selenium (Se)	Micrograms per liter: Dissolved Selenium (Se)	Micrograms per liter: Total Mercury (Hg)	Micrograms per liter: Dissolved Mercury (Hg)	Suspended sediment concentration (mg/L)	Suspended sediment (percent finer than 0.062 mm)
1	Salmon Creek at Brush Prairie	9-14	1100	5.69	30	82	15.2	7.2	10.3	0	--	0	--	0	--	3	3	0	--	10	0	0	--	0.0	--	--	--
	do.	10- 3	1000	5.51	11	108	11.0	7.1	10.2	0	--	0	--	0	--	--	15	15	29	10	0	0	--	.0	--	--	--
	do.	10-17	0920	5.50	13	115	11.9	7.1	9.2	0	--	--	7	0	--	4	5	22	6	20	10	0	--	.0	--	--	--
	do.	10-25	0930	5.52	13	105	6.8	7.2	11.9	1	--	1	--	0	--	3	--	5	--	10	--	0	--	.0	--	--	--
2	Salmon Creek at Salmon Creek County Park	9-20	1100	5.01	40	132	11.0	7.8	10.2	0	--	1	0	0	--	3	3	28	0	0	--	0	--	.0	--	--	--
	do.	10- 5	0830	4.94	28	153	10.9	7.5	10.9	1	1	10	0	0	--	0	--	100	2	10	10	0	--	.0	--	--	--
	do.	10-19	0830	4.91	27	150	10.1	7.2	11.0	1	1	3	3	0	--	4	3	28	8	10	10	0	--	.0	--	--	--
3	Cougar Creek at mouth	9-27	1100	6.19	2	222	13.4	7.9	10.8	1	1	0	--	0	--	4	1	4	12	10	0	0	--	.0	--	--	--
										Storm event																	
1	Salmon Creek at Brush Prairie	11-30	1230	7.95	390	65	--	--	--	1	0	29	1	30	0	14	8	220	1	50	30	0	0	.0	0.0	140	72
2	Salmon Creek at Salmon Creek County Park	do.	1130	6.46	600E	84	--	--	--	1	0	16	7	20	0	8	7	96	43	30	30	0	0	.0	.0	69	--
3	Cougar Creek at mouth	do.	1040	2/1.64	2/10	104	--	--	--	3	2	8	6	60	0	29	5	240	46	110	30	0	0	.0	.0	2,000	44
	do.	do.	1315	2/1.86	2/15	74	--	--	--	3	1	2	4	60	0	27	11	88	39	90	40	0	0	.0	.0	2,390	39

1/ Water samples may have been contaminated with lead and(or) cadmium from nitric acid.

2/ The stage and discharge measurements are from gaging station 14213040 records.

Bottom Material

Two types of bottom material were collected during low flow at each site. Fine bottom sediments were analyzed for size and extractable metals, and coarse material was analyzed for size.

Fine-sediment samples were collected in duplicate from areas along the streambanks where the current was slow because of obstruction by vegetation. Particle-size analyses, determined by methods described by Guy (1969), are shown in table 4. The less than 0.02-mm-sized material from the second fine-sediment sample was analyzed for extractable cadmium, chromium, copper, lead, manganese, zinc, and mercury at the U.S. Geological Survey Central Laboratory in Arvada, Colo. (table 6).

Table 4.--Particle-size analyses of fine stream-bottom material

Site no.	Station identification	Sieving method	Percentage									
			Greater than 2.0 mm	Less than 2.0 mm	Less than 1.0 mm	Less than 0.5 mm	Less than 0.35 mm	Less than 0.25 mm	Less than 0.125 mm	Less than 0.062 mm	Less than 0.016 mm	Less than 0.0[illegible] mm
1	Salmon Creek at Brush Prairie	Wet	1	99	99	73	44	24	10	5	3	2
2	Salmon Creek at Salmon Creek County Park	Wet	0	100	100	93	82	65	37	26	13	7
3	Cougar Creek at mouth	Wet	1	99	95	70	49	26	10	7	2	1

Cobble-material samples were collected in duplicate at each site in the riffle area using a 1- by 1-ft metal frame as a quantifier. The material was measured along its primary and secondary axes to the nearest 0.25 in. Percentage composition by size was calculated using the secondary axis as a measure of the smallest sieve size that each rock might pass through. The results are shown in table 5.

Periphyton

Periphyton samples were collected from each site during low-flow conditions in September. In October, additional sampling was done at the two Salmon Creek sites to determine variability over time.

The samples were analyzed for (1) identification, abundance, and diversity of organisms; and (2) trace-metal concentrations. Samples for the first type of analysis were preserved with solutions of 40 percent Formalin + $CuSO_4$ and 20 percent detergent, in accordance with Slack and others (1973). The

Table 5.--Secondary axis size of coarse material from the stream bottom in riffle areas

Site no.	Station and sample identification	Date	Total number of rocks measured per ft^2	Percentage			
				Less than 100 mm	Less than 75 mm	Less than 50 mm	Less than 25 mm
1	Salmon Creek at Brush Prairie						
	Sample A	9-14-78	51	100	100	90	37
	Sample B	do.	116	100	100	97	88
2	Salmon Creek at Salmon Creek County Park						
	Sample A	9-20-78	17	100	94	72	6
	Sample B	do.	32	100	88	34	0
3	Cougar Creek at mouth						
	Sample A	9-27-78	37	100	97	65	8
	Sample B	do.	28	100	79	50	0

samples to be analyzed for trace metals were chilled, with no preservatives added, and extractable metals were determined for the dried material at the U.S. Geological Survey Central Laboratory in Arvada, Colo. (E. L. Skinner, U.S. Geological Survey, written commun., February 15, 1979).

Two sampling techniques were used. The preferred technique for collecting samples for organism identification involved removing periphyton from 10 rocks, chosen at random along a transect across the creek bottom, by scraping a 1-in.-square area with a 1-in.-wide glass microscope slide. Additional periphyton required for metal analysis were either scraped from many rocks in 1-in. squares or from fewer rocks in 2-in. squares, depending on the volume of periphyton. Generally, a minimum of 10 grams was collected to ensure accurate trace-metal analysis.

Periphyton could not always be completely scraped from porous rocks; and, because the distribution of algal species was often extremely uneven over individual rock surfaces, a 1-in. square was not always representative of the population. In these instances, an alternate technique was used, involving collection of periphyton in 2-in. squares from enough rocks to obtain more than 10 grams. After mixing each sample, a subsample was removed and preserved for identification, using methods described by Slack and others (1973). A diversity index (H) was determined for each sample. (See appendix.)

Results of trace-metal analyses are listed in table 6; periphyton identification, abundance, and diversity are listed in table 7.

Table 6.--Analyses of trace metals in benthic invertebrate and periphyton samples and bottom material with particle sizes less than 0.02 mm

[Results expressed as micrograms per gram of dry weight. ND, not detected; --, not determined]

Site no.	Station identification	Date	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Zinc
				Benthic invertebrates					
1	Salmon Creek at Brush Prairie	9-14-78	10	8	64	200	3,200	--	1,600
	do.	10- 3-78	8	5	35	180	4,500	ND	230
	do.	10-17-78	6	8	36	160	3,400	ND	160
	do.	10-25-78	8	4	32	140	4,200	ND	170
2	Salmon Creek at Salmon Creek County Park	9-20-78	6	6	28	140	640	ND	120
	do.	10- 5-78	6	4	48	140	620	ND	140
	do.	10-19-78	6	4	22	100	560	ND	110
3	Cougar Creek at mouth	9-27-78	25	10	150	800	380	--	140
				Periphyton					
1	Salmon Creek at Brush Prairie	9-14-78	6	10	320	120	4,200	--	92
	do.	10- 3-78	12	5	45	180	6,200	--	95
	do.	10-17-78	6	10	36	120	4,000	ND	64
	do.	10-25-78	5	8	42	120	3,800	ND	64
2	Salmon Creek at Salmon Creek County Park	9-20-78	6	12	32	100	3,000	ND	100
	do.	10- 5-78	6	8	38	100	2,600	ND	76
	do.	10-19-78	6	16	34	120	1,600	ND	60
3	Cougar Creek at mouth	9-27-78	6	20	16	100	1,200	ND	120
				Bottom material					
1	Salmon Creek at Brush Prairie	9-14-78	0	21	50	0	1,400	0.37	71
2	Salmon Creek at Salmon Creek County Park	9-20-78	0	22	28	78	2,200	.06	78
3	Cougar Creek at mouth	9-27-78	0	24	18	36	430	.10	48

Table 7.–*Periphyton identification, abundance, and diversity*
[Taxonomic references, Patrick and Reimer (1966, 1975), and Prescott (1961)]

Division Class Order Family *Genus species*	Common name	Percentage of organisms					
		Salmon Creek at Brush Prairie (site 1)			Salmon Creek at Salmon Creek County Park (site 2)		Cougar Creek at mouth (site 3)
		9/14/78	10/17/78	10/25/78	9/20/78	10/19/78	9/27/78
Chlorophyta	Green algae						
Chlorophyceae							
Ulotrichales							
Ulotrichacea							
Ulothrix sp		1.1	---	---	---	---	---
Chrysophyta	Yellow-brown algae						
Bacillariophyceae	Diatoms						
Centrales	Centric diatoms						
Coscinodiscaceae							
Melosira varians		10.0	14.0	4.9	3.2	---	---
Pennales	Pennate diatoms						
Diatomacea							
Diatoma vulgare		---	---	---	---	10.1	---
Fragilariaceae							
Fragilaria vaucheriae		---	---	---	---	1.8	---
Synedra ulna		---	0.7	---	---	---	0.5
Achnanthaceae							
Achnanthes lancealata		2.2	---	---	.8	.6	.5
A. Linearis		2.2	---	.7	6.5	4.2	1.1
A. minutissima		---	---	---	1.6	1.2	---
Cocconeis placentula		17.7	.7	---	4.8	1.2	---
Rhoicosphenia curvata		10.0	7.7	5.6	9.7	3.6	---
Misc. pennate diatoms		4.4	1.4	.7	4.0	1.8	2.1
Naviculaceae	Naviculoid						
Navicula biconica		---	---	---	---	5.4	.5
N. cryptocephala		8.9	3.5	3.5	23.5	---	10.6
N. cryptocephala veneta		8.9	4.9	2.1	1.6	.6	.5
N. salinarum		---	---	---	---	20.3	---
N. tripunctata		3.4	---	---	---	2.4	65.6
Gomphonemaceae							
Gomphonema angustata		---	13.3	6.3	---	---	---
G. herculeana		---	---	---	.8	1.2	---
G. parvulum		2.2	---	---	---	.6	---
G. subclavatum		2.2	---	2.1	---	1.2	---
G. tenellum		---	---	---	.8	---	---
G. spp.		7.8	2.8	.7	7.3	4.2	---

Table 7.–*Periphyton identification, abundance, and diversity*–Continued
[Taxonomic references, Patrick and Reimer (1966, 1975), and Prescott (1961)]

Division Class Order Family *Genus species*	Common name	Percentage of organisms					
		Salmon Creek at Brush Prairie (site 1)			Salmon Creek at Salmon Creek County Park (site 2)		Cougar Creek at mouth (site 3)
		9/14/78	10/17/78	10/25/78	9/20/78	10/19/78	9/27/78
Chrysophyta (continued)							
Bacillariophyceae (continued)							
Pennales (continued)							
Cymbellaceae							
Cymbella affinis		1.1	1.4	3.5	---	---	---
C. cymbiformis		---	.7	---	---	---	---
C. minuta		7.8	4.9	2.1	13.8	2.4	---
C. sinuata		3.4	---	---	.8	---	---
Nitzschiaceae							
Nitzschia acicularis		---	.7	---	.8	---	---
N. amphibia		3.4	14.6	20.2	5.6	9.6	3.7
N. dissipata		1.1	14.0	11.2	4.0	7.2	1.6
N. frustulum		---	2.1	1.4	---	2.4	5.3
N. palea		1.1	7.0	17.5	4.8	8.4	1.6
N. recta		---	---	---	---	---	.5
N. spp.		1.1	3.5	3.5	4.8	7.2	1.1
Surirellaceae							
Surirella angustata		---	---	0.7	---	---	---
S. ovata		---	---	---	.8	---	4.8
Cyanophyta	Blue-green algae						
Myxophyceae							
Oscillatoriales	Filamentons						
Oscillatoriaceae							
Lyngbya sp		---	---	10.5	---	2.4	---
Oscillatoria sp		---	2.1	2.8	---	---	---
Total	---	100	100	100	100	100	100
Total organism count (in thousands)	---	50	15,000	2,900	9,000	17,000	21,000
Diversity ($\bar{H}$)	---	3.83	3.66	3.59	3.66	3.92	1.99

Benthic Invertebrates

Benthic invertebrate samples were collected on the same schedule as the periphyton samples. The samples were collected at random from riffle areas at each site, avoiding areas disturbed during previous sampling. Sampling was done using a 1- by 1-ft Surber sampler with mesh openings of 0.21 mm. Rocks and other bottom materials were gently rubbed clean by hand, allowing the dislodged organisms to drift with the current into the Surber net. Cleaned rocks were set to one side to prevent them from being washed back into the framed area and to minimize the number of benthic organisms dislodged directly upstream from the framed area. For the same reason, the collector worked downstream or to the side of the sampler. Where possible, rocks and gravel were removed and cleaned to a depth of about 6 in. Benthic invertebrate identifications and numbers are shown in table 8. The results of trace-metal determinations for benthic invertebrates are listed in table 6.

One Surber sample from each sampling was preserved, using 70 to 90 percent ethanol for identification and quantification. The invertebrates were extracted from the detritus, sorted by hand under 10-power magnification, and identified with the aid of the keys and references footnoted in table 8. Diversity indexes were calculated as shown in the appendix.

Two to four additional Surber samples from each sampling were combined, and the invertebrates were extracted from the detritus, weighed, and frozen. The combined samples generally provided the 10 grams desirable for the analysis of metals in the dried material. The analyses were made at the U.S. Geological Survey Central Laboratory in Arvada, Colo. (E. L. Skinner, U.S. Geological Survey, written commun., February 15, 1979).

Drift nets were tried for the collection of invertebrates for metal analysis, but they did not give satisfactory results. Drift nets set on September 14 at site 1 between 1730 and 2000 hours yielded neither the necessary quantity of invertebrates nor a sample representative of the invertebrates collected with the Surber sampler.

Table 8.–*Benthic invertebrate identification, abundance, and diversity*
[+ indicates presence; number undeterminable]

PHYLUM / CLASS / Order / Family / *Genus species*	Common name	Number and percentage of total invertebrates															
		Salmon Creek at Brush Prairie (site 1)								Salmon Creek at Salmon Creek County Park (site 2)						Cougar Creek at mouth (site 3)	
		9/14/78		10/3/78		10/17/78		10/25/78		9/20/78		10/5/78		10/19/78		9/27/78	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
NEMATODA[1]	Nematodes	4	0.18	--	--	2	0.09	2	0.10	--	--	1	0.03	--	--	3	0.43
ANNELIDA																	
OLIGOCHAETA[1]	Aquatic earthworms	22	1.01	34	3.27	145	6.52	84	4.05	7	0.25	139	4.21	89	2.90	26	3.71
ARTHROPODA																	
CRUSTACEA (class)																	
Amphipoda	Scuds																
Gammaridae																	
Anisogammarus[1,2,3]		--	--	--	--	--	--	--	--	2	.07	4	.12	1	.03	53	7.55
OSTRACODA (subclass)[1]	Seed shrimp	--	--	--	--	4	.18	--	--	--	--	--	--	--	--	--	--
BRANCHIOPODA (subclass)																	
Diplostraea																	
Cladocera (suborder)[1]	Water fleas	--	--	--	--	3	.13	--	--	--	--	--	--	+	--	--	--
COPEPODA (subclass)[1]																	
Cyclopoida		--	--	--	--	3	.13	5	.24	--	--	--	--	258	8.40	--	--
INSECTA																	
Diptera	True flies																
Tipulidae	Crane flies																
Antocha[1,2,4]		3	.14	4	.38	9	.40	5	.24	5	.18	14	.42	10	.33	--	--
(pupae)[1,2,4]		--	--	--	--	--	--	--	--	1	.03	1	.03	--	--	--	--
Unknown genus[1,2,4]		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Simuliidae[1,2,4]	Black flies, buffalo flies	30	1.38	1	.10	1	.05	2	.10	--	--	1	.03	--	--	--	--
Stratiomyiidae[2,4]	Soldier flies	1	.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Empididae	Dance flies																
Unknown genus No. 1[2,4]		1	.05	--	--	--	--	3	.14	1	.03	--	--	--	--	--	--
Unknown genus No. 2[2,4]		--	--	1	.10	3	.13	1	.05	--	--	--	--	1	.03	--	--
(pupae)[2]		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Chironomidae	Midges																
(larvae)[1,2,4,6]		253	11.61	88	8.46	155	6.97	216	10.41	614	21.99	639	19.36	116	3.77	492	70.09
(pupae)[1,2]		8	.37	19	1.83	11	.49	11	.53	43	1.54	72	2.18	8	.26	21	2.99
(adults)[2]		--	--	3	.29	--	--	--	--	7	.25	4	.12	7	.23	3	.43
Unknown family[1,4]																	
(Misc. adults)		--	--	--	--	--	--	2	.16	2	.07	--	--	--	--	--	--

See footnotes at end of table.

Table 8.–*Benthic invertebrate identification, abundance, and diversity*–Continued
[+ indicates presence; number undeterminable]

PHYLUM / CLASS / Order / Family / *Genus species*	Common name	Number and percentage of total invertebrates															
		Salmon Creek at Brush Prairie (site 1)								Salmon Creek at Salmon Creek County Park (site 2)						Cougar Creek at mouth (site 3)	
		9/14/78		10/3/78		10/17/78		10/25/78		9/20/78		10/5/78		10/19/78		9/27/78	
		No.	per-cent	No.	per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent	No.	Per-cent
ARTHROPODA–Continued																	
INSECTA–Continued																	
Diptera–Continued																	
Trichoptera	Caddis flies																
Hydropsychidae																	
Hydropsyche[1,2,4,5,6] /		103	4.72	65	6.25	49	2.20	60	2.89	1,273	45.59	948	28.72	1,087	35.37	8	1.14
Cheumatopsyche[1,2,4,5,6] /		1,034	47.43	254	24.42	364	16.37	345	16.63	154	5.52	160	4.85	226	7.35	--	--
Unknown genus[1,4,5] /		--	--	--	--	--	--	1	.05	--	--	2	.06	--	--	--	--
(pupae)[4] /		--	--	--	--	--	--	--	--	2	.07	--	--	--	--	--	--
Rhyacophilidae																	
Rhyacophila[1,2,4,5,6] /		15	0.69	3	0.29	8	0.36	9	0.43	--	--	--	--	--	--	--	--
Himalopsyche[1,4,5,6] /																	
(Rhyacophila grandes[2] /)		13	.60	4	.38	5	.22	7	.34	--	--	--	--	2	.07	--	--
(pupae)		6	.27	--	--	--	--	--	--	5	.24	--	--	--	--	--	--
Hydroptilidae																	
Stactobiella[1,2,4,5] /		--	--	--	--	--	--	--	--	--	--	1	.03	--	--	--	--
Leptoceridae																	
Oecetis[1,2,4,5] /		--	--	--	--	--	--	--	--	--	--	2	.06	9	0.29	--	--
Philopotamidae																	
Wormaldia[1,2,4,5,6] /		1	.05	--	--	--	--	--	--	9	.32	--	--	--	--	--	--
(pupae)[4] /		2	.09	--	--	--	--	--	--	6	.21	3	.09	--	--	--	--
Glossosomatidae																	
Anagapetus[1,2,4,5,6] /		19	.87	--	--	8	.36	11	.53	37	1.33	8	.24	14	.46	--	--
(pupae)[4] /		4	.18	--	--	1	.05	2	.10	24	.86	5	.15	8	.26	--	--
(adults)[4] /		--	--	1	.10	--	--	--	--	--	--	--	--	1	.03	--	--
Plecoptera	Stone flies																
Nemouridae																	
Nemoura (Malenka)[1,2,4,7] /		168	7.70	158	15.19	205	9.22	173	8.34	174	6.23	340	10.30	206	6.70	--	--
Perlidae																	
Acroneuria (Hesperoperla)[1,2,4,7] /		1	.05	2	.19	1	.05	1	.05	--	--	--	--	--	--	--	--
Calineuria[1,2,4,7] /		3	.14	1	.10	1	.05	4	.19	--	--	--	--	--	--	--	--

See footnotes at end of table.

Table 8.–*Benthic invertebrate identification, abundance, and diversity*–Continued
[+ indicates presence; number undeterminable]

PHYLUM / CLASS / Order / Family / *Genus species*	Common name	Number and percentage of total invertebrates															
		Salmon Creek at Brush Prairie (site 1)								Salmon Creek at Salmon Creek County Park (site 2)						Cougar Creek at mouth (site 3)	
		9/14/78		10/3/78		10/17/78		10/25/78		9/20/78		10/5/78		10/19/78		9/27/78	
		No.	percent	No.	percent	No.	percent	No.	percent	No.	percent	No.	percent	No.	percent	No.	percent
ARTHROPODA–Continued																	
INSECTA–Continued																	
Plecoptera–Continued																	
Perlodidae																	
Isoperla[1,2,4,7]		--	--	--	--	43	1.93	58	2.80	8	0.29	9	0.27	16	0.52	--	--
Arcynopteryx[1,2,4,7]		--	--	--	--	--	--	--	--	3	.11	11	.33	4	.13	--	--
Isogenus[1,2,4,7]		--	--	--	--	1	.05	--	--	5	.18	3	.09	--	--	--	--
Unknown genus[1,2,4,7]		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Chloroperlidae																	
Hastaperla[1,2,4]		14	0.64	12	1.15	10	.45	11	.53	9	.32	20	.61	11	.36	--	--
Taeniopterygidae																	
Taeniopteryx[1,2,4]		--	--	5	.48	1	.05	6	.29	--	--	--	--	--	--	--	--
Capniidae																	
Paracapnia[1,2,4]		--	--	--	--	--	--	--	--	--	--	12	.36	--	--	--	--
Unknown family[1,2,4,6]		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Coleoptera	Beetles																
Elmidae	Riffle beetles																
(larvae)[1,2,4,8]		267	12.25	62	5.96	475	21.36	333	16.05	89	3.19	256	7.75	176	5.73	1	0.14
(adults)[1,2,4,8]		58	2.66	15	1.44	66	2.97	63	3.04	7	.25	9	.27	14	.46	--	--
Unknown family[1,2,4]		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Hymenoptera	Aquatic wasps																
Scelionidae[2,4]																	
Unknown genus No. 1		--	--	--	--	--	--	--	--	4	.14	--	--	--	--	--	--
Unknown genus No. 2		--	--	--	--	--	--	--	--	1	.03	--	--	--	--	--	--
Ephemeroptera	Mayflies																
Tricorythidae																	
Tricorythodes[1,2,4,9]		--	--	--	--	--	--	--	--	2	.07	6	.18	5	.16	--	--
Ephemerellidae																	
Ephemerella		--	--	1	0.10	3	0.13	5	0.24	--	--	--	--	--	--	--	--
Leptophlebiidae																	
Paraleptophlebia[1,2,4,6]		32	1.47	70	6.73	179	8.05	173	8.34	102	3.65	281	8.51	299	9.73	--	--
Bactidae																	
Baetis[1,2,4,6,10]		29	1.33	110	10.58	173	7.78	247	11.91	65	2.33	22	.67	20	.65	87	12.39
(imago)[2]		--	--	--	--	1	.05	--	--	3	.11	--	--	1	.03	--	--
Heptageniidae																	
Rhithrogena[1,2,4,6,10]		33	1.51	76	7.31	184	8.27	103	4.97	80	2.86	97	2.94	229	7.45	--	--
Aphidae	Aphids																
Unknown family (winged)[2]		--	--	--	--	--	--	--	--	--	--	1	.03	2	.07	2	.28
(wingless)[2]		--	--	--	--	--	--	--	--	--	--	--	--	--	--	4	.57

See footnote at end of table.

Table 8.–*Benthic invertebrate identification, abundance, and diversity*–Continued
[+ indicates presence; number undeterminable]

PHYLUM / CLASS / Order / Family / *Genus species*	Common name	Number and percentage of total invertebrates															
		Salmon Creek at Brush Prairie (site 1)								Salmon Creek at Salmon Creek County Park (site 2)						Cougar Creek at mouth (site 3)	
		9/14/78		10/3/78		10/17/78		10/25/78		9/20/78		10/5/78		10/19/78		9/27/78	
		No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
ARTHROPODA–Continued																	
ARACHNOIDEA																	
Hydracarina[1]	Water mites	50	2.29	43	4.13	89	4.00	102	4.92	43	1.54	228	6.90	251	8.17	1	0.14
MULLUSCA																	
GASTROPODA	Snails																
Mesogastropoda																	
Pleuroceridae																	
Goniobasis[1,2,11]		2	0.09	4	0.39	9	0.40	9	0.43	--	--	--	--	1	0.03	--	--
Bulimidae (Hydrobiidae)																	
Amnicola[1,2,11]		--	--	--	--	1	.05	--	--	--	--	1	0.03	--	--	--	--
Basommatophora																	
Ancylidae[1,2]	Limpets	4	.18	3	.29	11	.49	19	.92	--	--	--	--	--	--	--	--
PELECYPODA	Clams																
Nuculoidea																	
Sphaeriidae	Fingernail clams																
Pisidium?[1,2]		--	--	--	--	--	--	--	--	--	--	2	0.06	1	.03	1	.14
OTHER																	
UNKNOWN		--	--	1	.10	--	--	1	.05	--	--	--	--	--	--	--	--
EGG MASSES		+	--	+	--	+	--	+	--	--	--	--	--	+	--	--	--
Total		2,180	100	1,040	100	2,224	100	2,074	100	2,792	100	3,302	100	3,073	100	702	100
Diversity ($\bar{H}$)		2.39		3.08		3.29		3.37		2.29		2.83		2.85		1.40	
Hmax		4.32		4.25		6.48		4.52		4.24		4.53		4.46		21.55	
Hmin		0.084		0.15		0.11		0.27		0.083		0.087		0.069		.16	
Relative evenness (e)		0.544		0.714		0.499		0.721		0.531		0.617		0.633		.544	

1/ Edmondson (1959).
2/ L. A. Fusté, (U.S. Geological Survey, WRD, personal commun., January 3 and 4, 1978) for verification and (or) identification.
3/ Holsinger (1972).
4/ Merritt and Cummins (1978).
5/ E. L. Quan (Oregon Department of Environmental Quality, personal commun., October 1978) for verification.
6/ Anderson (1976).
7/ Bauman, Gaufin, and Surdick (1977)
8/ Brown (1972).
9/ Edmunds, Jensen, and Berner (1976).
10/ Usinger (1956).
11/ Henderson (1929, 1936).

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APPENDIX

The following diversity equation, as derived by Patten (1962) from the Shannon-Weaver Equation, was used to calculate periphyton and benthic invertebrate species diversity:

$$\bar{H} = -K\left[\sum_{i=1}^{m} \frac{n_i}{N} \log \frac{n_i}{N}\right]$$

where

K = a factor to convert logs from base 10 to a desired base (base 2, for which K = 3.3219),

m = the number of taxa in a unit area,

n_i = the number of individuals in the ith species (taxon),

N = the total number of individuals in the collection, and

$\bar{H}$ = the diversity in bits (binary digits, in base 2)/individual.

The greater the value of $\bar{H}$, the greater the diversity.

To calculate maximum and minimum diversity indexes, the following two equations were used:

For maximum diversity,

$$Hmax = K\,[\log N! - m \log (N/m)!];$$

For minimum diversity,

$$Hmin = K\,(\log N! - \log [N - (m-1)]!).$$

The relative evenness (e) of the sample is one factor used to determine the relationship of number of individuals within a species (taxon) to the total number of individuals. Relative evenness (Zand, 1965) was calculated for benthic samples as follows:

$$e = \frac{\bar{H} - Hmin}{Hmax - Hmin}$$

Relative evenness may range from 0 for the least even sample to 1 for the most even sample.