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DEPARTMENT OF
ECOLOGY

Review of Sediment Quality Data for the Similkameen River

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Review of Sediment Quality Data for the Similkameen River

by
Art Johnson and Rob Plotnikoff

Environmental Assessment Program
Olympia, Washington 98504-7710

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Abstract

Chemical and biological data were reviewed from sediment samples collected at nine sites in the Similkameen River during 1995 – 1999. Except for arsenic, the level of chemical contamination is low. Arsenic concentrations have exceeded sediment quality guidelines in the Palmer Lake/Nighthawk area. Bioassays with *Hyalella azteca* and Microtox, however, have given inconsistent indications of toxicity. Limited benthic macroinvertebrate sampling also points to the slow-moving reach near Palmer Lake/ Nighthawk as potentially having a low-level metals contamination problem. This would be the area to focus on, if further sediment sampling were conducted.

Acknowledgements

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Background

The 72-mile long Similkameen River originates in the Cascade Range along the international border between British Columbia (B.C.) and Washington State. It flows north through B.C., then turns south to cross the border and meet the Okanogan River at Oroville, the last 27 miles of the Similkameen being in Washington (Figure 1). Mining, forestry, and agriculture are the major activities in the drainage.

Environment Canada and the B.C. Ministry of Environment, Lands, and Parks jointly monitor water quality in the Similkameen River at a station near the U.S. border (Chopaka Bridge, federal site no. BC08NL0005). Results have shown that elevated concentrations of arsenic and copper occur during freshets in the spring and early summer. The source of arsenic is thought to be tailings in the mining area between Hedley, B.C. and the border (Stewart, 1998; Pommen, 1998). The elevated copper levels appear to be a naturally occurring, basin-wide phenomenon.

Historically, cyanide concentrations at the Chopaka Bridge station have exceeded B.C. water quality objectives on numerous occasions. Although there are mining-related sources in the drainage, it has been concluded that these results are due to sample contamination, or possibly from iron cyanide in road salts or naturally occurring sources (Pommen and Ryan, 1992).

The Washington State Department of Ecology (Ecology) monitors water quality near the mouth of the Similkameen River at Oroville (ambient station 49B070). The limited metals data available for this station also show a spring/early summer peak in arsenic and copper. The Similkameen is currently on the 303(d) list for exceeding the U.S. Environmental Protection Agency (EPA) human health criteria for arsenic, based on water sampling done by Ecology in 1995-96 (Johnson, 1997). Water quality violations of state aquatic life standards have not been observed for arsenic, copper, or other metals.

In B.C., the main mining influences on the river are "a copper mine on Wolfe Creek, which drains to the Similkameen River between Princeton and Hedley, a gold mine on Cahill Creek, which drains to the Similkameen River downstream from Hedley, and old mines in the Hedley area" (Stewart, 1998). Mining has been on a smaller scale in Washington. There are several abandoned mines between the border and the community of Nighthawk. Tailings piles from the only large operation, the Kabba-Texas, once bordered the river bank just upstream of Nighthawk. A cleanup was recently completed, and the tailings now reside in an upland disposal site.

Lack of data on mining impacts to the Similkameen was the impetus for three sediment quality surveys conducted by the Ecology Environmental Assessment Program during 1995 – 1999. Table 1 shows the survey dates, number of samples collected, and analyses conducted. Figure 1 shows the sampling locations. A complete list of the chemicals analyzed can be found in Appendix A. Appendix B has the latitude and longitude of each sampling site.

An initial screening survey was conducted in August 1995 (Johnson, 1997). This effort was limited to an analysis of grain size and metals concentrations at four sites between Chopaka Bridge (river mile 36.1) and Enloe Dam (r.m. 8.9). The major area of sediment accumulation in the river is between the dam and Shankers Bend (r.m. 10.5). A second, but less significant

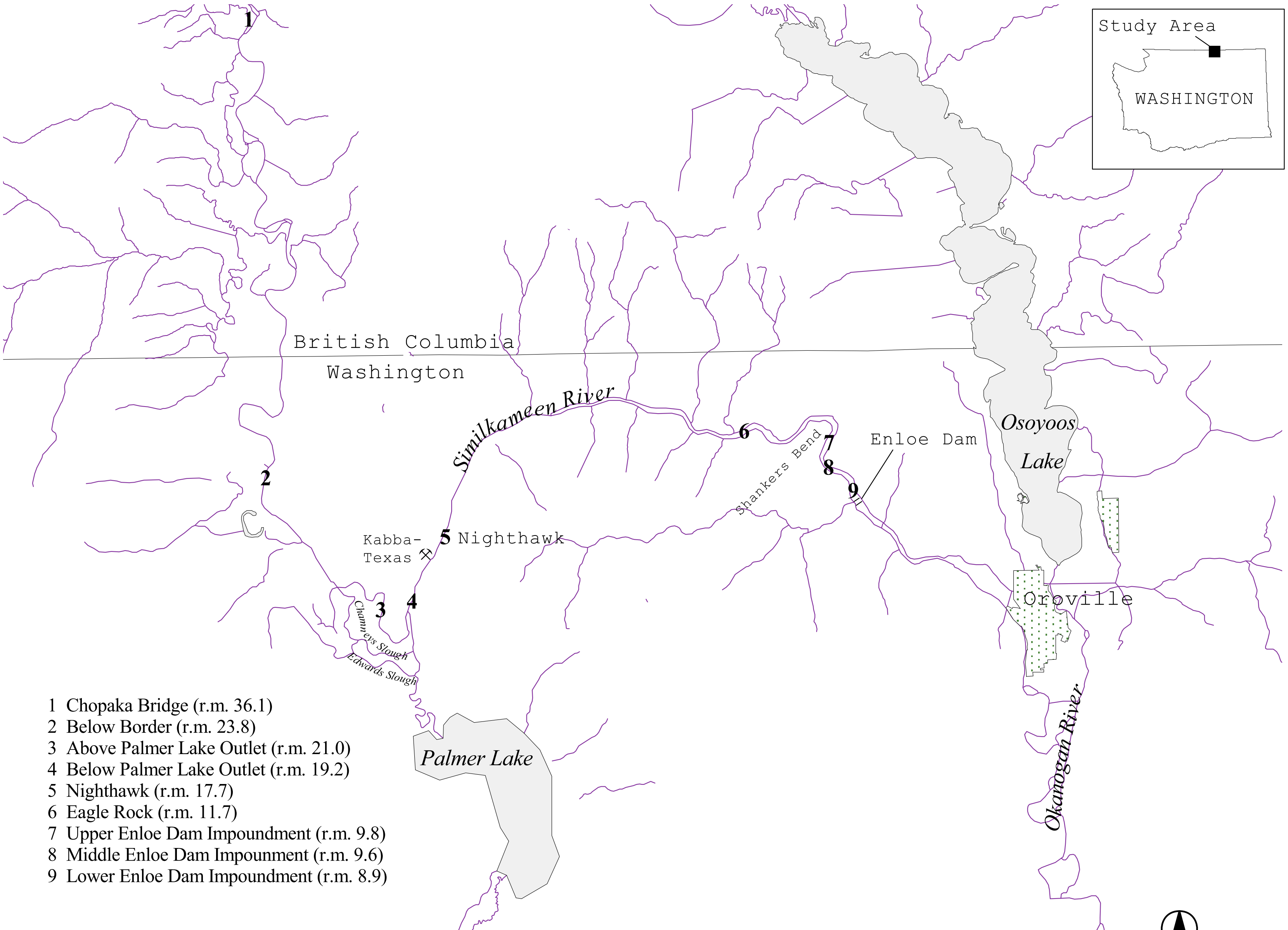

Figure 1. Location of Department of Ecology Sediment Samples Collected from the Similkameen River, 1995 - 1999

Table 1. Sediment Quality Surveys Conducted by Ecology in the Similkameen River

Date	Reach	number of samples	grain size	total organic carbon	metals	cyanide	pesticides/PCBs	semivolatiles	dioxins	bioassays	benthic invertebrates
29-30 Aug. 95	Chopaka Bridge to Enloe Dam	4	x		x						
23-24 Sept. 98	Border to Enloe Dam	7	x	x	x	x				x	x
30 Sept. 99	Enloe Dam impoundment	5	x		x	x	x	x	x		

depositional area in terms of volume, is located just above Palmer Lake where the river divides to form several sloughs. Because of difficult access, only one site has been sampled in this part of the river.

Further sampling was conducted in September 1998 to follow up on finding elevated arsenic concentrations at two of the locations sampled in 1995. Seven sites were sampled between the border and Enloe Dam. In addition to metals, the 1998 analyses included cyanide, sediment bioassays, and an evaluation of the benthic macroinvertebrate community. The bioassays were the ten-day acute test with the amphipod *Hyalella azteca* and the Microtox test, which measures reduction of light output by a luminescent bacteria. Benthic macroinvertebrate samples were examined for shifts in community structure and evidence of biological abnormalities, potentially resulting from metals exposure.

The third and final set of samples was collected in response to a request from the Colville Confederated Tribes. The Colvilles were concerned about the possibility of chemical contamination in sediment deposits behind Enloe Dam. Shallow cores were obtained in the upper, middle, and lower impoundment during September 1999 and analyzed for a range of chemical contaminants that included metals, cyanide, pesticides, PCBs, and chlorinated dioxins and –furans. This information was to assist the tribes, state, and other watershed groups make management decisions relating to dam operations/re-licensing, potential dam removal, total maximum daily loads (TMDLs), current mining activities in the watershed, and ESA recovery projects.

The sediment quality data obtained through these efforts are summarized in the present report. The results are reviewed to identify chemicals or locations where toxicity to aquatic life may be a concern.

Sampling Methods

Chemistry and Bioassays

The 1995 and 1998 sediment samples were collected with a 0.06 m^2 stainless steel Ponar grab and consisted of the top 2 cm and top 10 cm surface layers, respectively. Each sample was a composite of three to five grabs. The 1999 Enloe Dam core samples were taken with a 4-inch vibra-corer fitted with an acrylic liner. The corer had difficulty penetrating the hard packed sand encountered behind the dam. As a result only shallow cores were obtained, from 30 to 60 cm in length.

Sediments were removed from the grabs with stainless steel scoops and homogenized by stirring in stainless steel bowls. Subsamples of the homogenates were placed in glass jars with Teflon lid liners, cleaned to EPA QA/QC specifications (EPA, 1990), or in Whirl-Pak bags for grain size. The samples were put in individual polyethylene bags and placed on ice immediately after collection.

Stainless steel scoops and bowls used to manipulate the sediments were cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, de-ionized water, and pesticide-grade acetone. The equipment was then air-dried and wrapped in aluminum foil. The grabs were cleaned similarly and wrapped in aluminum foil before going into the field. Grabs were washed by brushing with site water between samples.

The cores were capped, placed on ice, and returned to Ecology Headquarters, where they were frozen for approximately two weeks. The cores were thawed, divided into 30 cm sections, homogenized, and put in sample containers as described above for the grab samples. The samples were then re-frozen pending analysis.

Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected from sand depositional areas at five locations along the river (sites 2, 3, 4, 5, and 7 in Figure 1). Four 0.02m^2 Ponar grabs were collected from each location and placed in separate containers. Containers were labeled with location, date collected, habitat type, and collectors names. Macroinvertebrate samples were preserved with 85% non-denatured ethanol. Additional information recorded for each site included temperature, pH, conductivity, and dissolved oxygen.

Laboratory Methods

Chemistry

The sediment samples were analyzed at the Ecology Manchester Environmental Laboratory in Manchester, WA, except grain size was analyzed by Rosa Environmental & Geotechnical Laboratory in Seattle, WA, and chlorinated dioxins and –furans were analyzed by Pace Analytical in Minneapolis, MN. Methods of analysis are listed in Table 2.

Table 2. Analytical Methods for Similkameen River Sediment Samples

Analysis	Method	Number
Grain Size	Sieve & pipette	- -
Total Organic Carbon	Combustion/NDIR	PSEP 9060
Ag,Al,Be,Cd,Cr,Cu,Fe,Mn,Ni,Sb,Zn	ICP	SW3050/6010
As	GFAA	SW3050/7060
Pb	GFAA	SW3050/7421
Se	GFAA	SW3050/7740
Tl	GFAA	SW3050/7841
Hg	CVAA	EPA 245.5
Cyanide	Distillation/colorimetric	SM 4500CNC
Semivolatiles	GC-MS	SW8270
Chlorinated Pesticides & PCBs	GC-ECD	SW8081,-82
Nitrogen & Phosphorus Pesticides	GC-AED, GC-ITD	SW8085
Chlorinated Dioxins & -Furans	High resolution GC-MS	8290*

Metals samples digested by SW3050, except mercury
PSEP = Puget Sound Estuary Program
*with enhancements from EPA 1613B

Manchester Laboratory staff prepared written reviews on the quality of the chemical data for this project. The reviews include an assessment of sample condition on receipt at the laboratory, compliance with holding times, and results for instrument calibration, method blanks, laboratory control samples, standard reference materials, surrogates, matrix spikes, and matrix spike duplicates. The data reviews and complete chemical data are available from the author on request.

The only significant shortcomings in the quality of the data were for antimony, thallium, and phthalates. Recoveries of antimony and thallium were low in laboratory control samples and in matrix spikes for the 1998 and/or 1999 samples. The affected data are qualified as estimates.

The method blank for the semivolatiles analysis was contaminated with diethylphthalate, di-N-butylphthalate, butylbenzylphthalate, and bis(2-ethylhexyl)phthalate. Where these compounds were found in field samples, they were considered real and not the result of contamination if the levels were five-times the amount in the method blank (EPA five-times rule).

Bioassays

The sediment bioassays were conducted by CH2M Hill in Corvallis, OR. *Hyalella* amphipod tests were performed according to *Standard Guide for Conducting Sediment Toxicity Tests with Freshwater Invertebrates*, ASTM E 1383-90. Microtox tests were performed according to *Solid-Phase Testing Protocols*, Microtox M500 Manual, version 3 (Microbics Corp., 1994) using the luminescent bacterium *Vibrio fischerie*.

The amphipods were obtained from Chesapeake Cultures, Nayes, VA. The freeze-dried bacteria for the Microtox test were obtained from Azu Environmental, Carlsbad, CA. All test organisms appeared vigorous and in good condition prior to testing.

The water used for acclimation and dilution water during the amphipod tests was reconstituted moderately hard water with a total hardness of 98 mg/L as $CaCO_3$, alkalinity of 60 mg/L as $CaCO_3$, and a pH of 7.5. Dilution water used for Microtox testing was a 3.4% sodium chloride solution. The laboratory control for the amphipods was 20-grade washed silica sand.

Reference toxicants use in the tests were cadmium for *Hyalella* and phenol for Microtox. The resulting 48-hour LC_{50} values were 11.3 ug/L and 21.8 mg/L, respectively. Control limits are 1.3 - 19.6 ug/L and 14.3 - 23.9 mg/L, respectively, indicating the organisms were within their expected sensitivity ranges.

Benthic Macroinvertebrates

Sediment volume for each sample was estimated in the laboratory by decanting into a container and allowing sediment to settle overnight. The sediment was further decanted through a 500 micron sieve and rinsed out into petri dishes in preparation for removal of macroinvertebrates. A 10X-30X magnification dissecting microscope was used in sorting macroinvertebrates from sediment. Ten percent of material passing through the sieve was examined for loss of macroinvertebrates.

Slide mounting of chironomids and oligochaetes was done for all specimens in order to make genus and family-level identifications, respectively. For other taxa, cladocerans were identified to genus, copepods identified to order (Cyclopoida), and ostracods were identified to subclass (Ostracoda).

Chironomidae mouthparts were examined in slide-mounted specimens for signs of deformities. Warwick and Tisdale (1988) provide description and illustration for deformities in the following taxonomic groups: Orthocladiinae (sub-family), Tanytarsini (tribe), Chironomini (tribe), and Tanypodinae (sub-family). Permanent slides of specimens with mouthpart deformities were made and affected individuals further identified with an arrow on the cover slip.

Results and Discussion

Grain Size and Total Organic Carbon

The grain size and total organic carbon (TOC) data are in Table 3.

Table 3. Grain size and TOC in Similkameen River Sediment Samples

Site No.	Date	Site No.	Depth Interval	Gravel	Sand	Silt	Clay	TOC
			UPPER RIVER					
1	29-Aug-95	358246	0-2 cm	0.0	99.0	1.0	0.0	NA
2	23-Aug-98	398060	0-10 cm	0.0	97.3	2.2	0.5	0.36
			PALMER LAKE - NIGHTHAWK					
3	24-Aug-98	398061	0-10 cm	0.1	92.2	6.5	1.2	0.36
4	30-Aug-95	358244	0-2 cm	0.0	56.0	36.0	8.0	NA
4	24-Aug-98	398062	0-10 cm	0.0	69.7	25.6	4.7	1.2
5	30-Aug-95	358243	0-2 cm	1.0	77.0	17.0	5.0	NA
5	24-Aug-98	398063	0-10 cm	1.2	95.7	2.7	0.5	0.26
			EAGLE ROCK					
6	24-Aug-98	398064	0-10 cm	0.0	96.4	2.8	0.9	0.31
			ENLOE DAM					
7	23-Aug-98	398065	0-10 cm	0.0	97.6	2.0	0.4	0.15
7	30-Sep-99	408020	0-1 ft	0.0	96.0	3.5	0.0	NA
7	30-Sep-99	408021	1-2 ft	1.3	97.6	1.1	0.0	NA
8	30-Sep-99	408022	0-1 ft	0.0	100	0.0	0.0	NA
8	30-Sep-99	408023	1-2 ft	1.1	98.9	0.0	0.0	NA
9	30-Aug-95	358242	0-2 cm	0.0	98.0	1.0	0.0	NA
9	23-Aug-98	398066	0-10 cm	0.4	97.2	2.0	0.3	0.21
9	30-Sep-99	408024	0-1 ft	0.5	98.3	1.3	0.0	NA

TOC = total organic carbon

NA = not analyzed

The sediments in most areas, including the Enloe Dam impoundment, consisted almost entirely of sand. Finer material was found in the vicinity of Palmer Lake/Nighthawk, especially sites 4 and 5 which had 22 - 44% fines (silt + clay). TOC was analyzed in selected samples only. Concentrations were low, ranging from 0.15 - 0.36% TOC, except 1.2% upstream of Palmer Lake outlet at site 3.

Chemicals Detected

Table 4 summarizes results from the metals and cyanide analyses.

With the exception of copper and arsenic, metals concentrations were generally comparable throughout the study area. The finer sediments between Palmer Lake and Nighthawk at sites 4 and 5, and one of the samples just above Enloe Dam at site 9, had copper concentrations of 43 - 60 mg/Kg (ppm) and arsenic concentrations of 21 - 46 mg/Kg. Copper and arsenic levels in sediments from other parts of the river were 12 - 28 mg/Kg and 9.5 - 17 mg/Kg, respectively.

Sites 4 and 5 bracket the site of the abandoned Kabba-Texas mine, previously mentioned. It is unlikely that the tailings that once bordered the river here are the source of the elevated arsenic, given the low concentrations in this material (Table 5). Although the tailings are elevated in copper, lead, zinc, cadmium, and silver relative to river sediments, concentrations of these metals were higher in sediment samples collected above Kabba-Texas (site 4) than below (site 5).

The core samples taken behind Enloe Dam were grossly sectioned into 0-30 cm and 30-60 cm increments, so do not provide a detailed vertical profile. However, coupled with previous samples of the surface layer, the data indicate that metals concentrations decrease with depth. For example, arsenic concentrations in the 0-2 cm, 0-10 cm, and 0-30 cm layers at site 9 were 21, 14, and 10 mg/Kg, respectively, while copper concentrations were 45, 21, and 17 mg/Kg. The lowest concentrations of these and other metals within the study area (sites 1 through 9) were found in the deeper (older) sediment layers behind Enloe Dam.

Cyanide was analyzed in sediments from seven sites sampled in 1998. No cyanide was detectable at or above 0.10 mg/Kg.

Organic compounds have only been analyzed in the Enloe Dam cores. Table 6 has the data for semivolatiles, PCBs, and pesticides. Table 7 has the chlorinated dioxins and -furans data.

Nineteen semivolatile compounds were detected. Concentrations were generally low, less than 100 ug/Kg (ppb) in most cases. As with metals, the higher concentrations tended to be found in the surface sediments.

The most frequently detected semivolatiles were polyaromatic hydrocarbons (PAH), dibenzofuran, and retene. These compounds occurred in all or almost all samples. Petroleum and combustion of fossil fuel are sources of PAH and dibenzofuran. Retene is often found in association with wood particles, which were evident in some of these samples. Pine, in particular, is a source of retene (Windholz, 1983). Among the semivolatiles detected, retene was present at the highest concentrations in all but one of the core samples. Concentrations ranged from 7.9 - 522 ug/Kg.

Di-N-butylphthalate was detected at an elevated concentration of 3,490 ug/Kg in the 0-30 cm sample from upper Enloe Dam site 7. Di-N-butylphthalate has a number of potential sources including but not limited to plastics, paints, adhesives, coverings, inks, and insecticides. Because the method blank for this analysis was contaminated with phthalates, the accuracy of this result is questionable.

Table 4. Results of Metals and Cyanide Analyses on Similkameen River Sediment Samples (mg/Kg, dry weight)

Site No.	Date	Sample No.	Depth Interval	Fe	Al	Mn	Zn	Cu	As	Cr	Ni	Pb	Cd
						UPPER RIVER							
1	29-Aug-95	358246	0-2 cm	**12900**	**7030**	**236**	**35**	**22**	**12**	**12**	**12**	**2.4**	0.3 U
2	23-Aug-98	398060	0-10 cm	**14000**	**6980**	NA	**32**	**25**	**11**	**13**	**11**	**3.3**	0.5 U
						PALMER LAKE - NIGHTHAWK							
3	24-Aug-98	398061	0-10 cm	**15700**	**7790**	NA	**35**	**28**	**17**	**15**	**15**	**3.9**	0.5 U
4	30-Aug-95	358244	0-2 cm	**19500**	**10700**	**389**	**56**	**60**	**30**	**21**	**19**	**5.4**	0.3 U
4	24-Aug-98	398062	0-10 cm	**19900**	**10100**	NA	**48**	**51**	**43**	**22**	**19**	**5.4**	0.5 U
5	30-Aug-95	358243	0-2 cm	**17000**	**8490**	**300**	**46**	**43**	**46**	**18**	**17**	**4.5**	0.3 U
5	24-Aug-98	398063	0-10 cm	**13400**	**7040**	NA	**29**	**17**	**9.5**	**11**	**9.1**	**2.4**	0.5 U
						EAGLE ROCK							
6	24-Aug-98	398064	0-10 cm	**14700**	**7230**	NA	**33**	**24**	**19**	**13**	**12**	**3.0**	0.5 U
						ENLOE DAM							
7	23-Aug-98	398065	0-10 cm	**14200**	**7080**	NA	**31**	**18**	**12**	**13**	**12**	**2.4**	0.5 UJ
7	30-Sep-99	408020	0-1 ft	NA	NA	NA	**36**	**21**	**15**	**15**	**11**	**3.2**	**1.1**
7	30-Sep-99	408021	1-2 ft	NA	NA	NA	**31**	**13**	**7**	**11**	**7.8**	**2.0**	**0.86**
8	30-Sep-99	408022	0-1 ft	NA	NA	NA	**32**	**13**	**7.8**	**12**	**8.6**	**2.2**	**0.81**
8	30-Sep-99	408023	1-2 ft	NA	NA	NA	**30**	**12**	**7.2**	**11**	**7.9**	**2.0**	**0.79**
9	30-Aug-95	358242	0-2 cm	**16200**	**8940**	**305**	**50**	**45**	**21**	**18**	**16**	**4.1**	0.3 U
9	23-Aug-98	398066	0-10 cm	**14600**	**7275**	NA	**32**	**21**	**14**	**14**	**12**	**2.8**	0.5 U
9	30-Sep-99	408024	0-1 ft	NA	NA	NA	**33**	**17**	**10**	**13**	**9.2**	**2.3**	**0.94**

Detections highlighted in **BOLD**
NA = not analyzed
U = not detected at or above reported value
J = estimated value
UJ = not detected at or above reported estimated value

Table 4. (continued)

Site No.	Date	Sample No.	Depth Interval	Ag	Be	Tl	Hg	Sb	Se	CN
					UPPER RIVER					
1	29-Aug-95	358246	0-2 cm	0.3 U	NA	NA	0.01 U	NA	0.4 U	NA
2	23-Aug-98	398060	0-10 cm	**0.66**	**0.24**	**0.38** J	**0.012**	4 UJ	0.3 U	0.10 U
					PALMER LAKE - NIGHTHAWK					
3	24-Aug-98	398061	0-10 cm	**0.78**	**0.28**	**0.50** J	**0.018** J	4 UJ	0.3 U	0.10 U
4	30-Aug-95	358244	0-2 cm	**0.30** J	NA	NA	**0.012**	NA	0.4 U	NA
4	24-Aug-98	398062	0-10 cm	**0.83**	**0.38**	0.3 U	**0.029**	4 UJ	0.3 U	0.10 U
5	30-Aug-95	358243	0-2 cm	**0.30** J	NA	NA	0.01 U	NA	0.4 U	NA
5	24-Aug-98	398063	0-10 cm	**0.59**	**0.24**	0.3 U	**0.031**	4 UJ	0.3 U	0.10 U
					EAGLE ROCK					
6	24-Aug-98	398064	0-10 cm	**0.74**	**0.23**	0.3 U	**0.0085**	4 UJ	0.3 U	0.10 U
					ENLOE DAM RESERVOIR					
7	23-Aug-98	398065	0-10 cm	**0.58**	**0.21**	0.3 U	**0.0072**	4 UJ	0.3 U	0.10 U
7	30-Sep-99	408020	0-1 ft	2 U	**1.3**	0.3 U	**0.013**	5 UJ	0.3 U	NA
7	30-Sep-99	408021	1-2 ft	2 U	**0.97**	0.3 U	0.01 U	5 UJ	0.3 U	NA
8	30-Sep-99	408022	0-1 ft	2 U	**1.2**	0.3 U	0.01 U	5 UJ	0.3 U	NA
8	30-Sep-99	408023	1-2 ft	2 U	**1.0**	0.3 U	0.01 U	5 UJ	0.3 U	NA
9	30-Aug-95	358242	0-2 cm	0.3 U	NA	NA	**0.012**	NA	0.4 U	NA
9	23-Aug-98	398066	0-10 cm	**0.73**	**0.23**	0.3 U	**0.014** J	4 UJ	0.3 U	0.10 U
9	30-Sep-99	408024	0-1 ft	2 U	**1.1**	0.3 U	0.01 U	5 UJ	0.3 U	NA

Detections highlighted in **BOLD**
NA = not analyzed
U = not detected at or above reported value
J = estimated value
UJ = not detected at or above reported estimated value

Table 5. Metals Concentrations in Kabba-Texas Tailings (mg/Kg, dry weight)

Investigator:	Ecology & Environment (1991)			Johnson (1997)
Location:	Background Soil	Tailings near Mine Shaft	Center of Tailings Pile	Tailings on River Bank
Sample No.:	SB1	SB6	SB7	358245
Iron	NA	NA	NA	**18,300**
Aluminum	NA	NA	NA	**2,330**
Manganese	**536**	**846**	**271**	**175**
Zinc	**56**	**7,820**	**56**	**1,340**
Copper	**30**	**1,300**	**28**	**531**
Arsenic	**4.9**	**7**	**14**	**12**
Chromium	**28**	**21**	**11**	**8.1**
Nickel	**26**	**18**	**12**	**7.8**
Lead	**9.6**	**13,000**	**5.6**	**355**
Silver	0.9 U	**97**	0.8 U	**3.9**
Mercury	0.1 U	**0.8**	0.1 U	**0.06**
Selenium	NA	NA	NA	0.4
Cadmium	0.6 U	**68**	0.6 U	**10**

Detections highlighted in **BOLD**
U = not detected at or below reported value
P = below minimum quantitation limit
J = estimated value
NA = not analyzed

PCBs and pesticides were not detected in any of the Enloe Dam sediment samples. Detection limits were < 7 ug/Kg for PCBs and < 1 ug/Kg for chlorinated pesticides. Detection limits were variable for organophosphorus and nitrogen pesticides, but were generally < 10 ug/Kg for the former and < 50 ug/Kg for the latter.

Only a few of the 17 dioxins and furans analyzed were detectable, primarily in the 0-30 cm layer from upper impoundment site 7. Chlorinated dioxins and furans have no commercial uses, but are unintended byproducts formed during combustion of organic matter in the presence of chlorine, incineration of municipal and hospital wastes, and chlorine bleaching of wood pulp (Yake et al., 1998). 2,3,7,8-tetrachlorodibenzo-p-dioxin (dioxin), the most toxic of these compounds, was not detected in any samples at or above 0.46 - 1.6 ng/Kg (pptr).

Table 6. Summary of Results from Analyzing Semivolatiles, PCBs, and Pesticides in Core Samples Collected behind Enloe Dam in September 1999 (ug/Kg, dry weight; only detected compounds shown)

Site No:	7		8		9
Location:	Upper Reservoir		Middle Reservoir		Lower Res.
Depth Interval (cm):	0-30	30-60	0-30	30-60	0-30
Sample No:	408020	408021	408022	408023	408024
Semivolatiles					
Polyaromatic Hydrocarbons					
Naphthalene	**13**	6.7 U	**7.8** J	12 U	**7.9** J
1-Methylnaphthalene	**14**	6.7 U	**5.8** J	**5.6** J	**7.6** J
2-Methylnaphthalene	**17**	6.7 U	**9.2** J	**8.2** J	**10** J
Fluorene	**8.9** J	6.7 U	12 U	12 U	12 U
Phenanthrene	**55**	**4.2** J	**8.9** J	**8.0** J	**12** J
Anthracene	**23**	6.7 U	12 U	12 U	12 U
Fluoranthene	13 U	**4.2** J	**8.7** J	12 U	**9.7** J
Pyrene	**8.4** J	6.7 U	**6.6** J	**6.3** J	**7.7** J
Benzo(a)anthracene	13 U	**5.2** J	12 U	**9.4** NJ	12 U
Chrysene	13 U	6.7 U	12 U	12 U	**9.6** J
Total PAH	**139**	**14**	**47**	**38**	**64**
Miscellaneous Compounds					
2-Methylphenol	**8.5**	6.7 U	12 U	12 U	**5.9** J
4-Chloro-3-Methylphenol	13 U	6.7 U	12 U	12 U	**17**
2-Nitroaniline	13 U	6.7 U	12 U	12 U	**36**
3-Nitroaniline	**49**	6.7 U	12 U	12 U	12 U
Dibenzofuran	**12** J	6.7 U	**6.4** J	**6.3** J	**7.0** J
Retene	**522**	**7.9**	**83**	**48**	**203**
Carbazole	**1.2** J	6.7 U	12 U	12 U	12 U
Di-N-butylphthalate	**3490** E	54 U	386 U	711 U	243 U
Butylbenzylphthalate	26 U	**10**	19 U	23 U	22 U
PCBs	ND	ND	ND	ND	ND
Chlorinated Pesticides	ND	ND	ND	ND	ND
Organophosphorus Pesticides	ND	ND	ND	ND	ND
Nitrogen Pesticides	ND	ND	ND	ND	ND

Detections highlighted in **BOLD**
U = not detected at or above reported value
J = estimated value
NJ = evidence analyte is present; value is an estimate
E = estimated value that exceeds the calibration
ND = not detected

Table 7. Results from Analyzing Chlorinated Dioxins and -Furans in Core Samples Collected behind Enloe Dam in September 1999 (ng/Kg, dry weight)

Site No:	7		8		9
Location	Upper Reservoir		Middle Reservoir		Lower Res
Depth Interval (cm):	0-30	30-60	0-30	30-60	0-30
Sample No:	408020	408021	408022	408023	408024
Dioxins					
2378-TCDD	0.46 U	0.48 U	0.65 U	1.6 U	0.73 U
12378-PeCDD	0.67 U	0.58 U	0.92 U	0.83 U	0.67 U
123478-HxCDD	0.66 U	0.47 U	0.56 U	0.60 U	0.59 U
123678-HxCDD	0.92 U	0.39 U	0.38 U	0.70 U	0.59 U
123789-HxCDD	0.68 U	0.44 U	0.33 U	0.68 U	0.44 U
1234678-HpCDD	**21**	0.60 U	0.78 U	1.2 U	0.58 U
OCDD	**300**	5.1 U	9.0 U	4.3 U	3.8 U
Furans					
2378-TCDF	0.61 U	0.59 U	0.38 U	0.81 U	0.79 U
12378-PeCDF	0.77 U	0.37 U	0.38 U	0.51 U	0.58 U
23478-PeCDF	0.29 U	0.24 U	0.36 U	0.70 U	0.34 U
123478-HxCDF	0.62 U	0.35 U	0.37 U	0.60 U	0.44 U
123678-HxCDF	0.64 U	0.24 U	0.26 U	0.51 U	0.46 U
234678-HxCDF	**0.42** J	**0.36** J	0.37 U	0.67 U	0.48 U
123789-HxCDF	0.43 U	0.45 U	0.38 U	0.46 U	0.66 U
1234678-HpCDF	**2.6** J	0.37 U	0.48 U	0.45 U	0.57 U
1234789-HpCDF	1.1 U	0.52 U	0.23 U	0.31 U	0.38 U
OCDF	**19**	0.77 U	**0.50**	1.4 U	**1.3** J
TEQ =	**0.6**	**0.047**	**0.017**	**0.004**	0

Detections highlighted in **BOLD**
U = not detected at or above reported value
J = estimated value
TEQ = 2,3,7,8-TCDD Toxic Equivalents

The toxicity of mixtures of dioxins and furans can be expressed in terms of equivalent concentrations of dioxin (toxicity equivalent or TEQ). TEQs in the Enloe Dam cores ranged from 0 to 0.6 ng/Kg. TEQs were higher in the 0-30 cm layer than in the 30-60 cm layer.

Sediment Quality Guidelines

To determine if the chemical concentrations detected in Similkameen River sediments are a potential concern for aquatic life, the data were compared to freshwater sediment quality guidelines from three sources (Table 8). An Ecology study (Cubbage et al., 1997) proposed Freshwater Sediment Quality Values from an analysis of bioassay and chemistry data in Ecology's FSEDQUAL database on freshwater sediments statewide. The province of Ontario (Persaud et al., 1993) has determined Severe Effects Levels from simultaneously collected data on benthic invertebrate communities and chemical concentrations in freshwater sediments in Ontario. Lastly, the National Biological Service analyzed sediment bioassay data to derive Probable Effect Concentrations and other benchmarks for the Great Lakes (EPA, 1996).

None of the above sources had guidelines for chlorinated dioxins or -furans. EPA (1993) has calculated that the following dioxin TEQs in sediment may pose a risk to aquatic life and wildlife (ng/Kg).

Organism	Low Risk	High Risk (Sensitive Species)
Fish	60	100
Mammalian Wildlife	2.5	25
Avian Wildlife	21	210

No freshwater sediment guidelines were available for phenols, anilines, or retene. Except for retene, these compounds were infrequently detected in Similkameen River sediment and the concentrations were low.

There are marine guidelines for 2-methylphenol and retene. Ecology has a marine Sediment Quality Standard of 63 ug/Kg for 2-methylphenol (173-204 WAC). An Apparent Effects Threshold (AET) of 1,700 - 2,000 ug/Kg has been determined for retene in Puget Sound sediments (PTI, 1989). The AET approach was used to derive the state marine standards.

Similkameen River sediments were well within the above guidelines except for arsenic and di-N-butylphthalate. Arsenic exceeded the Ontario Severe Effects Level of 33 mg/Kg at sites 4 and 5 near Nighthawk, but did not exceed the other two freshwater guidelines for arsenic, both set at 57 mg/Kg. The di-N-butylphthalate concentration reported for site 7 behind Enloe Dam exceeded the Freshwater Sediment Quality Value for this compound. As previously noted, the accuracy of this result is questionable.

Table 8. Freshwater Sediment Quality Guidelines

Chemical Parameter	Freshwater Sediment Quality Value[1]	Severe Effects Level[2]	Probable Effect Concentration[3]
Metals (mg/Kg, dry weight)			
Iron	- -	40,000	- -
Aluminum	- -	- -	58,030
Manganese	1,800	1,100	1,081
Zinc	410	820	1,530
Lead	450	250	396
Copper	390	110	78
Chromium	260	110	160
Cadmium	5.1	10	12
Nickel	46	75	38
Arsenic	57	33	57
Mercury	0.41	2	- -
Antimony	3	- -	- -
Silver	6.1	- -	- -
Cyanide (mg/Kg, dry weight)	- -	0.1	- -
Organics (ug/Kg, dry weight)			
Total LPAH	27,000	- -	3,400
Total HPAH	36,000	- -	4,400
Total PAH	60,000	10,000	13,700
Di-N-butylphthalate	43	- -	- -
Carbazole	140	- -	- -
Dibenzofuran	32,000	- -	- -

[1]Cubbage et al. (1997)

[2]Persaud et al. (1993) - organics SELs are mg/Kg TOC; cyanide guideline is lowest effect level.

[3]EPA (1996)

Sediment Bioassays

Sediment bioassays have been conducted for four locations sampled in the Similkameen River in 1998: site 2 in the upper river near the border, site 5 near Nighthawk, and sites 7 and 9 behind Enloe Dam (Table 9). All sites showed some evidence of toxicity in the *Hyalella* amphipod test. Percent survival ranged from 10% at Enloe Dam site 7 to 60% near Nighthawk site 5. *Hyalella* survival in the laboratory control was 90%. These results show no obvious correlation with the concentrations of arsenic, other metals, or organic compounds measured in the samples.

Except for upper river site 2, the same samples tested non-toxic with Microtox. The EC-50 at site 2 was 29% (effective sediment concentration reducing light output by 50%). The metals and cyanide analysis of this sample failed to point to a reason for the effect. Organic compounds were not analyzed.

Table 9. Results of Bioassays on Similkameen River Sediment Samples

Site No.	Date	Sample No.	*Hyalella azteca* Percent Survival	Microtox EC-50 (%)
		UPPER RIVER		
2	23-Aug-98	398060	15*	29
		PALMER LAKE - NIGHTHAWK		
3	24-Aug-98	398061	NA	NA
4	24-Aug-98	398062	NA	NA
5	24-Aug-98	398063	60*	>20
		EAGLE ROCK		
6	24-Aug-98	398064	NA	NA
		ENLOE DAM		
7	23-Aug-98	398065	10*	>20
9	23-Aug-98	398066	42*	>20

* = significantly different (p<.005) from laboratory control (90% survival)
NA = not analyzed

Benthic Macroinvertebrates

Benthic macroinvertebrates and ancillary water quality data were collected at sites 2, 3, 4, 5, and 7 in 1998.

Water quality did not differ dramatically between sites, except for conductivity (Table 10). Surface water temperatures were generally cool except at site 7 in the upstream portion of the reservoir formed by Enloe Dam. Conductivity at site 3 was exceptionally high at 860 umhos/cm, likely a result of sluggish water movement at this site. Dissolved oxygen concentrations were moderate and did not present a significant source of stress to biological communities.

Table 10. Water Quality Conditions during Benthic Macroinvertebrate Sampling in the Similkameen River

Site No.	Date	Time	Temperature (^{o}C)	pH (S.U.)	Conductivity (umhos/cm)	D.O. (mg/L)
			UPPER RIVER			
2	24 Sept. 98	1415	12.4	8.2	248	9.9
			PALMER LAKE - NIGHTHAWK			
3	24 Sept. 98	1115	14.2	7.7	860	8.5
4	24 Sept. 98	1515	14.3	8.0	227	9.6
5	24 Sept. 98	0900	12.0	7.7	210	9.1
			ENLOE DAM			
7	23 Sept. 98	1245	16.7	8.4	232	9.5

Sediment volume from macroinvertebrate collections was examined for bias in abundance estimates (Appendix C). Sediment volumes did not appear to be related to the abundance of macroinvertebrates in samples. Site 4 had the largest abundance estimates and some of the larger sediment volumes collected, but may be due to greater organic content providing a food source for sediment-dwelling macroinvertebrates.

Most of the macroinvertebrates collected were classified as predators, collector-gatherers, or collector-filterers (Appendix C). Collector-gatherers dominated the biotic communities at all stations, particularly some genera of the family Chironomidae (midges). Samples were collected from depositional habitat and were expected to contain larger quantities of fine particulate organic material, the food source for collector-gatherers. Predators were found in similar abundance at all stations and is consistent with predictions based on predator-prey interactions (Vannote et al., 1980).

A metals tolerance index (MTI) was calculated for each replicate sample (Table 11). This index value provides an aggregate score that reflects the tolerance of community taxa to environmental degradation by metals. The MTI is calculated as follows:

$$MTI = \Sigma (\%RA_i * t_i)$$

where, $\%RA_i$ = percent relative abundance of taxon "i"
t_i = metals tolerance value of taxon "i"

Table 11. Metals Tolerance Index Scores for Benthic Macroinvertebrate Samples Collected from the Similkameen River in September 1998

Site No.	Rep. 1	Rep. 2	Rep. 3	Rep. 4	mean
			UPPER RIVER		
2	5.00	4.10	3.49	2.67	3.82
			PALMER LAKE - NIGHTHAWK		
3	3.89	4.67	4.33	4.52	4.35
4	4.50	4.22	4.53	4.73	4.50
5	3.89	3.69	4.11	3.63	3.83
			ENLOE DAM		
7	3.68	4.19	3.51	3.66	3.76

McGuire and Ingman (1996) developed the MTI with information collected from the Clark Fork River in Montana. They found that scores lower than 4 indicate little or no direct effect of metals on the macroinvertebrate community. The calibration of tolerance scores for taxa identified in the present project has not been completed.

Each site had an MTI score for at least one of the replicate samples that was higher than 4. Site 3 had three of the four replicates with MTI scores ranging from 4.33 to 4.67 and a mean value of 4.35. Site 4 had all four replicates with MTI scores greater than 4 (4.22 - 4.73, mean of 4.50). Most of the species collected from the river were moderately tolerant to metals accumulation in sediments, and community tolerance was reflected by the MTI scores.

Based on the MTI, a moderate metals effect is suggested for sites 3 and 4. Low-gradient locations like these where organic material is able to accumulate in sediments potentially have greater concentrations of adsorbed metals and other contaminants. Analysis of separately collected sediment samples shows this to be true for arsenic, copper, and other metals at site 4 (Table 4).

Mouthpart deformities were identified from chironomid specimens collected from each site (Table 12). The highest rate of deformities was found at site 3, a slow-moving side channel of the river. All deformities were detected in the genus *Chironomus*. A low rate of mouthpart deformities was found at site 4 near the Kabba-Texas mine. The largest abundance of *Chironomus* occurred at site 3. *Chironomus* larvae were absent at sites 5 and 7. A list of specific mouthpart deformities is provided in Appendix D.

Table 12. Mouthpart Deformities in Samples of *Chironomus* sp. Larvae Collected from the Similkameen River in September 1998

Site No.	Number of Larvae Collected	Number with Deformed Menta	Number with Deformed Pecten Epipharynges	Percent with Deformities
		UPPER RIVER		
2	28	0	0	0
		PALMER LAKE - NIGHTHAWK		
3	32	2	0	6.3
4	473	5	1	1.3
5	0	0	0	0
		ENLOE DAM		
7	0	0	0	0

More sampling would be needed to have confidence that there are significant site differences in the rate of *Chironomus* deformities. However, the results are consistent with the MTI in identifying sites 3 and 4 as potentially having some level of adverse effect on the benthic community.

Deformities in *Chironomus* mouthparts have been related to elevated levels of lead and copper in the sediments (Janssens de Bisthoven et al., 1998). Neither of these metals was strongly elevated in the sediment samples collected separately from sites 3 and 4. There is no information linking the rate of this type of deformity to arsenic contamination.

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Conclusions and Recommendations

Conclusions

The chemical and biological findings on sediment samples collected in the Similkameen River during 1995 – 1999 are summarized in Table 13.

Table 13. Summary of Sediment Quality Indicators for the Similkameen River

Indicator	Location:	Upper River		Palmer Lake - Nighthawk			Eagle Rock	Enloe Dam		
	Site No:	1	2	3	4	5	6	7	8	9
Chemicals exceeding guidelines		none	none	none	**arsenic**	**arsenic**	none	DBP?	none	none
Survival in *Hyalella* bioassay		na	**15%**	na	na	**60%**	na	**10%**	na	**42%**
EC-50 in Microtox bioassay		na	**29%**	na	na	>20%	na	>20%	na	>20%
Metals Tolerance Index		na	3.82	**4.35**	**4.50**	3.83	na	3.76	na	na
Chironomus deformities*		na	0%	**6.2%**	1.3%	sp. abs.	na	sp. abs.	na	na

Potentially significant findings highlighted in **BOLD**
DBP = di-N-butylphthalate (possibly due to laboratory contamination)
na = not analyzed
sp. abs. = species absent
*small sample size

Except for arsenic, the level of chemical contamination is low. Arsenic concentrations have exceeded sediment quality guidelines, but only in samples collected between Palmer Lake and Nighthawk. The most thorough chemical analyses have been on the Enloe Dam sediment cores and these have not identified any contaminants of significant concern. The levels of metals and organic compounds analyzed appear to be slightly higher in the surface than in the subsurface deposits behind the dam.

Only limited biological evaluations of the sediments have been conducted. There are inconsistencies in results from sediment bioassays. The benthic macroinvertebrate data again point to the Palmer Lake/Nighthawk area as potentially having a low-level metals contamination problem.

Areas in the Similkameen River that have slack-water during low-flow times of the year put biological communities at greater risk from contaminant exposure. Flooding and sediment transport appear to minimize the accumulation of metals in most areas. The condition of benthic macroinvertebrate communities that live in sand and fine sediments may change between years depending on the hydrologic condition of this basin.

Recommendations

Any further investigations into the quality of sediments in the Similkameen River should focus on the slow-moving reach that begins in the sloughs upstream of Palmer Lake and extends down through the Nighthawk area. Sampling should include Champneys and Edwards sloughs to fill this data gap. Because of the low gradient between the Similkameen River and Palmer Lake, and the potential for sediments to be deposited there during periods of flooding, the concentrations of metals in Palmer Lake sediments should be evaluated.

References

Cubbage, J., D. Batts, and J. Breidenbach. 1997. Creation and Analysis of Freshwater Sediment Quality Values in Washington State. Washington State Dept. Ecology, Olympia, WA. Pub. No. 97-323A.

Diggins, T.P. and K.M. Stewart. 1998. Chironomid deformities, benthic community composition, and trace elements in the Buffalo River (New York) Area of Concern. Journal of the North American Benthological Society 17(3): 311-323.

Ecology. 1995a. Sediment Management Standards. Washington Administrative Code (WAC) Chapter 173-204. Washington State Dept. Ecology, Olympia, WA.

Ecology. 1995b (draft). Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards. Washington State Dept. Ecology, Olympia, WA.

Ecology & Environment. 1991. Site Inspection Report for Kabba-Texas Mine, Nighthawk, Washington. Prep. for EPA Region 10, Seattle, WA.

EPA. 1990. Specifications and Guidance for Obtaining Contaminant-Free Sample Containers. U.S. Environmental Protection Agency, OSWER Directive #93240.0-05

EPA. 1993. Interim Report on Data and Methods for Assessment of 2,3,7,8-Tetrachloro-dibenzo-p-dioxin Risks to Aquatic Life and Associated Wildlife. U.S. Environmental Protection Agency, Office of Research and Development. EPA 600/R93-055.

EPA. 1996. Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod *Hyalella azteca* and the Midge *Chironomous riparious*. EPA 905/R96-008.

Epler, J.H. 1995. Identification Manual for the Larval Chironomidae (Diptera) of Florida (revised edition). Bureau of Surface Water Management, Florida Department of Environmental Protection, Tallahassee, FL.

Farag, A.M., D.F. Woodward, J.N. Goldstein, W. Brumbaugh and J.S. Meyer. 1998. Concentrations of metals associated with mining waste in sediments, biofilm, benthic macroinvertebrates, and fish from the Coeur d'Alene River Basin, Idaho. Archives of Environmental Contamination and Toxicology 34:119-127.

Janssens de Bisthoven, L., J.F. Postma, P. Parren, K.R. Timmermans and F. Ollevier. 1998. Relations between heavy metals in aquatic sediments and in *Chironomus* larvae of Belgian lowland rivers and their morphological deformities. Canadian Journal of Fisheries and Aquatic Sciences 55: 688-703.

Johnson, A., 1997. Survey of Metal Concentrations in the Similkameen River. Memorandum to J. Milton. Washington State Dept. Ecology, Olympia, WA.

McGuire, D.L. and G.L. Ingman. 1996. Clark Fork River Macroinvertebrate Community Biointegrity: 1994 assessment. Montana Department of Environmental Quality Report, Water Quality Division.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of Environment and Energy. ISBM 0-7729-9248-7.

Pommen, L.W. 1992. Personal communication. B.C. Ministry of Environment, Lands, and Parks, Victoria, BC.

Pommen, L.W. and A. Ryan. 1992. The Similkameen River Cyanide Puzzle. Presented at the Canada-B.C. Cyanide Workshop, October 9, 1992, North Vancouver, B.C. B.C. Environment, Water Quality Branch, and Environment Canada, Pacific and Yukon Region.

PSEP. 1996. Puget Sound Estuary Program (PSEP): Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. EPA Region 10, Office of Puget Sound, Seattle, WA.

PTI. 1989. Contaminated Sediments Criteria Report. Prep. for Washington State Dept. Ecology. PTI Environmental Services, Bellevue, WA.

Stewart, A., 1998 (draft). State of Water Quality of Similkameen River 1979 – 1997. Environment Canada and B.C. Ministry of Environment, Lands, and Parks.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137.

Warwick, W.F. and N.A. Tisdale. 1988. Morphological deformities in *Chironomus*, *Cryptochironomus*, and *Procladius* larvae (Diptera: Chironomidae) from two differentially stressed sites in Tobin Lake, Saskatchewan. Canadian Journal of Fisheries and Aquatic Sciences 45: 1123-1144.

Windholz, M. (ed). 1983. The Merck Index. Merck & Co., Rahway, NJ.

Yake, B., S. Singleton, and K Erickson. 1998. Washington State Dioxin Source Assessment. Washington State Dept. Ecology, Olympia, WA. Pub. No. 98-320.

Appendices

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Appendix A. Chemicals Analyzed in Similkameen River Sediment Samples

CAS No.	Chemical Name
Priority Pollutant Metals	
7440360	Antimony
7440382	Arsenic
7440417	Beryllium
7440439	Cadmium
7440473	Chromium
7440508	Copper
7439921	Lead
7439976	Mercury
7440020	Nickel
7782492	Selenium
7440224	Silver
7440280	Thallium
7440666	Zinc
Misc. Trace Elements	
7429905	Aluminum
7439896	Iron
7439954	Magnesium
7439965	Manganese
Cyanide	
57125	Cyanide
Semivolatile Organics	
50328	Benzo(a)pyrene
51285	2,4-Dinitrophenol
53703	Dibenzo(a,h)anthracene
56553	Benzo(a)anthracene
58082	Caffeine
59507	4-Chloro-3-Methylphenol
62533	Aniline
62759	N-Nitrosodimethylamine
65850	Benzoic Acid
67721	Hexachloroethane

CAS No.	Chemical Name
Semivolatile Organics	
77474	Hexachlorocyclopentadiene
78591	Isophorone
83329	Acenaphthene
84662	Diethylphthalate
84742	Di-N-Butylphthalate
85018	Phenanthrene
85687	Butylbenzylphthalate
86306	N-Nitrosodiphenylamine
86737	Fluorene
86748	Carbazole
87683	Hexachlorobutadiene
87865	Pentachlorophenol
88062	2,4,6-Trichlorophenol
88744	2-Nitroaniline
88755	2-Nitrophenol
88755	2-Nitrophenol
90120	1-Methylnaphthalene
90120	1-Methylnaphthalene
91203	Naphthalene
91203	Naphthalene
91576	2-Methylnaphthalene
91587	2-Chloronaphthalene
91941	3,3'-Dichlorobenzidine
92524	1,1'-Biphenyl
92875	Benzidine
95487	2-Methylphenol
95501	1,2-Dichlorobenzene
95578	2-Chlorophenol
95954	2,4,5-Trichlorophenol
98953	Nitrobenzene
99092	3-Nitroaniline
100016	4-Nitroaniline
100027	4-Nitrophenol
100516	Benzyl Alcohol

Appendix A. Chemicals Analyzed (continued)

CAS No.	Chemical Name
Semivolatile Organics	
101553	4-Bromophenyl-Phenylether
104405	Phenol, 4-Nonyl-
105679	2,4-Dimethylphenol
106445	4-Methylphenol
106467	1,4-Dichlorobenzene
106478	4-Chloroaniline
108601	2,2'-Oxybis[1-chloropropane]
108952	Phenol
110861	Pyridine
111444	Bis(2-Chloroethyl)Ether
111911	Bis(2-Chloroethoxy)Methane
117817	Bis(2-Ethylhexyl) Phthalate
117840	Di-N-Octyl Phthalate
118741	Hexachlorobenzene
120127	Anthracene
120821	1,2,4-Trichlorobenzene
120832	2,4-Dichlorophenol
121142	2,4-Dinitrotoluene
122667	1,2-Diphenylhydrazine
129000	Pyrene
131113	Dimethylphthalate
132649	Dibenzofuran
132650	Dibenzothiophene
191242	Benzo(ghi)perylene
192972	Benzo[e]pyrene
193395	Indeno(1,2,3-cd)pyrene
198550	Perylene
205992	Benzo(b)fluoranthene
206440	Fluoranthene
207089	Benzo(k)fluoranthene
208968	Acenaphthylene
218019	Chrysene
360689	3B-Coprostanol
Semivolatile Organics	
483658	Retene
534521	4,6-Dinitro-2-Methylphenol
541731	1,3-Dichlorobenzene
581420	2,6-Dimethylnaphthalene
606202	2,6-Dinitrotoluene
621647	N-Nitroso-Di-N-Propylamine
832699	1-Methylphenanthrene
2245387	1,6,7-Trimethylnaphthalene
2531842	2-Methylphenanthrene
7005723	4-Chlorophenyl-Phenylether
Polychlorinated Biphenyls	
11096825	PCB - 1260
11097691	PCB - 1254
11104282	PCB - 1221
11141165	PCB - 1232
12672296	PCB - 1248
12674112	PCB - 1016
53469219	PCB - 1242
Organochlorine Pesticides	
50293	4,4'-DDT
53190	2,4'-DDD
58899	Gamma-BHC (Lindane)
60571	Dieldrin
72208	Endrin
72435	Methoxychlor
72548	4,4'-DDD
72559	4,4'-DDE
76448	Heptachlor
115322	Kelthane
133062	Captan
309002	Aldrin

Appendix A. Chemicals Analyzed (continued)

CAS No.	Chemical Name	CAS No.	Chemical Name
Organochlorine Pesticides		**Nitrogen-Containing Pesticides**	
319846	Alpha-BHC	957517	Diphenamid
1024573	Heptachlor Epoxide	1114712	Pebulate
1031078	Endosulfan Sulfate	1134232	Cycloate
2385855	Mirex	1194656	Dichlobenil
2425061	Captafol	1582098	Treflan (Trifluralin)
3424826	2,4'-DDE	1610179	Atraton
5103719	Cis-Chlordane (Alpha-Chlordane)	1610180	Prometon (Pramitol 5p)
5103731	Cis-Nonachlor	1861401	Benefin
5103742	Trans-Chlordane (Gamma)	1897456	Chlorothalonil (Daconil)
7421934	Endrin Aldehyde	1912249	Atrazine
8001352	Toxaphene	1918167	Propachlor (Ramrod)
27304138	Oxychlordane	1929777	Vernolate
33213659	Endosulfan II	2008415	Butylate
39765805	Trans-Nonachlor	2212671	Molinate
53494705	Endrin Ketone	2303164	Di-allate (Avadex)
56534022	Alpha-Chlordene	2303175	Triallate
5653404G	Gamma-Chlordene	5234684	Carboxin
319857	Beta-BHC	5902512	Terbacil
319868	Delta-BHC	7287196	Prometryn
789026	2,4'-DDT	15299997	Napropamide
959988	Endosulfan I	15972608	Alachlor
1022226	DDMU	21087649	Metribuzin
		21725462	Cyanazine
Nitrogen-Containing Pesticides		23184669	Butachlor
63252	Carbaryl	23950585	Pronamide (Kerb)
101213	Chlorpropham	26399360	Profluralin
113484	MGK264	27314132	Norflurazon
122349	Simazine	34014181	Tebuthiuron
122394	Diphenylamine	40487421	Pendimethalin
139402	Propazine	42874033	Oxyfluorfen
314409	Bromacil	43121433	Triadimefon
330541	Diuron	51218452	Metolachlor
759944	Eptam	51235042	Hexazinone
834128	Ametryn	55283686	Ethalfluralin (Sonalan)
886500	Terbutryn (Igran)	57837191	Metalaxyl

Appendix A. Chemicals Analyzed (continued)

CAS No.	Chemical Name
Nitrogen-Containing Pesticides	
59756604	Fluridone
60168889	Fenarimol
Organophosphorus Pesticides	
55389	Fenthion
56382	Parathion
56724	Coumaphos
60515	Dimethoate
62737	Dichlorvos (DDVP)
78342	Dioxathion
78488	Tribufos (DEF)
86500	Azinphos (Guthion)
115902	Fensulfothion
121755	Malathion
122145	Fenitrothion
126750	Demeton-S
150505	Merphos (1 & 2)
297994	Phosphamidan
298000	Methyl Parathion
298022	Phorate
298033	Demeton-O
298044	Disulfoton (Di-Syston)
299843	Ronnel
333415	Diazinon
563122	Ethion
732116	Imidan
786196	Carbophenothion
944229	Fonofos
950356	Methyl Paraoxon
961115	Tetrachlorvinphos (Gardona)
2104645	EPN
2652719	Azinphos Ethyl
2921882	Chlorpyriphos
3383968	Abate (Temephos)
Organophosphorus Pesticides	
3689245	Sulfotepp
5598130	Methyl Chlorpyrifos
7786347	Mevinphos
13194484	Ethoprop
22224926	Fenamiphos
31218834	Propetamphos
35400432	Bolstar (Sulprofos)
Polychlorinated Dibenzo-p-dioxins	
1746016	2,3,7,8-TCDD
40321764	1,2,3,7,8-PeCDD
39227286	1,2,3,4,7,8-HxCDD
57652857	1,2,3,6,7,8-HxCDD
19408743	1,2,3,7,8,9-HxCDD
35822469	1,2,3,4,6,7,8-HpCDD
3268879	OCDD
Polychlorinated Dibenzofurans	
51207319	2,3,7,8-TCDF
57117416	1,2,3,7,8-PeCDF
57117314	2,3,4,7,8-PeCDF
70648269	1,2,3,4,7,8-HxCDF
57117449	1,2,3,6,7,8-HxCDF
60851345	2,3,4,6,7,8-HxCDF
72918219	1,2,3,7,8,9-HxCDF
67562394	1,2,3,4,6,7,8-HpCDF
55673897	1,2,3,4,7,8,9-HpCDF
39001020	OCDF

Appendix B. Location of Ecology Sediment Sampling Sites in the Similkameen River, 1995-99

Site No.	Description	River Mile	Latitude	Longitude
1	Chopaka Bridge, B.C.	36.1	49 04 48	119 42 36
2	Left bank near Norman Cutchie residence	23.8	48 58 23	119 42 25
3	Backwater area in river bend	21.0	48 56 36	119 39 57
4	Right bank near public fishing access above Kabba-Texas	19.2	48 56 31	119 39 24
5	Above Nighthawk bridge	17.7	48 57 11	119 38 54
6	Right bank off Eagle Rock	11.7	48 58 54	119 32 19
7	Upper Enloe Dam impoundment	9.8	48 58 40	119 30 33
8	Middle Enloe Dam impoundment	9.6	48 58 24	119 30 33
9	Lower Enloe Dam impoundment	8.9	48 58 01	119 29 59

NAD27 datum

Appendix C. Benthic Macroinvertebrate Data for the Similkameen River, Collected September 23-24, 1998

Taxon	Functional Feeding Group	Metals Index	Site Number 2				Site Number 3				Site Number 4			
			Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep. 3	Rep. 4
Oligochaeta:Tubificidae (imm.)	CG	6					4	4	3	4	33	25	42	127
Oligochaeta:Tubificidae:*Limnodrilus* sp.	CG													
Oligochaeta:Naididae (imm.)	CG	5											1	
Oligochaeta:Naididae:*Ophiodonais serpentina*	CG													
Pelecypoda: Sphaeriidae	CG	3												
Acari	PA	5								1		1		2
Cladocera: Macrothricidae:*Ilyocryptus* sp.	CF						1				16	33	33	51
Ostracoda	CG										5	14	9	17
Copepoda: Cyclopoida	CG										6	1	4	12
Ephemeroptera: Baetidae:*Baetis tricaudatus*	CG	5									1			
Ephemeroptera: Tricorythidae:*Tricorythodes* sp.	CG	4			1									
Ephemeroptera: Caenidae:*Caenis* sp.	CG	3								1				
Trichoptera: Leptoceridae:*Oecetis* sp.	OM	3									1			
Coleoptera: Elmidae:*Dubiraphia* sp.	CG	4									6	6	4	7
Diptera: Simuliidae:*Simulium* sp.	CF	5									1			
Diptera: Tipulidae:*Hexatoma* sp.	PR	2				2								
Diptera: Empididae:*Hemerodromia* sp.	PR	4												
Diptera: Ceratopogonidae:*Culicoides* sp.	PR	5	6	2			4	5	1	3	5	4	3	
Diptera: Chironomidae:*Chironomus* sp.	CG	4		28			11	3	10	8	81	115	105	172
Diptera: Chironomidae:*Cryptochironomus* sp.	PR	5												
Diptera: Chironomidae:*Demicryptochironomus* sp.	CG	4												
Diptera: Chironomidae:*Lipiniella* sp.	UN						1	2						
Diptera: Chironomidae:*Microtendipes* sp.	CG	4												
Diptera: Chironomidae:*Paracladopelma* sp.	UN	4			1									
Diptera: Chironomidae:*Phaenopsectra* sp.	SC	4												
Diptera: Chironomidae:*Polypedilum* sp.	OM	4			4				3		1		1	
Diptera: Chironomidae:*Robackia* sp.	CG	4		7		1								1
Diptera: Chironomidae:*Stichtochironomus* sp.	CG				4		1				2	1		
Diptera: Chironomidae:*Cladotanytarsus* sp.	CG	3			15									
Diptera: Chironomidae:*Stempellinella* sp.	UN				1									
Diptera: Chironomidae:*Tanytarsus* sp.	CF	3			8		22	3	1	3	6	20	5	17
Diptera: Chironomidae:*Nanocladius* sp.	CG	4			1									
Diptera: Chironomidae:*Orthocladius* sp.	CG	5		1	5									
Diptera: Chironomidae:*Odontomesa* sp.	CG	5		1									1	
Diptera: Chironomidae:*Procladius* sp.	PR	5					5			5	4	4	4	2
Diptera: Chironomidae:*Thienemannimyia* sp.	PR	3												
Diptera: Chironomidae:unidentified pupae	UN				3		3	2	1	1	3		2	1
TOTAL			6	39	43	3	52	19	19	26	171	224	214	409
Sediment volume (ml.)			795	1260	860	1160	965	650	610	690	990	1070	990	940
Estimated density of organisms (# per square foot)			12	78	86	6	104	38	38	52	342	448	428	818
Community Metals Index Tolerance Score			5.00	4.10	3.49	2.67	3.89	4.67	4.33	4.52	4.50	4.22	4.53	4.73

Appendix C. Benthic Macroinvertebrate Data (continued)

Taxon	Site Number 5				Site Number 7				Functional Feeding Group Code:
	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Rep. 1	Rep. 2	Rep. 3	Rep. 4	
Oligochaeta:Tubificidae (imm.)	1		6	1					CG = collector gatherer
Oligochaeta:Tubificidae:*Limnodrilus* sp.					1				PA = parasite
Oligochaeta:Naididae (imm.)						3	3	3	OM = omnivore
Oligochaeta:Naididae:*Ophiodonais serpentina*	1								CF = collector-filterer
Pelecypoda: Sphaeriidae			1						SC = scraper
Acari				1		1		1	UN = unknown
Cladocera: Macrothricidae:*Ilyocryptus* sp.									
Ostracoda									
Copepoda: Cyclopoida									
Ephemeroptera: Baetidae:*Baetis tricaudatus*									
Ephemeroptera: Tricorythidae:*Tricorythodes* sp.									
Ephemeroptera: Caenidae:*Caenis* sp.				1					
Trichoptera: Leptoceridae:*Oecetis* sp.								1	
Coleoptera: Elmidae:*Dubiraphia* sp.			1						
Diptera: Simuliidae:*Simulium* sp.									
Diptera: Tipulidae:*Hexatoma* sp.									
Diptera: Empididae:*Hemerodromia* sp.				1					
Diptera: Ceratopogonidae:*Culicoides* sp.	6	1	2	4		3		1	
Diptera: Chironomidae:*Chironomus* sp.									
Diptera: Chironomidae:*Cryptochironomus* sp.					1	2	3	3	
Diptera: Chironomidae:*Demicryptochironomus* sp.	2								
Diptera: Chironomidae:*Lipiniella* sp.	4			1	2	8	2	1	
Diptera: Chironomidae:*Microtendipes* sp.							1		
Diptera: Chironomidae:*Paracladopelma* sp.	1	2				2	2	2	
Diptera: Chironomidae:*Phaenopsectra* sp.					1				
Diptera: Chironomidae:*Polypedilum* sp.									
Diptera: Chironomidae:*Robackia* sp.	2	20			31			1	
Diptera: Chironomidae:*Stichtochironomus* sp.			1		6	10	34	24	
Diptera: Chironomidae:*Cladotanytarsus* sp.		7			6	4	6	6	
Diptera: Chironomidae:*Stempellinella* sp.									
Diptera: Chironomidae:*Tanytarsus* sp.	11	4	14	23	11	3	13	11	
Diptera: Chironomidae:*Nanocladius* sp.						1			
Diptera: Chironomidae:*Orthocladius* sp.									
Diptera: Chironomidae:*Odontomesa* sp.									
Diptera: Chironomidae:*Procladius* sp.	1		4	4		2			
Diptera: Chironomidae:*Thienemannimyia* sp.	2	1			3		1		
Diptera: Chironomidae:unidentified pupae		2	4	2	4	3	2	4	
TOTAL	31	37	33	38	66	42	67	58	
Sediment volume (ml.)	525	510	490	525	615	750	560	640	
Estimated density of organisms (# per square foot)	62	74	66	76	132	84	134	116	
Community Metals Index Tolerance Score	3.89	3.69	4.11	3.63	3.68	4.19	3.51	3.66	

Appendix D. Details on Mouthpart Deformities in Samples of *Chironomus* sp. Larvae Collected from the Similkameen River in September 1998

Slide number	Station and replicate	Deformity (using definitions of Warwick & Tisdale, 1988)	Reference (to Figures in Warwick & Tisdale, 1988)
1	Sta. 2 Rep. 1	integral deformity	Figure 5 t
2	Sta. 2 Rep. 3	missing outer lateral tooth	Figure 5 k
3, specimen A	Sta. 3 Rep. 1	fused median tooth	Figure 4 m
3, specimen B	Sta. 3 Rep. 1	split median tooth	Figure 4 h
4	Sta. 3 Rep. 1	split median tooth	Figure 4 h
5	Sta. 3 Rep. 1	malformed median tooth	Figure 4 e
6	Sta. 3 Rep. 2	Kohn gap, median tooth	Figure 4 n
7	Sta. 3 Rep. 3	fused teeth of pecten epipharyngis	Figure 10 f