A Department of Ecology Report

WASHINGTON STATE
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ECOLOGY

Assessment of Metals Contamination in Sediments of Gibbons Creek Remnant Channel

Summary

Priority pollutant metals were analyzed in sediment samples collected in January 1998 from Gibbons Creek remnant channel in the vicinity of Camas-Washougal Industrial Park and the Pendleton Woolen Mill (PWM) land application site. The objectives were to determine the extent and significance of the contamination reported by previous investigators and to determine if the PWM sprayfield was a contributing source. Three industrial park facilities upstream of PWM had been identified as sources of chromium, arsenic, and copper.

Results showed that arsenic concentrations increased by an order of magnitude in channel sediments below 32nd Street (upstream limit of contamination) and that zinc, chromium, copper, lead, and cadmium increased by factors of 2–3. The highest arsenic concentration occurred below the 32nd Street storm sewer, which serves Allweather Wood Treaters and Burlington Environmental, previously identified sources of arsenic and other metals. The highest concentrations of chromium, copper, and other metals were found further downstream below the third known source, Exterior Wood, but is probably due to a combination of discharges to the channel. No appreciable elevations were observed in the other metals analyzed: nickel, mercury, silver, beryllium, and selenium. These findings are consistent with results from an earlier survey in 1990. Due to analytical difficulties, no useful data were obtained on antimony or thallium.

Sediments from three of the 12 sites analyzed in the remnant channel had arsenic concentrations ranging from 49–62 mg/Kg, a level expected to have an adverse effect on sediment-dwelling organisms. Sediments at nine sites exceeded the MTCA soil cleanup level for arsenic of 20 mg/Kg. With the exception of one area near the PWM sprayfield that exceeded adverse effects levels for zinc and chromium, and the MTCA soil cleanup level for chromium, other metals were not found in concentrations considered to be a significant concern.

by Art Johnson
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PWM biosolids and sprayfield surface soils had an order of magnitude higher concentrations of zinc and chromium than sediments in the remnant channel and several times higher concentrations of copper. There was equivocal evidence of biosolids being present in the sediments at one location only, Site E at the extreme downstream end of the channel. Sediments at this location had higher zinc, chromium, and copper concentrations than elsewhere in the creek and had zinc:chromium ratios that approached those in sprayfield soils and biosolids. There were no indications that the sprayfield was a source of metals contamination to any other part of the channel.

Samples were examined microscopically to determine if wool fibers could be used as a tracer of the biosolids. Only a few badly deteriorated fibers were identified at Site E, and none could be conclusively identified at other locations adjacent to the sprayfield. The analyst concluded that the fibers were poor tracers of the biosolids because of their low mobility once applied to soil and finite life in the environment.

Selected sediment samples were analyzed for petroleum and the pesticide dieldrin, a chemical of concern at PWM. A high concentration of total petroleum hydrocarbons (TPH), estimated at 40,000 mg/Kg, was identified in the sediments at Site E. This appeared to be lube oil. The MTCA cleanup level for TPH in soil and industrial soil is 200 mg/Kg. It was not possible to determine if oil may have contributed to the elevated metal concentrations seen at this site. No dieldrin was detected in the sediments at detection limits of 1.2-3.2 ug/Kg, a finding in keeping with historical data.

Recommendations

1. Eliminate sources of arsenic to Gibbons Creek remnant channel.

2. During the season when Pendleton Woolen Mill sprayfield is in use, inspect the area at the downstream end of the remnant channel (adjacent to Site E in this study) for evidence of runoff to the channel.

3. Investigate potential sources of petroleum to the channel in the vicinity of Site E.

Background

The Department of Ecology, Environmental Investigations and Laboratory Services Program (EILS), conducted a survey of metal concentrations in the remnant channel of Gibbons Creek, in the vicinity of Camas/Washougal Industrial Park and the Pendleton Woolen Mill (PWM) land application site (Figure 1). This part of the creek was re-routed in 1992 to flow directly south into the Columbia River through Steigerwald Lake National Wildlife Refuge, rather than west along the industrial park.

A previous Ecology study had concluded that the remnant channel sediments are contaminated with chromium, arsenic, copper, and, to a lesser extent, zinc, cadmium, and lead (Erickson and Tooley, 1996). Sources of contamination include, but may not be limited to, facilities in the industrial park. Allweather Wood Treaters and Exterior Wood have NPDES discharges of stormwater runoff to the channel that are sources of chromium, arsenic, and copper. Their outfalls are scheduled to be removed. Ground water beneath Burlington Environmental is contaminated with arsenic (and solvents). A sewer that discharges at 32nd Street receives stormwater from Allweather Wood and drains contaminated ground water beneath Burlington Environmental. Exterior Wood's discharge is located further downstream between 27th Street and the PWM sprayfield. The location of other storm sewers is poorly documented and most are inaccessible.

PWM applies waste-activated sludge to a six-acre field that borders the lower shoreline of the remnant channel. Application takes place from April through October and has been going on since the mid-1970s. Up until 1993, applications occurred year-round (CH2M Hill, 1992a). Although the sprayfield soils have high concentrations of chromium and zinc (Carey, 1996), sampling of the adjacent channel sediments by CH2M Hill (1992b) showed a gradient of increasing concentrations going away from the sprayfield. PWM has argued this indicates the source is on the opposite bank (i.e., Exterior Wood).

The main objectives of the present survey were to: 1) assess the extent and significance of metals contamination in the surface sediments between 32nd Street and the channel mouth, and 2) determine if PWM biosolids are a contributing source.

Selected samples were also analyzed for the pesticide dieldrin and total petroleum hydrocarbons (TPH). Dieldrin, a chemical of concern at PWM, was analyzed to confirm previous findings by CH2M Hill that the channel sediments have not been contaminated. Petroleum was analyzed at the suggestion of Bob Carrell, Manchester Environmental Laboratory (MEL), based on a preliminary examination of one of the sediment samples.

Survey Description

Sampling locations are shown in Figure 1. Sampling sites were located above and below known or suspected stormwater inputs, and included sites that had been sampled previously by CH2M Hill (1992b) and Erickson and Tooley (1996). Sites 1–10 were from center channel, with the uppermost – Site 1 above 32nd Street – being upstream of known sources of contamination. Sites A through E were near shore, adjacent to the PWM sprayfield.

Field work was conducted on January 8, 1998. Each sediment sample consisted of a composite of the top 2-cm layer from three grabs. Samples could only be obtained at 12 of the 15 sites planned for the remnant channel because the bottom was rocky at Sites 2, 3, and 5.

Samples of the surface soils (top 2-cm) were collected from three areas of the sprayfield, PWM -1, -2, and -3. These samples were located where residual biosolids from last year's applications were evident, judged from their dark black color, reasoning that this would be the material most vulnerable to surface runoff. A biosolids sample (aeration basin return activated sludge) was also obtained.

Channel sediments were analyzed for the 13 EPA priority pollutant metals, grain size, total organic carbon (TOC), and percent solids. Soil and biosolids samples were analyzed similarly, except grain size was not done. Selected samples were examined microscopically for evidence of PWM biosolids. Dieldrin was analyzed in samples from Sites 7, 8, and E; TPH was analyzed for Sites 1, 6, 8, and E.

A quality assurance plan was prepared for this survey (Johnson, 1997).

Sampling Methods

Channel sediments were collected with a 0.05 m^2 stainless steel Ponar grab. A grab was considered acceptable if not over-filled with sediment, overlying water was present and not excessively turbid, the sediment surface relatively flat, and desired depth penetration achieved. Material touching the side walls of the grab was not taken. Sprayfield soils were collected with stainless steel scoops.

The sediment and soil samples were placed in stainless steel buckets and homogenized by stirring. Subsamples of the homogenate were placed in 4-oz. or 8-oz. glass jars with teflon lid liners, cleaned to EPA QA/QC specifications (EPA, 1990), or in Whirl-Pak bags for grain size. A one-gallon glass jar of the same type was used for the biosolids sample.

Stainless steel scoops, buckets, and spoons used to manipulate the sediments were cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, deionized water, and pesticide-grade acetone. The equipment was then air-dried and wrapped in aluminum foil. The same procedures were used to pre-clean the grab before going into the field. Between-sample cleaning of the grab consisted of thorough brushing and rinsing with site water.

All samples were put in individual polyethylene bags and placed on ice immediately after collection. They were transported to MEL within two days. Chain-of-custody was maintained (Appendix A).

Analytical Methods

Samples were analyzed at MEL, except for grain size which was done by Rosa Environmental, a contract laboratory selected by MEL.

Antimony, beryllium, cadmium, chromium, copper, lead, nickel, silver, and zinc were digested by EPA method 3050 (nitric acid and hydrogen peroxide) and analyzed by inductively coupled plasma (ICP), EPA method 200.7. Arsenic, selenium, and thallium were digested by EPA method 3050 and analyzed by graphite furnace atomic adsorption (GFAA), using EPA methods 206.2, 270.2, and 279.2, respectively. Mercury was digested and analyzed by EPA method 245.5, cold vapor atomic adsorption (CVAA). Determination of grain size and TOC followed the Puget Sound Estuary Protocols (EPA, 1996). Percent solids were analyzed by EPA method 160.3.

Samples selected for dieldrin analysis were extracted with acetone, exchanged to hexane, florisiled, and analyzed by capillary gas chromatography/electron capture detection (CC/ECD) following EPA SW-846 method 8080. Petroleum hydrocarbons were extracted into methylene chloride and analyzed by gas chromatography/flame ionization detection (GC/FID) using MEL's modification of EPA SW-846 methods 8000, 8015, and 3540. A stereo microscope was used to look for wool fibers.

Data Quality

Data quality for this project is good, except for antimony and thallium where no useful results were obtained. Antimony was not recovered in the matrix spikes or in a laboratory control sample. Thallium spike recoveries were low, 10-11%. Results for silver and chromium were marginally outside control limits. MEL qualified the silver data as estimated values; the chromium data were deemed acceptable without qualification. No problems were encountered in the other analyses. Appendix B contains the complete data reports and case narratives by MEL staff.

The precision of the data reported here can be gauged from results of duplicate analyses conducted on samples from Sites 8 and C and the biosolids sample (Table 1). Agreement between duplicates was within 20% or better for most constituents. Dieldrin and TPH were not analyzed in duplicate.

Results and Discussion

Metal Concentrations in Channel Sediments

The metal concentrations measured in remnant channel sediments are shown in Table 2, along with general physical/chemical parameters.

Sediments tended to be relatively coarse in the upper part of the study area, becoming finer downstream (>58% sand + clay). As previously noted, the bottom appeared to have been scoured at Sites 2, 3, and 5 where no samples could be obtained. The sediments in the lower channel were unconsolidated and had a high water content. TOC levels were variable, ranging from 1.6 to 11%.

Metals present in the highest concentrations were zinc (79-762 mg/Kg, dry weight) and chromium (19-364 mg/Kg), followed by copper (17-70 mg/Kg) and arsenic (5.6-53 mg/Kg). Arsenic concentrations increased by an order of magnitude downstream of Site 1 just above 32nd Street, while zinc, chromium, copper, lead, and cadmium increased by factors of 2-3. Concentrations of the other metals analyzed – nickel, mercury silver, beryllium, and selenium – did not increase appreciably going downstream.

The center channel data for those metals showing elevations are plotted in Figure 2. The highest arsenic concentration occurred below the 32nd Street storm sewer, suggesting it may be the major arsenic source to this reach of the channel. For other metals the highest concentrations were downstream of Exterior Wood's NDPES discharge. Although the sample closest to the outfall (Site 6) was among the least contaminated it was also comprised of the coarsest material collected (17% fines). The elevated metal concentrations further downstream of this outfall are probably best attributed to effects from a combination of discharges to the channel.

Previous Metals Data

The metals data obtained by CH2M Hill (1992b) on remnant channel sediments collected in 1990 are summarized in Table 3 and compared to present survey results. Although the CH2M Hill samples consisted of deeper sediment layers (top 10 cm vs. top 2 cm) and the sampling sites for the two studies did not coincide exactly, the data sets are in very close agreement. For example, median concentrations of zinc and chromium for Ecology and CH2M Hill, respectively, were 198 vs. 160 and 74 vs. 73 mg/Kg for center channel samples and 157 vs. 165 and 57 vs. 54 mg/Kg for right bank samples along the PWM sprayfield. CH2M Hill did not analyze for arsenic.

More recent but limited results on the sediment samples analyzed by Erickson and Tooley in 1994 are shown in Table 4. Appendix C has a map of sample locations. Only two of their sites, RC2 below 32nd Street and RC1 at the fork in the lower channel, were within the portion of channel sampled in 1990 and 1998. Metal concentrations in these two samples tended to be lower than found in the other two surveys.

The metal concentrations Erickson and Tooley measured further upstream in Steigerwald Wildlife Refuge (RC4) are almost identical to present study results immediately above 32nd Street. Concentrations in this range are typical of uncontaminated stream sediments and terrestrial soils (PTI, 1989-draft; San Juan, 1994). They report even lower concentrations at RC3, perhaps a reflection of the coarse material in this sample (Table 4).

Metals Criteria for Sediments

Table 5 compares results of the 1998 survey to lowest apparent effects thresholds (LAET) for freshwater aquatic life and to soil cleanup levels in the Model Toxics Control Act (MTCA). The LAET were developed by EILS from a statistical analysis of chemical and bioassay data on 245 sediment samples from Washington and Oregon (Cubbage et al., 1997). The LAET, along with Ecology's marine sediment quality standards (SQS), were concluded to be the most efficient and sensitive criteria for predicting biological effects of metals in sediments. The Cubbage et al. values are guidelines and have no regulatory status.

LAET are used here because they were derived for freshwater and are slightly more efficient (better likelihood of correctly predicting impacted sites) than the SQS. The LAET for metals tend to be slightly higher (i.e., more conservative) than the corresponding SQS. Appendix D shows how the LAET, SQS, MTCA, and various other sediment quality criteria compare.

As shown in Table 5, three of the 12 sites sampled in the remnant channel exceeded the LAET of 40 mg/Kg for arsenic – Site 4 below 32nd Street (62 mg/Kg) and Sites 7 and 8 in the lower channel (49-53 mg/Kg) – and several other sites approach the LAET. One site, Site E at the end of the channel next to PWM sprayfield, exceeded LAETs for chromium and zinc.

Figure 3 plots the 1998 data for arsenic, zinc, chromium, cadmium, lead, and copper as percent of LAET. These are the six metals that had been previously identified as sediment quality concerns in the remnant channel. Arsenic stands out as being the only metal with significant potential for sediment toxicity. With the exception of chromium and zinc at Site E, concentrations of other metals are well below thresholds for adverse effects.

Erickson and Tooley used a lowest effect level (LEL) developed in Ontario (Persaud et al., 1993) to conclude that metals other than arsenic were a significant problem. Because the LEL is tolerated by most (95%) benthic organisms, its simple exceedance is not necessarily an indicator of substantial toxicity. (See Appendix D for comparison with other sediment criteria.)

Most sites in the remnant channel (9 of 12) exceeded the MTCA soil cleanup level for arsenic of 20 mg/Kg (Table 5). Site E also exceeded MTCA for chromium, but not for zinc. No sites exceeded the MTCA cleanup levels for industrial soil; for arsenic and chromium these are 200 mg/Kg and 500 mg/Kg, respectively.

Source Evaluation of PWM Sprayfield

Results from metals analysis of the PWM soil and biosolids samples are at the bottom of Table 2. Relative to channel sediments these materials had an order of magnitude higher concentrations of zinc (1210-2670 mg/Kg) and chromium (1380-1740 mg/Kg). Copper concentrations are also several times higher than in the channel. All other metals analyzed at PWM were at similar or lower levels than found in the adjacent sediments.

Carey (1996) reports much lower concentrations of zinc, chromium, and copper in the sprayfield soils. This discrepancy likely stems from including deeper soils in the samples, 6–8 inches vs. approximately 1 inch, and that sampling sites for the present study were preferentially chosen to include residual biosolids.

Figure 4 shows the distribution of chromium and zinc in sediment and soil samples in the vicinity of the sprayfield. Four of the five near-shore sediment samples by PWM, A through D, had significantly lower concentrations than samples collected further off shore at sites 7–10 in center channel (Mann-Whitney, $p<.05$). These findings mirror CH2M Hill results from quarter point transects collected in 1990 (Appendix E). Taken together, results of these two surveys clearly point to sources on the opposite bank and/or upstream of PWM.

As already noted, Site E at the extreme downstream end of the channel next to the sprayfield had elevated concentrations of zinc (762 mg/Kg) and chromium (364 mg/Kg). These concentrations are one to two orders of magnitude higher than elsewhere in the channel. Based on visual observations during sample collection, it appeared that the lowest part of the bank along the sprayfield is above Site E and that, if biosolids are entering the channel, this would be the most likely route.

The conclusion that Site E may be contaminated with PWM biosolids is supported by examining zinc:chromium ratios (Figure 5). The ratio was 0.9–1.7 in PWM soil and biosolids samples, 2.1 in Site E sediments, and 2.2–4.2 in other sediment samples. Copper was higher at Site E than in other sediment samples (70 mg/Kg vs. 17-56 mg/Kg) which is also consistent with the presence of biosolids.

The PWM biosolids and soil samples were examined microscopically at MEL and compared to sediment samples from Sites A – E (Appendix F). The biosolids sample had 100-150 wool fibers per milliliter. Soil samples had "5% to 15%" of this number of fibers and "most showed significant deterioration". Some of the fibers were dyed and easily recognized (see photos in appendix).

A few badly deteriorated fibers could be seen in the sediment sample from Site E, but none could be conclusively identified at Sites A through D. The analyst concluded that the fibers are "a good indicator of where biosolids have been sprayed, but are probably poor indicators of biosolids mobility due to their entrapment in the soil" – because of their morphology – and " finite lifetime in the environment". The remainder of the biosolids material is amorphous and not easily traceable (Dickey Huntamer, MEL, personal communication).

Petroleum Hydrocarbons and Dieldrin

Results for the subset of sediment samples analyzed for TPH and dieldrin are shown in Table 6.

The sediments at Site E were heavily contaminated with petroleum and had a TPH concentration estimated at 40,000 mg/Kg. This appeared to be lube oil (Bob Carrell, MEL, personal communication). The applicable MTCA Method A cleanup level is 200 mg/Kg for both soil and industrial soil. The extent to which lube oil may have contributed to the elevated concentrations of zinc, chromium, and copper observed here, possibly from wear materials or additives in the oil, cannot be determined.

Some lubricating oil may have been present at two of the other three sites analyzed (6 and 8; Table 6). However, because of the large amount of interference from naturally occurring organic material in these samples, it was not possible for the analyst to confirm it was petroleum.

No dieldrin was detected at detection limits of 1.3-3.2 ug/Kg. Sediment concentrations below this range are not considered toxic (Cubbage et al., 1997; Batts and Cubbage, 1995; Nowell and Resek, 1994). Similar results were obtained for dieldrin in the CH2M Hill 1990 sediment samples.

Conclusions

Results from this study indicate that arsenic is currently the metal of most concern in the sediments of Gibbons Creek remnant channel. Sediments in several parts of the channel have arsenic concentrations that exceed or approach levels associated with adverse effects on sediment-dwelling organisms, and most areas exceed MTCA soil cleanup levels. Although there are some increases in other metals, most notably chromium and zinc, the concentrations are generally well below those associated with biological effects and cleanup levels.

Elevated concentrations and ratios of zinc, chromium, and copper in sediments at the end of the channel near PWM sprayfield provide equivocal evidence for the presence of biosolids. This finding was confirmed to a very limited extent through microscopic analysis. However, metals potentially associated with the lube oil detected at this site are a possible confounding factor. There were no indications of PWM biosolids in Gibbons Creek remnant channel upstream of this site.

Lube oil or other petroleum hydrocarbons could not be conclusively identified in sediments from other parts of the channel. No dieldrin contamination was detected, in keeping with historical data.

Acknowledgements

The assistance of Pendleton Woolen Mill employees Anna Lee and Noah Harvey in obtaining biosolids and soil samples for this study is very much appreciated. Manchester Laboratory staff who participated in sample analysis included Jim Ross, Randy Knox, Susan Davis, Sally Cull, Dickey Huntamer, Myrna Mandjikov, Bob Carrell, Debbie Lacroix, and Aileen Richmond.

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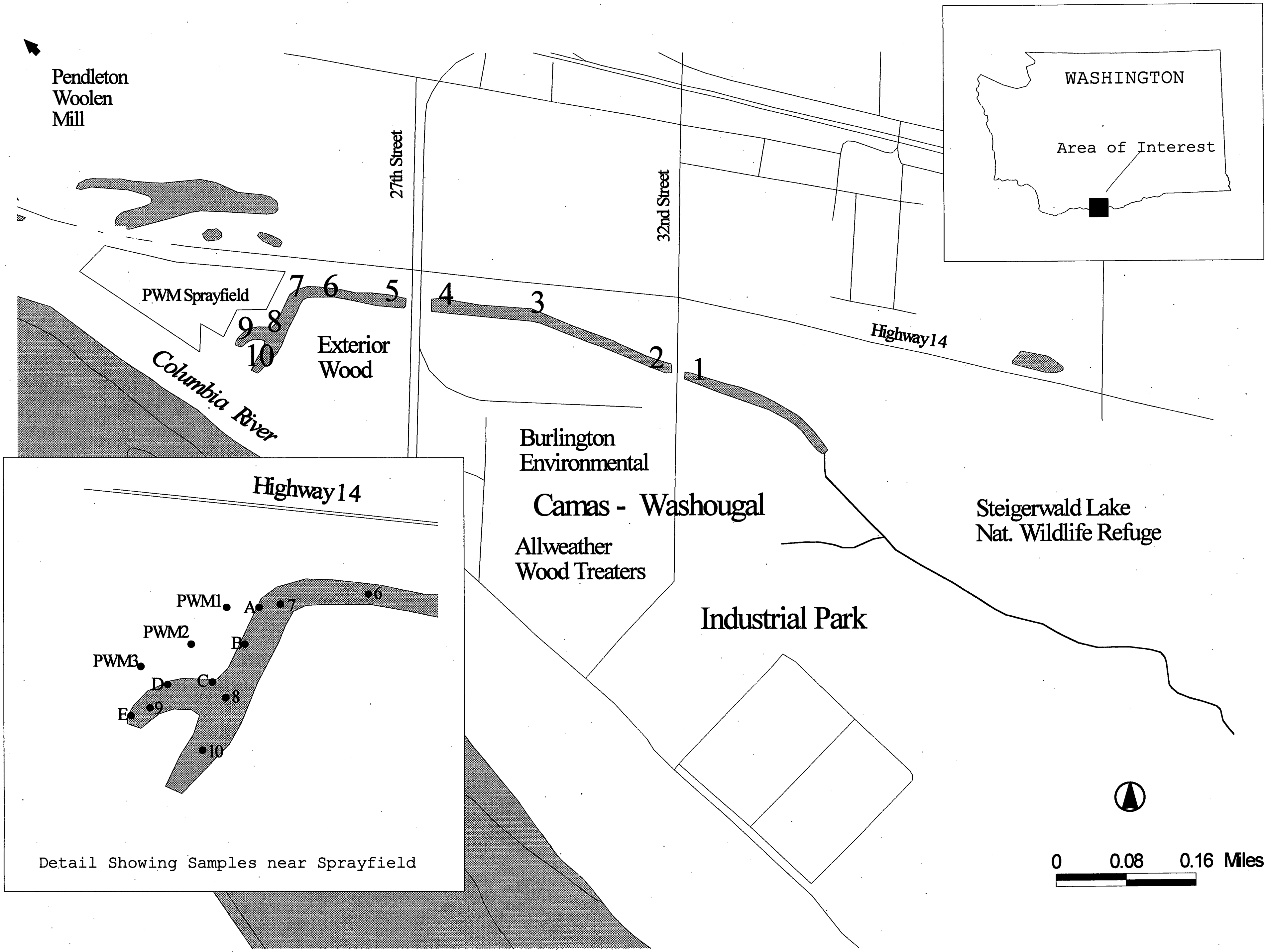

Figure 1. Location of Sediment and Soil Samples, Gibbons Creek Remnant Channel, January 1998

Figure 2. Concentrations of Selected Metals in Center Channel Sediments (mg/Kg, dry weight)
[1998 Data]

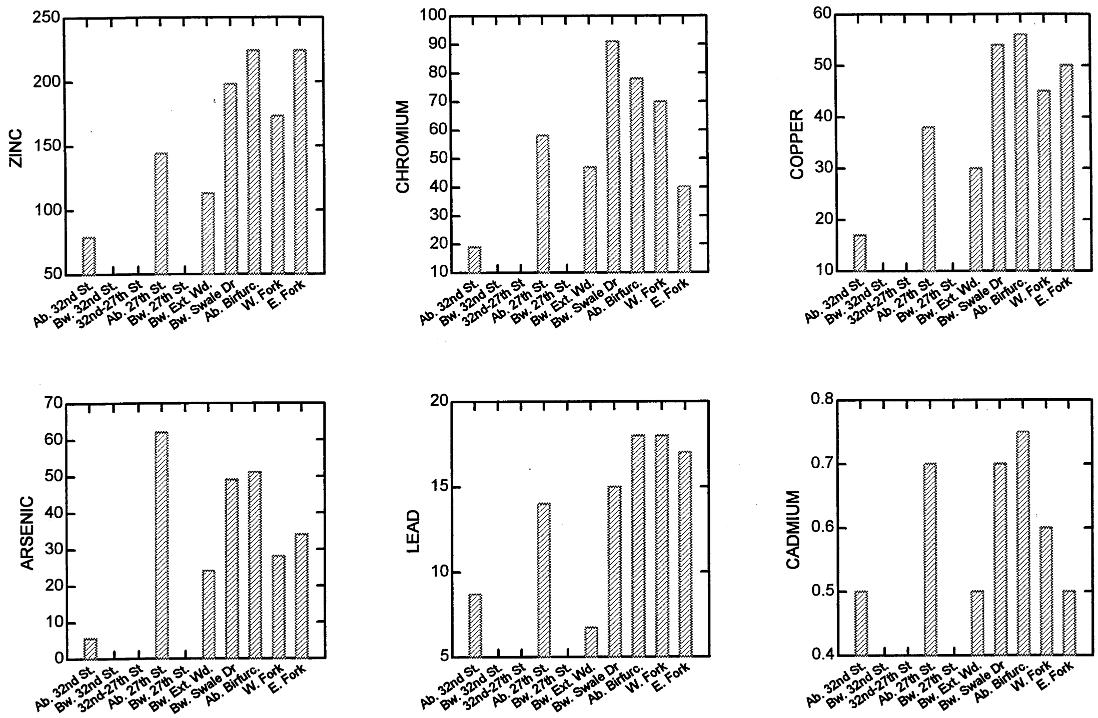

Figure 3. Metals Concentrations in Remnant Channel Sediments as Percent of LAET (1998 data, n = 12)

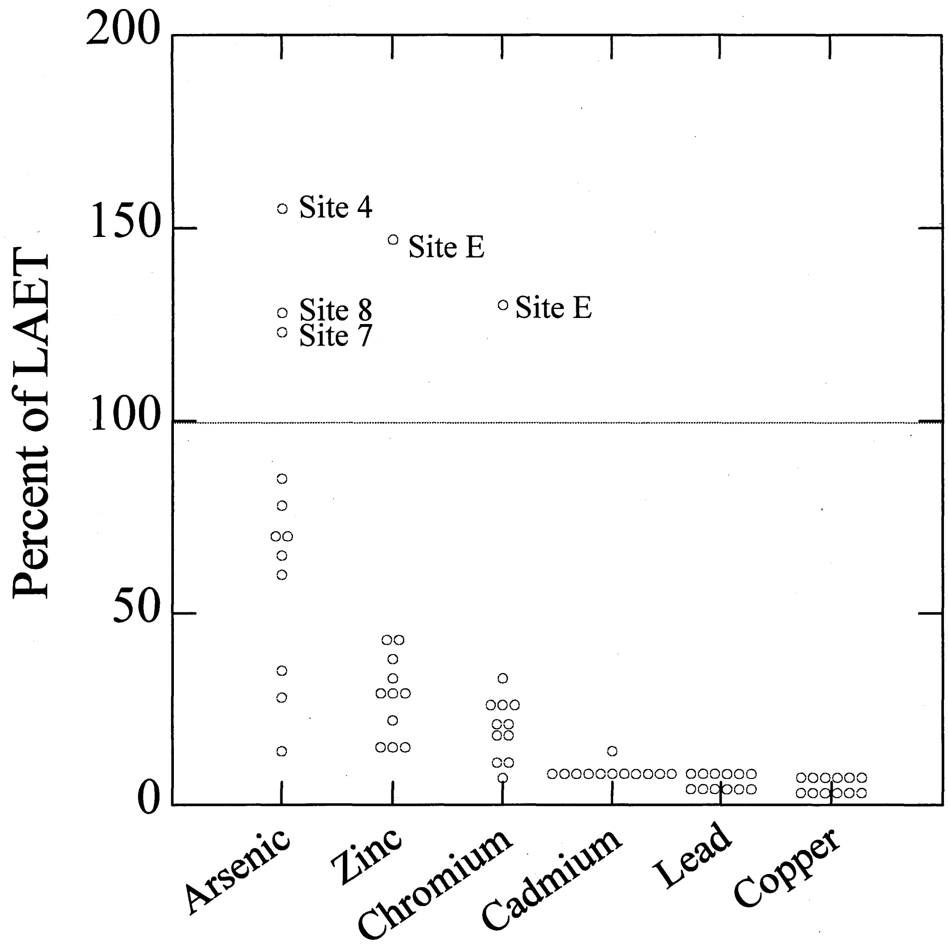

Figure 4a. Zinc Concentrations near PWM (ppm)

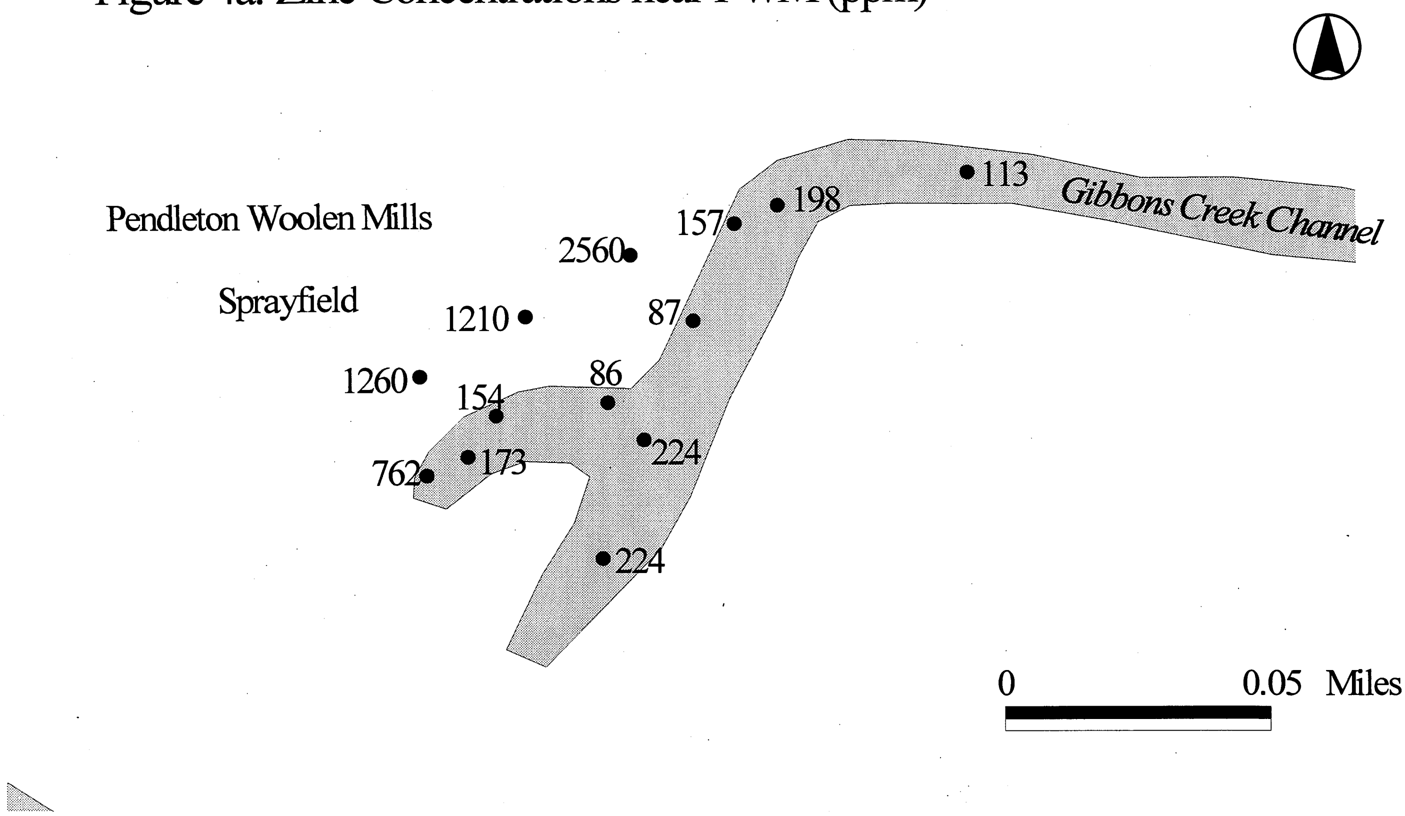

Figure 4b. Chromium Concentrations near PWM (ppm)

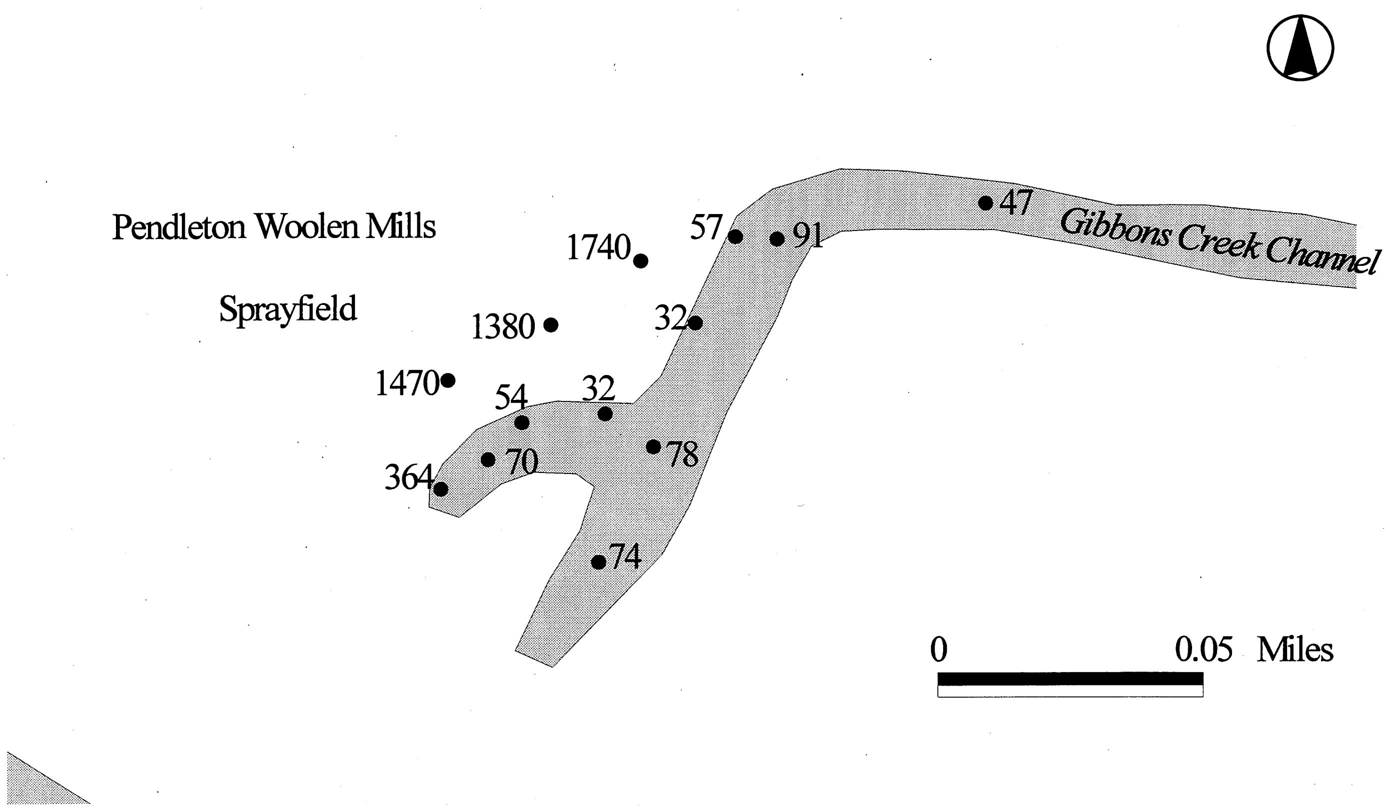

Figure 5. Zinc:Chromium Ratios in Channel Sediments and PWM Samples, 1998

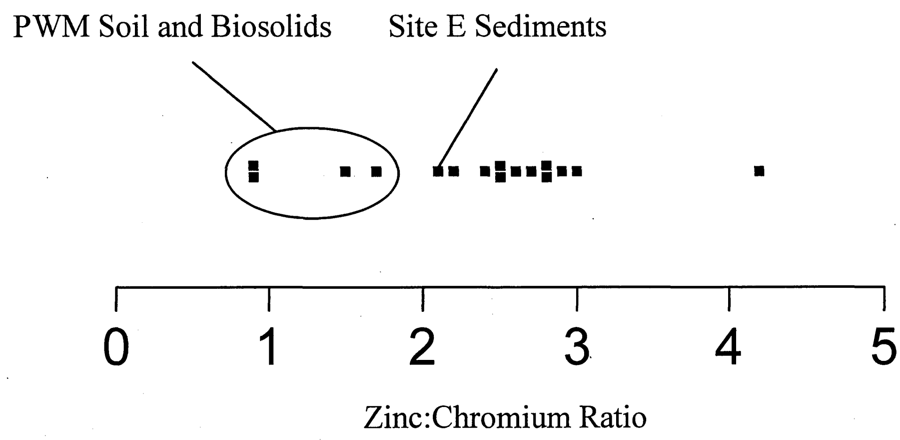

Table 1. Precision of Duplicate Analyses on Sediment Samples (relative percent difference[1])

Field ID:	8	C	PWM Biosolids
Sample No.:	028137	028142	028148
Zn	2%	19%	0.5%
Cr	1%	0%	0%
Cu	2%	20%	0%
As	8%	na	18%
Ni	0%	14%	2%
Pb	6%	33%	19%
Cd	nd	nd	17%
Hg	1%	na	31%
Ag	nd	nd	nd
Be	0%	15%	nd
Se	0%	na	22%
Fines (%)	1%	na	na
TOC (%)	8%	na	7%
Solids (%)	1%	na	6%

[1](duplicate range/duplicate mean) x 100

Table 2. Metal Concentrations in Gibbons Creek Remnant Channel Sediments and PWM Sprayfield Soils, Collected in January 1998 (mg/Kg, dry wt.)

Location	Field ID	Sample Number	Fines (%)	TOC (%)	Solids (%)	Zn	Cr	Cu	As	Ni	Pb	Cd	Hg	Ag	Be	Se
Center Channel Sediment Samples																
Above 32nd Street	1	028130	39	1.3	49	79	19	17	5.6	13	8.7	<.5	0.28	<.4	0.6	0.4
Below 32nd Street	2	028131	no sample, hard bottom													
Midway 32nd-27th Street	3	028132	no sample, hard bottom													
Above 27th Street	4	028133	26	7.6	16	144	58	38	62	14	14	0.7	0.13	<.4	0.7	0.6
Below 27th Street	5	028134	no sample, hard bottom													
Below Ext. Wood Outfall	6	028135	17	1.6	48	113	47	30	24	12	6.7	<.5	0.06	<.4	0.4	0.3
Below PWM Swale Drain	7	028136	58	4.6	25	198	91	54	49	14	15	0.7	0.14	<.4	0.8	0.5
Above Channel Bifurcation	8	028137	80	5.5	21	226	79	56	49	18	18	1.0	0.07	<.4	1.0	0.7
" (duplicate analysis)	8	028137	81	5.1	21	221	78	55	53	18	17	<.5	0.08	0.5	1.0	0.7
W. Fork, End of Channel	9	028138	66	3.4	31	173	70	45	28	18	16	0.6	0.15	0.4	0.8	0.4
E. Fork, End of Channel	10	028139	78	3.8	25	224	74	50	34	17	15	<.5	0.18	0.5	0.9	0.5
Right Bank Sediment Samples along PWM Sprayfield																
Near Site #7	A	028140	75	5.0	20	157	57	42	31	22	14	<.5	0.21	<.4	1.1	0.5
Between Sites #7 & #8	B	028141	72	1.8	37	87	32	26	14	19	8.0	<.5	0.10	<.4	0.8	<.3
Near Site #8	C	028142	79	1.7	37	94	32	28	11	15	10	<.5	0.04	<.4	0.7	<.3
" (duplicate analysis)	C	028142	na	na	na	78	32	23	na	13	7.2	<.5	na	<.4	0.6	na
Between Sites #8 & #9	D	028143	74	3.4	21	154	54	42	28	15	16	<.5	0.08	<.4	0.8	0.4
Near Site #9	E	028144	78	11	11	762	364	70	26	15	17	1.1	0.25	0.5	0.7	0.5
PWM Sprayfield Soil Samples, East End																
South	PWM-1	028145	na	40	14	2560	1740	148	1.0	12	18	2.3	0.85	<.4	0.2	1.2
Center	PWM-2	028146	na	42	20	1210	1380	104	2.8	9.5	21	1.8	1.1	<.4	0.2	0.6
North	PWM-3	028147	na	33	29	1260	1410	111	3.3	14	19	1.3	0.89	<.4	0.2	0.7
PWM Biosolids	--	028148	na	40	1.6	2660	1530	165	0.5	15	17	2.1	0.55	<.8	<0.2	0.4
" (duplicate analysis)	--	028148	na	43	1.5	2670	1530	165	0.6	15	14	2.5	0.75	<.8	<0.2	0.5

Table 3. Ecology 1998 Results Compared to CH2M Hill (1992) Data on Remnant Channel Sediments Collected in February 1990 (mg/Kg, dry wt.)

Location	Ecology ID No.	CH2MHill ID No.	Zinc		Chromium		Copper		Arsenic		Nickel		Lead		Cadmium	
			1998	1990	1998	1990	1998	1990	1998	1990	1998	1990	1998	1990	1998	1990
Center Channel Sediment Samples																
Above 27th Street	4	G1-M	144	160	58	43	38	34	62	na	14	16	14	15	0.7	1.0
Below PWM Swale Drain	7	G2-M	198	135	91	73	54	26	49	na	14	11	15	17	0.7	1.2
Above Channel Bifurcation	8	G3-M	223	208	78	105	56	75	51	na	18	20	18	24	0.8	1.6
W. Fork, End of Channel	9	G5-M	173	167	70	63	45	42	28	na	18	23	16	18	0.6	0.9
E. Fork, End of Channel	10	G4-M	224	154	74	74	50	48	34	na	17	19	15	14	≤.5	1.0
		Median =	**198**	**160**	**74**	**73**	**50**	**42**	**49**	**- -**	**17**	**19**	**15**	**17**	**0.7**	**1**
Right Bank Sediment Samples along PWM Sprayfield																
Near Site #7	A	G2-NB	157	165	57	54	42	33	31	na	22	18	14	15	<.5	1.1
Near Site #8	C	G3-NB	86	219	32	68	26	57	11	na	14	37	8.6	17	<.5	1.6
Near Site #9	E	G5-NB	762	126	364	41	70	30	26	na	15	18	17	13	1.1	0.9
		Median =	**157**	**165**	**57**	**54**	**42**	**33**	**26**	**- -**	**15**	**18**	**14**	**15**	**<.5**	**1.1**

Table 4. Metal Concentrations Reported by Erickson & Tooley (1996) in Remnant Channel Sediments Collected in September 1994 (mg/Kg, dry wt.)

Location	Field ID	Fines (%)	Zn	Cr	Cu	As	Ni	Pb	Cd	Hg	Ag	Be	Se	Tl	Sb
Steigerwald Wildlife Refuge	RC4	62	77	18	20	4.3	16	13	0.8	0.03	<.3	0.6	0.7	<.5	<3
1/4 Mile above 32nd Street	RC3	0	44	8.0	6.0	1.2	9.6	33	<.3	0.01	<.3	0.2	<.4	<.5	<3
Immediately Below 32nd Street	RC2	39	127	56	44	24	14	19	0.9	0.05	<.3	0.7	<.4	<.5	<3
Above Channel Bifurcation	RC1	69	138	65	47	19	14	15	1.3	0.04	<.3	0.6	<.4	<.5	<3

Table 5. Metal Concentrations in Remnant Channel Compared to Sediment Criteria (mg/Kg, dry wt.)

Metal	Remnant Channel Sediments (1998 data, n = 12)			Freshwater Lowest Apparent Effects Threshold [1]	Model Toxics Control Act[2]	Locations in Remnant Channel Exceeding:	
	Median	90th perc.	Maximum			LAET	MTCA
Antimony		------- no data -------		3	- -	- -	- -
Arsenic	**28**	**51**	**62**	40	20	4,7,8	4,6,7,8,9, 10,A,D,E
Cadmium	<.5	0.7	1.1	7.6	2.0	none	none
Chromium	58	90	**364**	280	100	E	E
Copper	42	56	70	840	- -	none	- -
Lead	14	17	18	260	250	none	none
Mercury	0.14	0.25	0.28	0.56	1.0	none	none
Nickel	15	19	22	46	- -	none	- -
Silver	<.4	0.5	0.5	4.5	- -	none	- -
Zinc	156	224	**762**	520	- -	E	- -

Note: Statistics calculated using detection limit

[1]Cubbage et al. (1997)

[2]Method A Cleanup Levels - Soil (WAC 173-340; Ecology, 1996)

Table 6. Results for Dieldrin and Total Petroleum Hydrocarbons in Gibbons Creek Remnant Channel Sediments Collected in January 1998 (dry wt.)

Location	Field ID Number	Sample Number	TPH (mg/Kg)	Dieldrin (ug/Kg)
Center Channel Sediment Samples				
Above 32nd Street	1	028130	<69	na
Below 32nd Street	2	028131	---- no sample ----	
Midway 32nd-27th Street	3	028132	---- no sample ----	
Above 27th Street	4	028133	na	na
Below 27th Street	5	028134	---- no sample ----	
Below Ext. Wood Outfall	6	028135	380	na
Below PWM Swale Drain	7	028136	na	<1.3
Above Channel Bifurcation	8	028137	410	<1.6
W. Fork, End of Channel	9	028138	na	na
E. Fork, End of Channel	10	028139	na	na
Right Bank Sediment Samples along PWM Sprayfield				
Near Site #7	A	028140	na	na
Between Sites #7 & #8	B	028141	na	na
Near Site #8	C	028142	na	na
Between Sites #8 & #9	D	028143	na	na
Near Site #9	E	028144	40,000est.	<3.2