88-e26

Segment No. 18-37-03

WA-37-1047

QUALITY OF WATER, SEDIMENT, AND BIOTA IN WIDE HOLLOW CREEK, WASHINGTON

by

Will Kendra

Washington State Department of Ecology
Water Quality Investigations Section
Olympia, Washington 98504-6811

March 1988

ABSTRACT

A low-flow survey was conducted on Wide Hollow Creek, Yakima County, in July 1987 to document existing water quality and identify contaminant sources. Results showed water quality degradation arose chiefly from nonpoint pollution, specifically fecal contamination from urban and agricultural runoff. Sediment toxicant scans showed metals were at background levels, while 4-methylphenol, total DDT, endosulfan, and MCPA were elevated. The distribution of stream invertebrates was found to be largely a function of habitat condition rather than water quality. Electrofishing yielded mostly shiners and dace, but the creek appeared capable of supporting a hardy gamefish like brown trout. Given its proximity to Yakima and consequent recreational potential, the creek may be a suitable candidate for an adopt-a-stream program. A number of recommendations were made to improve water, sediment, and biota quality.

INTRODUCTION

Wide Hollow Creek drains 65 square miles of Yakima County near the city of Yakima (Figure 1). The stream travels 21.7 river miles (RM) from its source at Oak Spring before joining the Yakima River near the town of Union Gap. The upper seven miles consist largely of headwater rivulets.

From RM 15 through 10 (end of Wide Hollow Road to 80th Avenue), the creek is surrounded by orchards and livestock pasture. A major tributary in this reach, Cottonwood Creek, is subject to similar land use. Between RM 10 and 7 (80th to 40th Avenue), Wide Hollow Creek flows through orchards and areas of light residential/commercial development. From RM 7 to 3 (40th Avenue to Ahtanum Road), the stream is bordered by pasture and an airport to the south; northward lies Yakima with residential, commercial, and light industrial land usage. Below RM 3, the creek flows through more pasture and skirts Union Gap before entering the Yakima River just east of Interstate 82.

Wide Hollow Creek is designated a Class A (Excellent) stream in Chapter 173-201 of the Washington Administrative Code (WAC). Characteristic uses include water supply, fish and wildlife habitat, and recreation. However, the urban and agricultural influences described above may degrade water quality in the creek to the exclusion of these beneficial uses.

In light of potential use impairment, the Central Regional Office (CRO) of Ecology asked the Water Quality Investigations Section (WQIS) to conduct a summer low-flow survey of Wide Hollow Creek. The goal: to document existing water quality and identify point and nonpoint sources of contamination. Specific objectives were:

1. Characterize water quality in Wide Hollow Creek and tributaries under low flow conditions.

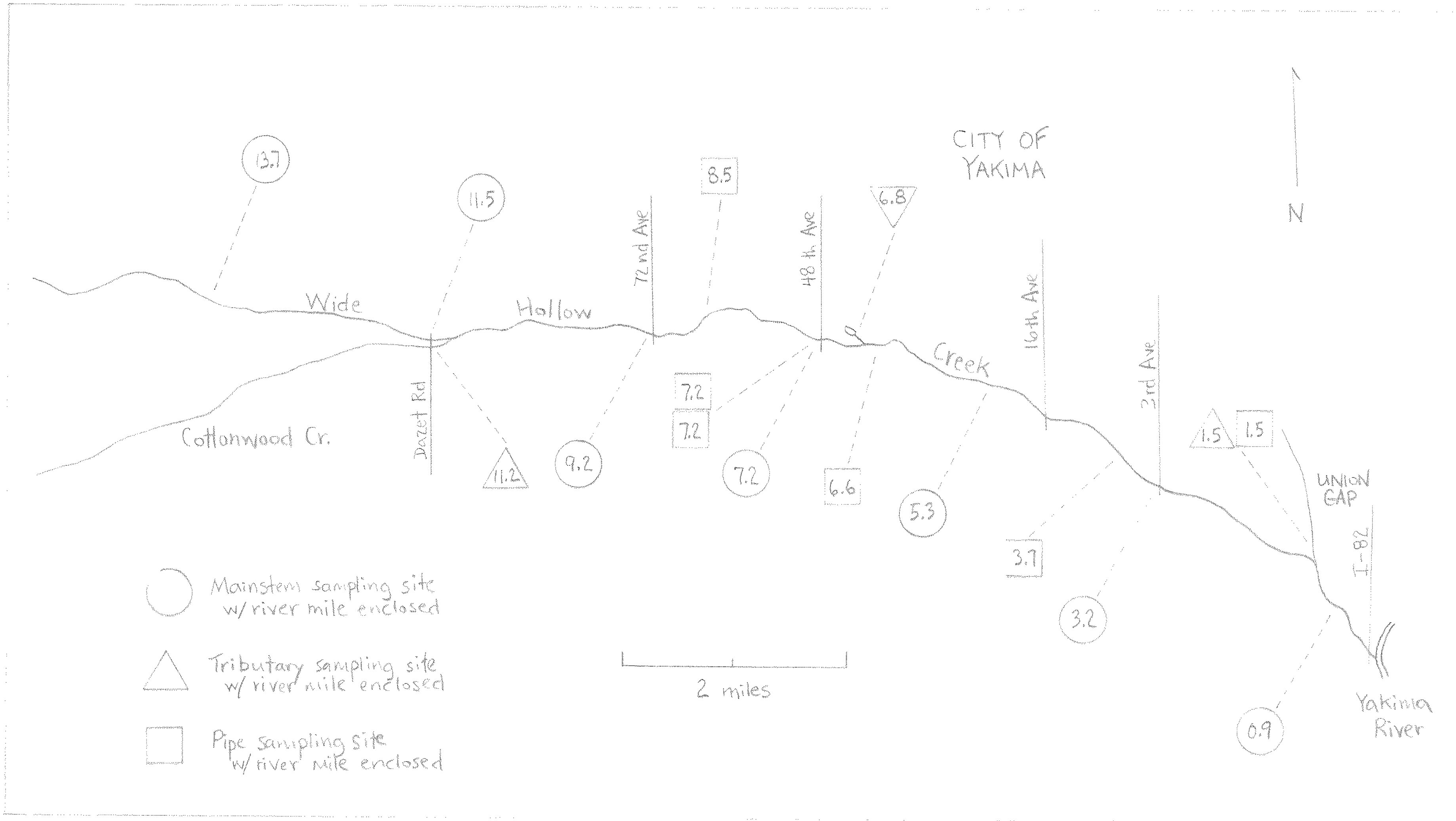

Figure 1. Map of Wide Hollow Creek showing location of sites sampled during a July 1987 water quality survey.

2. Identify organic and inorganic toxicants in streambed sediments.
3. Collect baseline fish and benthic macroinvertebrate data.
4. Relate changes in water quality, sediment, and biota to point and nonpoint source effects.
5. Recommend suitable sites for wet-weather sampling by CRO staff.

Several individuals contributed time and energy to the sampling effort: Tim Determan of WQIS, Kim Sherwood of CRO, Jim Spotts of the Washington State Department of Wildlife (WDW), and Roger Meyer, a science instructor at West Valley Junior High School. Region X of the Environmental Protection Agency (EPA) provided the sediment toxicant scans through the Washington Sediment Watch program.

METHODS

Water quality sampling was conducted July 21-22, 1987. Seven mainstem sites, three tributaries, and six pipes were sampled (Figure 1). Field measurements were temperature (mercury thermometer), pH and specific conductance (Beckman meters), dissolved oxygen (azide-modified Winkler titration), and discharge (velocity by Swoffer meter). Laboratory analyses included turbidity, chemical oxygen demand (COD), nutrients (ammonia, nitrate-nitrite, and total phosphorus), fecal coliform and enterococci bacteria, hardness, and total metals (Cd, Cr, Cu, Ni, Pb, and Zn).

Sampling proceeded in an upstream direction, with grabs being taken in mid-channel just below the surface. Water samples were iced and shipped by bus within 24 hours to the EPA/Ecology laboratory in Manchester, Washington, for processing and analysis as per EPA (1979), APHA et al. (1985), and Huntamer (1986).

Day-to-day variability was estimated by resampling three mainstem sites, one tributary, and one pipe on the second day (July 22). Sampling and analytical variability were assessed by collecting replicate samples for laboratory analysis at three mainstem sites. Also, a replicate discharge measurement was made at one site. The pH meter was periodically checked and recalibrated; drift did not exceed 0.2 unit.

An intensive dissolved oxygen survey was conducted during late afternoon ("dusk") on July 21 and at dawn on July 22. The goal was to characterize oxygen highs associated with daytime photosynthesis and nighttime lows due to respiration. The seven mainstem sites were sampled in a downstream direction within roughly one hour. Temperature, pH, and replicate oxygen determinations were made at each site.

An intensive fecal coliform survey was conducted on July 22 to investigate possible bacterial contamination associated with an unsewered stream reach between 3rd and 16th Avenues (RM 3.2 to 4.6). Replicate fecal coliform samples were collected at five sites within this reach and iced for shipment to the Manchester laboratory.

Streambed sediments (upper 1-2 inches) were sampled at RM 0.9 (pool below Main Street bridge) and RM 7.2 (pool above 40th Street bridge) on July 23 for toxics analysis (base-neutral/acid extractables, polychlorinated biphenyls, organochlorine and organophosphorus pesticides, herbicides, and metals). Two casts of an Emery pipe dredge were composited per site; homogenization was accomplished using beakers and spoons. All equipment was stainless steel and pre-cleaned using (in order) Liqui-Nox detergent, de-ionized water, 10 percent nitric acid, de-ionized water, methylene chloride, and acetone (the dredge was rinsed with acetone and stream water between sites).

Sediment samples for organics and total metals analysis were placed in priority pollutant-cleaned glass jars with teflon-lined lids (ICHEM); samples for grain size analysis were placed in Whirlpack bags. Samples were iced and transported to the Manchester laboratory within 24 hours. Organics and metals analyses followed methods specified in Huntamer (1986). Grain size and percent solids determinations were made by Parametrix, Inc. (Bellevue, WA) following the procedure of Holme and McIntyre (1971). Total organic carbon (TOC) was measured by Lauck's Testing Laboratories, Inc. (Seattle, WA) using techniques outlined in Tetra Tech, Inc. (1986). Metals and organics data were not corrected for spike recovery, nor were they normalized to grain size or TOC.

Three mainstem sites on Wide Hollow Creek were electrofished on July 23 to determine fish community composition and abundance. Habitat sampled included riffles, runs, and pools. Stunned fish were netted, identified to genus, and released. Total electroshocking time was recorded at each site for later calculation of catch per unit effort.

Benthic macroinvertebrates were sampled at all seven mainstem sites on July 22 and 23. To standardize sampling effort, 10 hand-sized rocks were selected at each site from riffles of similar current velocity, depth, and substrate. Rocks were washed so that dislodged organisms were swept downstream into a hand net (320 um mesh). Each composite sample was placed in a shallow pan with water; live organisms were picked at streamside over a 10-minute span and preserved in 70 percent ethanol. Categorical abundance of organisms remaining after 10 minutes was estimated by eye. Invertebrates were later identified to family using the keys of Merritt and Cummins (1978) and Pennak (1978).

A qualitative assessment of habitat condition was made at each mainstem site to assist in the interpretation of macroinvertebrate distribution patterns. Habitat characteristics included stream width and depth, substrate composition, bank stability and vegetation, canopy cover, and adjacent land use.

Weather during the three-day survey period was warm, with mostly clear skies but for an occasional rain shower. More intensive rainfall reportedly occurred during the several days preceding the survey (K. Sherwood, CRO, personal communication), but flows had subsided to dry-weather levels before the present sampling effort commenced.

RESULTS AND DISCUSSION

Water Quality - Mainstem

Spacing of the seven mainstem sampling sites was designed to permit study of land-use effects on Wide Hollow Creek. The two upstream sites (RM 13.7 and 11.5) were subject to orchard and pasture impacts. The two intermediate sites (RM 9.2 and 7.2) bordered orchards and light residential/commercial districts. The three downstream sites (RM 5.3, 3.2, and 0.9) were influenced by urban and livestock pasturing activities.

Conventional water quality variables showed good replicability, except for COD (Appendix A). Day-to-day variability at the three mainstem sites was also low. Temperature, pH, and dissolved oxygen varied with time of sampling due to solar warming and photosynthetic effects.

Downstream changes in water quantity and quality were evident (Figure 2). Streamflow peaked at RM 3.2, indicating a water loss of 5 to 8 cfs between RM 3.2 and 0.9. The loss is attributed to a number of withdrawals in this reach (J. Milton, CRO, personal communication). Changes in COD and total P concentrations may be a function of higher primary productivity at upstream stations. Specifically, downstream depletion of P could reflect assimilation by plants, which in turn would account for increased COD (i.e., organic matter). Nitrate-nitrite concentrations increased toward the mouth, probably due to leaching of nitrogenous fertilizers and animal waste from adjacent fields. The downstream depletion of P and accrual of N suggests P may be the nutrient which limits plant growth in Wide Hollow Creek.

The downstream increase in fecal coliform levels likely represents the cumulative effect of streamside livestock pasturing. For Class A waters, the state water quality standard specifies that fecal coliform bacteria shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10 percent of samples exceeding 200 organisms/100 mL (WAC 173-201-045). All mainstem sites except RM 9.2 violated this criterion.

Enterococci bacteria were sampled at three mainstem sites and one tributary for comparison to the new federal criterion for freshwater bathing (EPA 1986). For infrequent full-body-contact recreation, the geometric mean of enterococci bacteria should not exceed 33 organisms/100 mL, with no single sample exceeding 151 organisms/100 mL. This criterion was violated at all four sites (Appendix A).

Violations of the state and federal criteria were of particular significance at the two Randall Park sites, namely RM 7.2 and the pond outlet. Children wade and swim at these locations, despite at least one sign which cautions "no swimming, wading, or ice

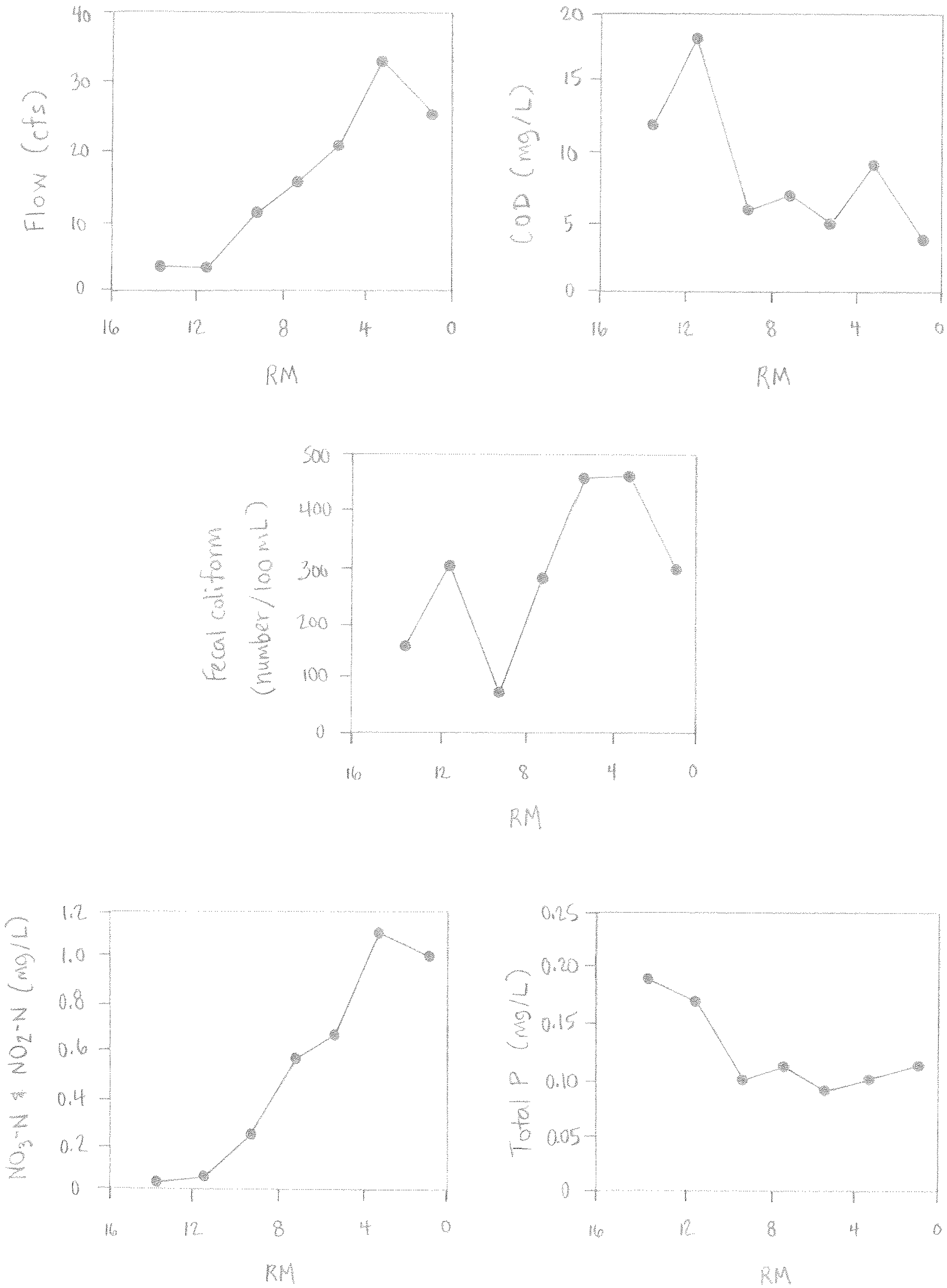

Figure 2. Changes in water quantity and quality in Wide Hollow Creek on July 21, 1987.

skating." The Yakima Health District should be notified of these findings so that stronger measures can be taken to protect bathers at Randall Park.

Mainstem pH levels were highest at RM 9.2 (Appendix A), where measurements both days exceeded the state water quality standard of 6.5 to 8.5. An orchard with an NPDES-permitted cooling water discharge at RM 9.8 was considered a possible source. Further investigation at 1230 on July 22 showed pH values of 9.2 and 9.1 at RM 9.8 and RM 10.4, respectively. Thus the elevated pH levels were probably not associated with a point source discharge, but instead were caused by high productivity in this stream reach. This conclusion is supported by the supersaturated dissolved oxygen levels observed between RM 7.2 and 11.5--these too exceeded the state standard of 110 percent saturation (total dissolved gas).

Metals concentrations at five mainstem sites and one tributary were comparable to levels found earlier by Ecology at other sites in the Yakima River basin (Johnson et al., 1986). All concentrations were well below federal toxicity thresholds (EPA 1986).

Water Quality - Inflows

Three tributaries and six pipes draining into Wide Hollow Creek were sampled. An attempt was made to document all inflows to the creek (Appendix B). The majority of inflows enter from the left (facing downstream) bank. Many are Drainage Improvement District (DID) outfalls; these drainage systems were installed as early as 1915 to facilitate groundwater collection and disposal (C. Buchanan, Yakima Co. Public Works Dept., personal communication).

The unnamed creek in Union Gap (RM 1.5) received a substantial portion of its flow on July 21 from excess well water (Appendix A). The water is continually pumped to provide lawn irrigation at Union Gap West Mobile Home Park; excess overflows to the creek. Quality of the overflow water was good, but dilution did little to reduce the high fecal coliform levels in the creek. The state bacterial standard was violated both days, but a waste source was not evident.

The pond at Randall Park, noted earlier for high bacterial concentrations, also had high temperature, turbidity, COD, and total P. Bacterial contamination in the pond may stem from wastes generated by the resident waterfowl population. Temperature was high because standing water naturally warms more than running water. The remaining parameters may be elevated due to waterfowl waste, primary production, and/or upstream inputs to DID 48 Lateral 1.

Cottonwood Creek (RM 11.2) was notable for high nitrate-nitrite and low dissolved oxygen concentrations. The nitrate-nitrite level was higher than the mainstem; heightened fertilizer use may be implicated. Low dissolved oxygen concentrations were also observed in the two tributaries discussed above. All three tributaries failed to meet the Class A water quality standard of 8.0 mg/L.

The outfall at 48th Avenue (RM 7.2) was by far the most contaminated inflow to Wide Hollow Creek (Appendix A). COD, total P, and bacterial levels were high, particularly on July 21 when the effluent was foamy. Laundromat or car wash effluent may account for much of the poor discharge quality. Incidentally, mainstem site 7.2 was located upstream of this discharge.

Of the remaining pipes, the DID outfall at RM 8.5 (64th Avenue) was noteworthy for having the highest discharge and lowest conductivity of all inflows. Also, the pipes at RM 6.6 (40th Ave) and 7.2 (50 meters east of 48th Avenue) merit mention because their source could not be identified.

The summation of flows for all tributaries and pipes does not account for the observed increases in mainstem flow (Appendix A). The drainage water budget is complicated by a network of diversions, canals, and return-flows. In addition, intensive irrigation during warmer months may result in substantial groundwater gains and/or losses by mainstem Wide Hollow Creek.

<u>Principal Components Analysis</u>

Principal components analysis (PCA) was used to compare mainstem and in-flowing water quality (a description of this multivariate statistical method is provided in Appendix C). The PCA produced two components which explain 77 percent of the variation between sampling sites (Figure 3).

The six outward-radiating lines represent the contribution of the original water quality variables to the principal components. Thus the first component may be interpreted as a "pollution" index, where stations with high P, COD, turbidity, and bacteria are situated to the left of the graph. The second principal component may represent an irrigation-return gradient, where sites high in nitrate-nitrite and conductivity are located on the upper portion of the plot.

Mainstem sites (circles) generally clumped together, with day-to-day samples showing close similarity (i.e., low variability). The unnamed tributary at Union Gap (△+▲ 1.5) had water quality not unlike the mainstem sites, as did the pipe at 40th Avenue (■ 6.6). The source of this particular discharge was not determined, but because of its similarity to mainstem sites, it may be drainage of groundwater near the creek.

The PCA also confirms that the pond at Randall Park (△ 6.8) and the pipe at 48th Avenue (□+■ 7.2) had the worst water quality of all inflows to Wide Hollow Creek (note that the latter showed improved water quality on the second sampling day). The Pioneer Street pipe (■ 3.7) was also an outlier, having high nitrate-nitrite and conductivity; its water quality was similar to the other pipe of unknown origin (■ 7.2*).

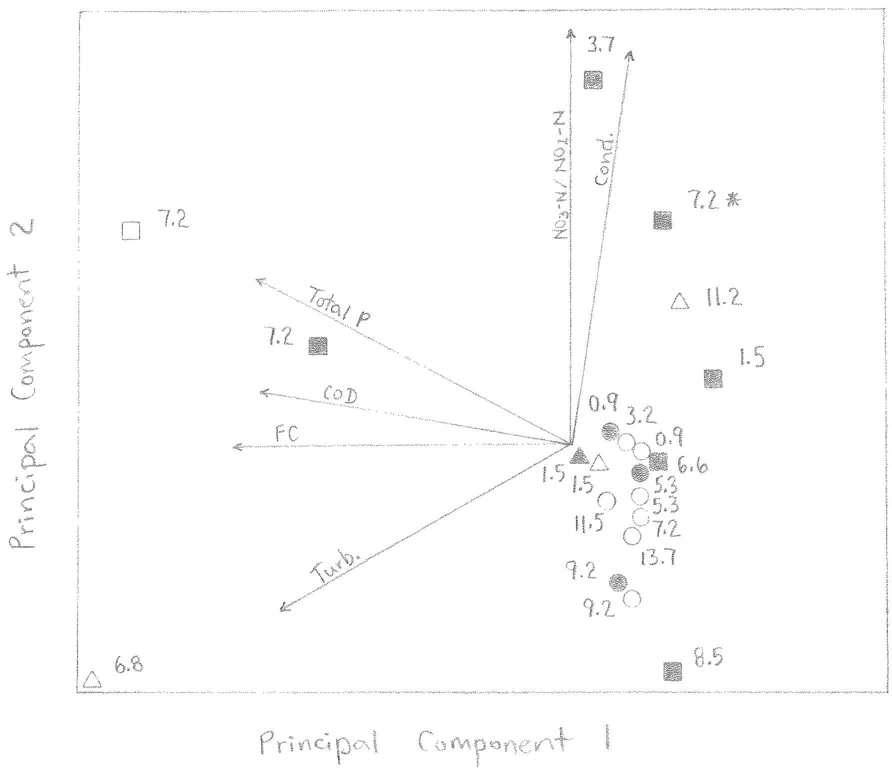

Figure 3. Scatterplot of principal component scores for all sites sampled during the July 1987 survey of Wide Hollow Creek. Numerals denote river mile; mainstem, tributary, and pipe sites are denoted by ○ , △ , and □ , respectively; unshaded sites were sampled 7/21, shaded sites on 7/22; ▩ 7.2* represents the pipe 50 meters east of 48th Avenue. Axes tickmarks and numbering were omitted for clarity.

Constituent Loads

Loads are the total weights of suspended and/or dissolved materials moving downstream at a certain point in time. Loads are calculated by multiplying constituent concentrations by discharge and adjusting units. Like discharge, loads in Wide Hollow Creek steadily increased in a downstream direction, peaking at RM 3.2 (Appendix D). Also, like discharge, the summation of loads from tributaries and pipes does not account for increases in mainstem loads. Again, this may be indicative of substantial groundwater inflows fed by intensive upland irrigation.

Water Quality - Present vs. Historical

Wide Hollow Creek has historically received point source discharges from fruit growers, meat packers, Union Gap wastewater treatment plant, and others. Currently, the only NPDES-permitted discharges to the creek are cooling waters from the local orchard industry. Water quality degradation now arises chiefly from nonpoint sources, including urban and agricultural stormwater runoff, irrigation return flows, and possibly failing septic systems.

Little water quality work had been done in Wide Hollow Creek before the present survey. Historical records from an Ecology ambient monitoring site contained July data for only two years (Table 1). Conductivity, ammonia, and total P appear to have decreased over time, but the data are too limited to draw any firm conclusions.

Dissolved Oxygen Survey

Dissolved oxygen levels in Wide Hollow Creek varied considerably from day to night (Figure 4; Appendix E). Daytime photosynthesis raised dissolved oxygen while nighttime respiration depleted it. Nighttime lows were below the water quality standard of 8.0 mg/L at six of the seven sites monitored.

Percent saturation was used in the above comparison to remove the effect of variable temperature. Day-to-night temperature differences were more pronounced at upstream sites because the smaller water volumes upstream are more susceptible to solar warming by day and evaporative cooling at night.

Changes in pH from dusk to dawn were less dramatic, except at RM 9.2 and 7.2. These two sites also had the highest daytime oxygen levels, so the elevated pH values were probably the result of enhanced primary production in this stream reach.

Fecal Coliform Survey

Results of bacterial sampling in the unsewered reach from 3rd to 16th Avenues showed good agreement between replicate samples (Appendix F). After testing to ensure normality and homogeneity of variance, analysis of variance (ANOVA) was performed

Table 1. Comparison of historical and present water quality in Wide Hollow Creek at Union Gap. Historical data from EPA's STORET database (Ecology ambient monitoring site 37E070 at RM 1.5); present values are two-day averages at RM 0.9.

Parameter	Date 7/21/71	7/24/74	7/21-22/87
Time	1105	1055	0810
Discharge (cfs)	26	32	24
Temperature (^{o}C)	19.3	17.3	16.7
pH (S.U.)	7.9	8.5	8.3
Conductivity (umhos/cm)	455	370	250
Dissolved Oxygen (mg/L)	9.1	12.8	8.7
Turbidity (NTU)	3	3	2
NH_3-N (mg/L)	0.26	0.11	<0.01
NO_3-N & NO_2-N (mg/L)	1.09	1.41	0.99
Total P (mg/L)	0.32	0.17	0.11

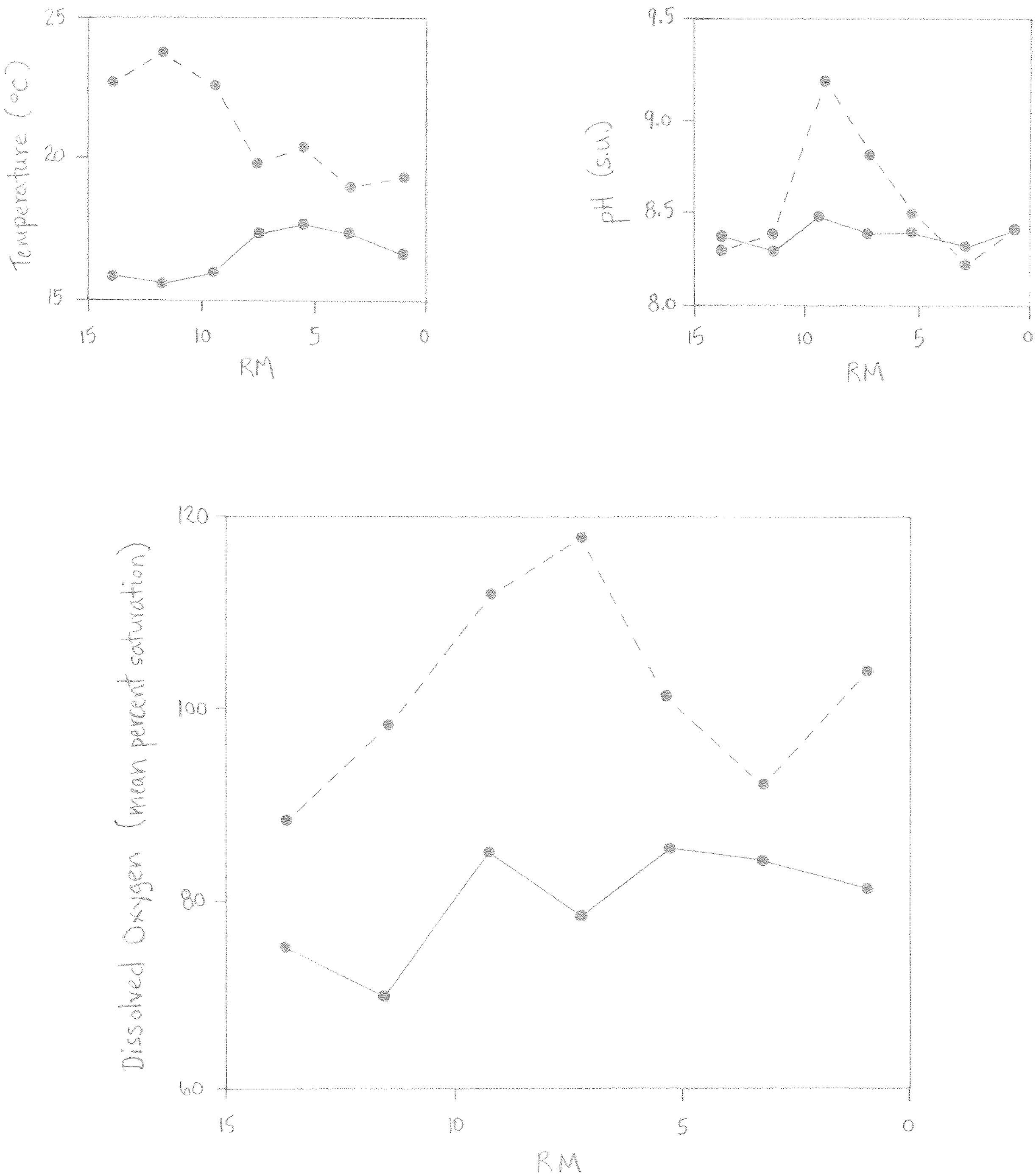

Figure 4. Comparison of temperature, pH, and dissolved oxygen along mainstem Wide Hollow Creek at dusk on 7/21 (dashed line) and dawn on 7/22 (solid line).

using raw data. There was a significant ($p < 0.05$) difference between the two upstream sites and three downstream sites, as well as between RM 4.0 and 3.7 (Figure 5).

Several sources of fecal contamination are implicated. Livestock pastures adjacent to the creek may contribute animal wastes. Pipes discharging in this reach may also be contaminated (Appendix B). Septic system failures are another potential source because soils near the creek may be saturated due to upland irrigation.

Wet-Weather Sampling Program

CRO requested guidance in designing a limited survey to characterize water quality in Wide Hollow Creek under wet-weather conditions. The following study plan should meet that objective:

- Sample three mainstem sites - RM 11.5 (orchard/pasture impacts), RM 7.2 (orchard and light residential/commercial impacts), and RM 0.9 (cumulative impact of agricultural and urban runoff).

- Sample three inflows expected to have poor water quality - RM 7.2 (48th Avenue), RM 6.8 (Randall Park pond outlet), and RM 4.9 (new city storm drain at Washington Avenue).

- Parameters - temperature, pH, conductivity, turbidity, total suspended solids, COD, nutrients (NH_3-N, NO_3-N/NO_2-N, and total P), fecal coliform, hardness, and total metals (Cd, Cr, Cu, Pb, Ni, and Zn). Only temperature and pH must be measured in the field.

This sampling scheme was designed to maximize data acquisition while keeping personnel requirements to a minimum. The sampling should be performed during the waning stages of a major rain event, preferably in autumn or spring, in order to better assess stormwater runoff impacts.

Sediment Toxics Scan

Bed sediments often act as a sink for toxicants and thus can provide a record of stream chemistry integrated over time. Wide Hollow Creek sediments were sampled at RM 0.9 and 7.2 for toxicant scans (Appendix G). Analytical holding times were exceeded, but the results nonetheless furnish an index of sediment quality (a QA review by R. Farlow of EPA found the toxics data to be "generally acceptable").

Metals concentrations at both sites were similar (Table 2). At present there are no toxicity criteria for metals in freshwater sediments, but the results can be placed in perspective by comparison to EPA freshwater dredge-disposal guidelines (Table 3). Copper and zinc appear to exceed the pollution threshold. However, Moen (1969) reported background copper and zinc levels in Yakima County stream sediments to be <50 mg/kg (82 of 87 samples) and <150 mg/kg (79 of 87 samples), respectively.

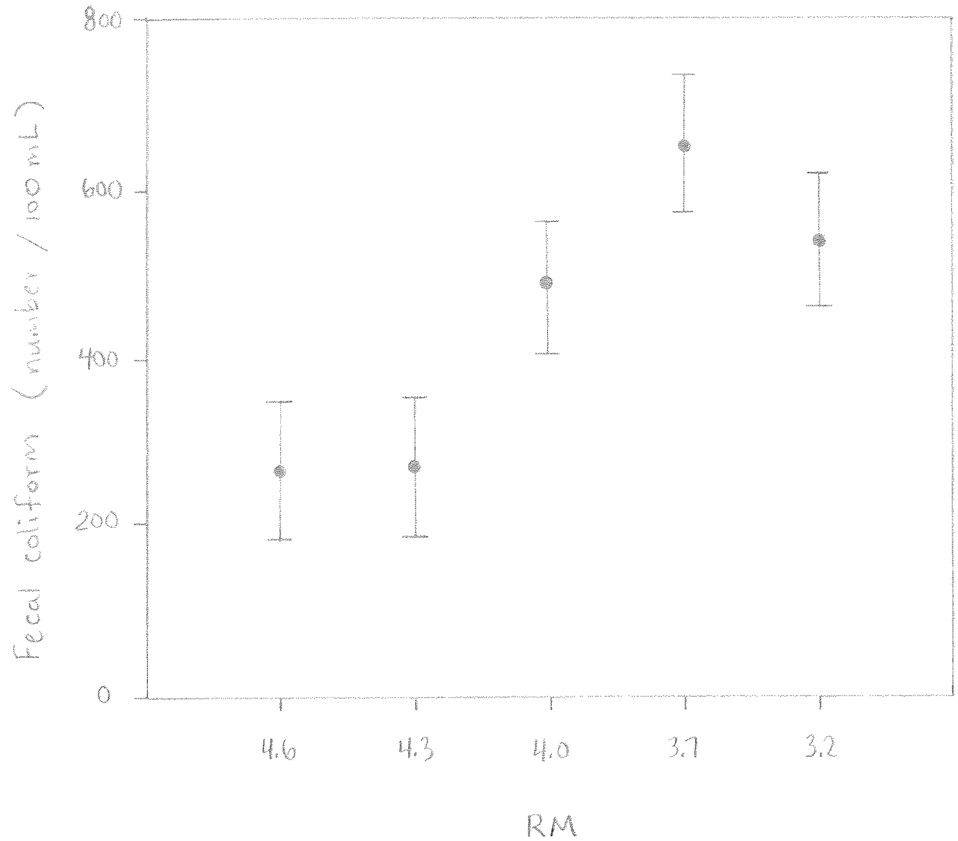

Figure 5. Arithmetic mean (n=2) fecal coliform concentrations at five lower Wide Hollow Creek sites on July 22, 1987. Error bars denote 95 percent Least Significant Different (LSD) intervals.

Table 2. Sediment quality at two Wide Hollow Creek sites on July 23, 1987. Data are from Appendig G; only toxicants exceeding the minimum detection limit are listed, excluding analytes showing blank contamination. Wet-weight results were corrected to a dry-weight basis.

Parameter	Units	River Mile	
		0.9	7.2
Total Solids	Pcnt wet wt	68.4	49.1
Total Organic Carbon	Pcnt dry wt	0.8	2.0
Grain Size			
Clay (<4um)	Pcnt dry wt	3.0	3.8
Silt (4um-62um)	"	15.5	22.7
Sand (62um-2mm)	"	64.8	71.1
Gravel (>2mm)	"	16.6	2.3
Metals			
Arsenic	mg/kg dry wt	0.9	2.5
Beryllium	"	0.53	0.43
Cadmium	"	0.33	0.14
Chromium	"	15.0	10.3
Copper	"	25.6	28.6
Lead	"	11	32
Mercury	"	0.036	0.028
Nickel	"	13.9	5.8
Silver	"	0.03	0.13
Zinc	"	132.5	92
Base-neutral/acid compounds			
Isophorone	ug/kg dry wt	16J	180J
Phenanthrene	"	41J	110J
Phenol, 4-methyl	"	<800	6,000J
Pyrene	"	<800	110J
Organochlorine Pesticides			
DDT, 4,4'-	ug/kg dry wt	12	53
DDE, 4,4'-	"	39	530
DDD, 4,4'-	"	22	240
Endosulfan, alpha-	"	<2	69
Endosulfan, beta-	"	<2	130
Endosulfan sulfate	"	25	140
Herbicides			
MCPA	ug/kg dry wt	500	5,500

J = Estimated value.

Table 3. EPA guidelines for the safe open-water disposal of dredged material in the Great Lakes (from Hamdy and Post 1985).

	Dredging Guideline (mg/kg)		
Parameter	Non-Polluted	Moderately Polluted	Heavily Polluted
Cadmium	--	--	>6
Chromium	<25	25-75	>75
Copper	<25	25-50	>50
Lead	<40	40-60	>60
Mercury	<1	--	>1
Nickel	<20	20-50	>50
Zinc	<90	90-200	>200
PCBs	<1	1-10	>10

Sediment metals concentrations were unexpectedly low, given the extent of urban stormwater runoff into Wide Hollow Creek.

Several base-neutral/acid (BNA) extractable compounds were detected in streambed sediments (Table 2). Isophorone, a solvent, was found at both sites, as was phenanthrene. The latter compound and pyrene are polycyclic aromatic hydrocarbons (PAHs), a class of compounds typically produced by combustion of fossil fuels and consequently often found in urban runoff. Concentrations of all three chemicals were low, but the estimated concentration of a fourth BNA compound, 4-methylphenol (=p-cresol), was high. This aromatic hydrocarbon is also a common constituent of urban runoff. At present there are no toxicity criteria for these or other organic toxicants in freshwater sediments.

DDT and two metabolites, DDE and DDD, were found at both sediment sampling sites (Table 2). DDT is a broad-spectrum chlorinated hydrocarbon insecticide. Its toxicity, persistence, and bioaccumulation posed both human health and environmental hazards, leading EPA to ban its agricultural use in 1972 (EPA 1980a). The high ratio of DDE/DDD to DDT in Wide Hollow Creek sediments indicates the contaminant source was likely historical, a conclusion reached by Johnson et al. (1986) for DDT residues in the Yakima River basin as a whole.

Total DDT (DDT+DDE+DDD) concentrations in Wide Hollow Creek were 73 and 820 ug/kg dry weight at RM 0.9 and 7.2, respectively. Johnson et al. (1986) sampled six Yakima River tributary mouths in 1985 and found a mean total DDT level of 39 ug/kg, with a high of 163 ug/kg in Sulphur Creek (average of two replicates). Total DDT at RM 7.2 was likely higher due to proximity to orchards. Johnson et al. did not detect DDT or its metabolites in Wide Hollow Creek water in 1985.

Endosulfan (alpha and beta isomers) was detected in sediments at RM 7.2, while one if its metabolites, endosulfan sulfate, was found at both sites (Table 2). Endosulfan is another broad-spectrum chlorinated hydrocarbon insecticide, but unlike DDT its use is not restricted (EPA 1985). Endosulfan was consistently one of the most toxic pesticides tested on fish (EPA 1980b), but as mentioned earlier, there are currently no toxicity criteria for organic toxicants in freshwater sediments.

Johnson et al. (1986) found endosulfan in sediments at only one of eleven sites sampled in the Yakima River drainage in 1985. That site was located on the mainstem Yakima River at Wapato Dam, less than four miles downstream from the mouth of Wide Hollow Creek. However, Johnson et al. believed nearby Birchfield Drain to be the source of endosulfan contamination. The reported concentration of 4.1 ug/kg (TOC=2.3 percent) at Wapato Dam was considerably less than the level found at RM 7.2, an expected result given the proximity of the latter site to orchards. Endosulfan was not detected in Wide Hollow Creek water samples collected in 1985 (Johnson et al. 1986).

MCPA was present in sediments at both RM 0.9 and 7.2 (Table 2). MCPA is a phenoxy herbicide similar to 2,4-D. The concentration at RM 7.2 was quite high, but the toxicity of MCPA to fish and wildlife is generally considered low (WSSA 1974; Hattula et al. 1978; Alexander et al. 1985).

No polychlorinated biphenyls (PCBs) or organophosphorus pesticides were detected during sediment sampling in Wide Hollow Creek (Appendix G). Johnson et al. (1986) similarly found no PCBs in sediments at 11 sites throughout the Yakima River basin.

In summary, toxicant scans showed Wide Hollow Creek sediments to be mostly free of contamination. However, reported values should be treated as estimates because analytical holding times were exceeded. While levels of the insecticides DDT and endosulfan were elevated, values were comparable to those found in other Yakima River tributaries. Concentrations of the herbicide MCPA were also high, but its toxicity to aquatic life is thought to be low.

Electrofishing Survey

Electrofishing catch rates were calculated to compare the density of fish species in Wide Hollow Creek (Table 4). The density of all taxa combined increased progressively upstream, probably due to changes in species composition. Redside shiners (Richardsonius balteatus) were dominant at RM 3.2, while dace (Rhinichthys sp.) were dominant at 7.2 and 11.5. The upstream decline in shiner density and concomitant increase in dace density may reflect the shiner preference for moderate downstream velocities versus the dace preference for swifter upstream waters (Scott and Crossman 1973).

Wide Hollow Creek has a past history of fish kills and is not currently planted by WDW. The single gamefish encountered, a small rainbow trout (Salmo gairdneri), was caught at RM 3.2, the site with the highest nighttime dissolved oxygen and lowest daytime water temperature. Local fishermen reported catching larger trout at RM 3.2 and 5.3, but water quality appeared marginal to support rainbow trout. However, the creek may support brown trout (Salmo trutta), which tolerate low dissolved oxygen, high temperature, and turbid water (Wydoski and Whitney 1979).

Macroinvertebrate Community Analysis

In total, 22 benthic macroinvertebrate taxa were found along mainstem Wide Hollow Creek (Appendix H). Midges (Chironomidae) were by far the most abundant form. A two-way indicator species analysis (TWINSPAN) was performed to reduce and interpret the complex invertebrate data set (a description of this multivariate statistical method is provided in Appendix C).

TWINSPAN results reveal that sites 0.9, 5.3, 9.2, and 13.7 were more similar to each other than to sites 3.2, 7.2, and 11.5 (Table 5). In other words, invertebrate communities at adjacent sites were dissimilar. The dendrogram at the bottom of the

Table 4. Results of an electrofishing survey of Wide Hollow Creek on July 23, 1987.

Sampling Site	River Mile	Shocking Time (seconds)	Units	Taxa			Total
				Dace	Shiners	Trout	
3rd Avenue	3.2	180	Number	2	32	1	35
			Catch/sec	<0.1	0.2	<0.1	0.2
48th Avenue	7.2	243	Number	102	39	0	141
			Catch/sec	0.4	0.2	0.0	0.6
Dazet Road	11.5	85	Number	79	11	0	90
			Catch/sec	0.9	0.1	0.0	1.1

Table 5. Results of a TWINSPAN analysis of benthic macroinvertebrate data from Wide Hollow Creek on July 22 and 23, 1987. Abundance was coded as follows: R (Rare) = 2-4, C (Common) = 5-25, and A (Abundant) = >25 organisms; "--" denotes organism absence (single occurences were treated as organism absence).

Taxa	River Mile						
	5.3	0.9	13.7	9.2	11.5	3.2	7.2
Baetidae (mayfly)	--	--	C	A	--	--	--
Hydropsychidae (caddisfly)	--	C	C	A	R	--	--
Talitridae (amphipod)	--	A	R	C	C	--	--
Chironomidae (midges)	A	A	A	A	C	A	A
Oligochaeta (worms)	--	--	--	C	C	R	R
Ostracoda (ostracods)	--	--	--	--	A	R	R
Physidae (snails)	--	--	--	R	C	--	A

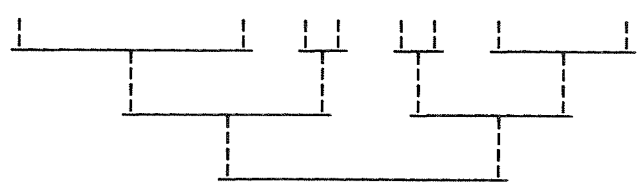

table shows actual clustering results. For example, the next division separates sites 0.9, 5.3, and 13.7 from 9.2, as well as sites 3.2 and 7.2 from 11.5.

Mainstem water quality data were analyzed further to determine whether changes in water quality account for the observed distribution of invertebrates. A PCA was performed using the same edited data set as before, except that several parameters from the intensive dissolved oxygen survey were included. If changes in water quality caused the unusual invertebrate distribution pattern, the PCA should show sites 0.9, 5.3, 9.2, and 13.7 clustered apart from sites 3.2, 7.2, and 11.5. Instead, the PCA shows stations aligning in a geographical gradient (Figure 6). That is, upstream sites have different water quality than downstream sites (RM 9.2 deviates from this trend as a result of high turbidity and elevated afternoon pH). Consequently, water quality was not a major determinant of invertebrate community composition.

An alternative hypothesis was that habitat quality accounted for the observed distribution pattern (Appendix I). The qualitative assessment of habitat revealed that the periphytonous green alga Cladophora was common at sites 0.9, 5.3, 9.2, and 13.7, but rare at RM 3.2, 7.2, and 11.5. Further, sites with periphyton common also had limited canopy cover, while sites with little periphyton were more shaded (thus limiting plant growth). These habitat characteristics directly affected the feeding habits of invertebrates: less shaded sites featured periphyton scrapers (Baetidae), filter feeders (Hydropsychidae), and aufwuchs browsers (Talitridae), while more shaded sites featured omnivorous scavengers (Oligochaeta, Ostracoda, and Physidae).

To recapitulate, water quality did not account for the distribution of benthic macroinvertebrates. Rather, canopy shading limited primary productivity (periphyton growth) and thus altered available food materials. This in turn altered secondary productivity--that is, the composition and abundance of stream invertebrates.

RECOMMENDATIONS

CRO should attempt to reduce fecal contamination in Wide Hollow Creek. Specific abatement and control measures might include:

1. Working with rural landowners to reduce animal pasturage effects (for example, fencing livestock to prevent creek access).
2. Investigating the source of bacterial problems in the unnamed tributary at Union Gap and in the pipe effluent at 48th Avenue. The latter was also foamy and had high COD and total P, possibly implicating an illegal laundromat or car wash discharge.
3. Conducting a dry-weather streamwalk between 3rd and 16th Avenues to identify sources of fecal contamination. The five mainstem sites within this reach should be resampled, as should all inflows located during the streamwalk.

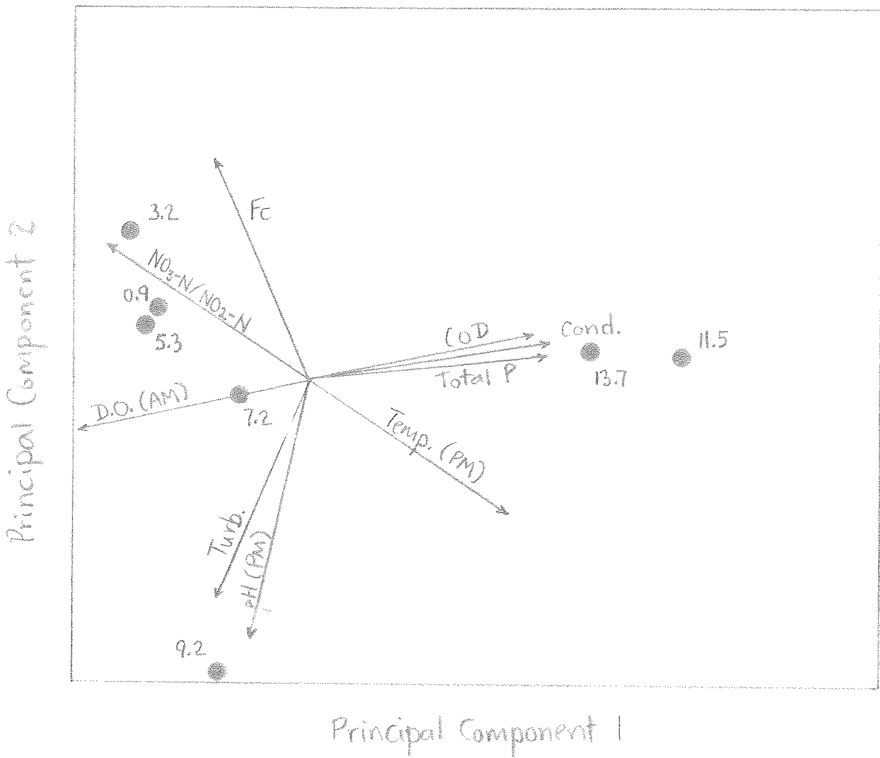

Figure 6. Scatterplot of principal component scores for mainstem Wide Hollow Creek sites sampled on July 21-22, 1987 (numerals denote river mile). Axes tickmarks and numbering were omitted for clarity. The first two principal components account for 87 percent of the among-station variance.

4. Notifying the Yakima Health District of bacterial standard violations in the creek and pond at Randall Park. Unsuspecting bathers, mainly children, are presently at risk swimming in those waters.

A limited wet-weather survey of Wide Hollow Creek should be performed by CRO to document the effects of stormwater runoff on water quality. The proposed sampling scheme detailed earlier was designed to maximize data acquisition while keeping personnel requirements to a minimum.

CRO should work with concerned parties (e.g., farmers, applicators, and inspectors) to reduce agricultural chemical inputs to the creek. Although no evidence of instream toxicity was found, nitrates were elevated in water, while endosulfan and MCPA were elevated in sediments.

Given its proximity to Yakima and consequent recreational potential, CRO should attempt to focus community attention on the problems confronting Wide Hollow Creek. Several actions may be appropriate:

1. Wide Hollow Creek could be considered as a candidate for an adopt-a-stream program.
2. CRO could approach WDW concerning the feasibility of stocking the creek with a hardy gamefish like brown trout, which tolerate marginal water quality conditions.
3. CRO could explore the possibility of having the West Valley Junior High School science program participate in long-term water quality monitoring of the creek. A science instructor there assisted with the present work and was enthusiastic about involving his students in further studies.

REFERENCES

Alexander, H.C., F.M. Gersich, and M.A. Mayes, 1985. Acute toxicity of four phenoxy herbicides to aquatic organisms. Bull. Environ. Contam. Toxicol. 35:314-321.

APHA et al. (American Public Health Association, American Water Works Association, and Water Pollution Control Federation), 1985. Standard methods for the examination of water and wastewater. 16th ed. Washington D.C. 1268 pp.

EPA (U.S. Environmental Protection Agency), 1979. Methods for chemical analysis of water and wastes. EPA 600/4-79-020. Cincinnati, OH. 460 pp.

EPA, 1980a. Ambient water quality criteria for DDT. EPA report 440/5-80-038. Washington D.C.

EPA, 1980b. Ambient water quality criteria for endosulfan. EPA report 440/5-80-046. Washington D.C.

EPA, 1985. Suspended, cancelled and restricted pesticides. 3rd rev. Washington D.C. 29 pp.

EPA, 1986. Quality criteria for water. EPA report 440/5-86-001. Washington D.C.

Hamdy, Y., and L. Post, 1985. Distribution of mercury, trace organics, and other heavy metals in Detroit River sediments. J. Great Lakes Res. 11(3):353-365.

Hattula, M.L., H. Reunanen, and A.U. Arstila, 1978. The toxicity of MCPA to fish: light and electron microscopy and the chemical analysis of the tissue. Bull. Environ. Contam. Toxicol. 19:465-470.

Hill, M.O., 1979. TWINSPAN: A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, NY. 90 pp.

Holme, N.A., and A.D. McIntyre, 1971. Methods for the study of marine benthos. International Biological Programme Handbook No. 16. Blackwell Scientific Publications, London, U.K. 334 pp.

Huntamer, D., 1986. Laboratory user's manual. Washington State Dept. of Ecology. Manchester, WA. 139 pp.

Johnson, A., D. Norton, and B. Yake, 1986. Occurrence and significance of DDT compounds and other contaminants in fish, water, and sediment from the Yakima River basin. Washington State Dept. of Ecology report 86-5. Olympia, WA. 89 pp.

Merritt, R.W., and K.W. Cummins (eds.), 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co., Dubuque, IA. 441 pp.

Moen, W.S., 1969. Analyses of stream sediment samples in Washington for copper, molybdenum, lead, and zinc. Washington State Dept. of Natural Resources Open File Report. Olympia, WA. 7+ pp.

Pennak, R.W., 1978. Fresh-water invertebrates of the United States. 2nd ed. John Wiley and Sons, New York, NY. 803 pp.

Scott, W.B., and E.J. Crossman, 1973. Freshwater fishes of Canada. Fisheries Res. Bd. Can. Bul. 184. Ottawa, Canada. 966 pp.

STSC, Inc., 1986. Statgraphics statistical graphics system. Rockville, MD.

Tetra Tech, Inc., 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Report to U.S. Environmental Protection Agency. Bellevue, WA. 46 pp.

WSSA (Weed Science Society of America), 1974. Herbicide handbook of the Weed Science Society of America. 3rd ed. Champaign, IL. 430 pp.

Wydoski, R.S., and R.R. Whitney, 1979. Inland fishes of Washington. University of Washington Press, Seattle, WA. 220 pp.

APPENDICES

Appendix A. Results of a water quality survey of Wide Hollow Creek, Washington, on July 21 and 22, 1987.

Sampling Site	River Mile*	Date	Time	Discharge (cfs)**	Temperature (°C)	pH (S.U.)	Conductivity (umhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% saturation)	Turbidity (NTU)	COD (mg/L)	NH_3-N (mg/L)	NO_3-N + NO_2-N (mg/L)	Total P (mg/L)	Fecal Coliform (#/100 mL)	Enterococci (#/100 mL)	Hardness (mg/L)	Cadmium (ug/L)	Chromium (ug/L)	Copper (ug/L)	Lead (ug/L)	Nickel (ug/L)	Zinc (ug/L)
Mainstem																							
Main St.	0.9	7/21	0730	25.5	16.4	--	240	8.10	85	2	4	0.01	1.0	0.11	290	--	140	0.3	<5	<5	<1	<5	<5
		7/21	Repl	--	--	--	--	--	--	1	5	<0.01	1.0	0.11	300	--	--	--	--	--	--	--	--
		7/22	0850	22.5	17.0	8.3	260	9.30	99	2	6	<0.01	0.98	0.12	610	--	--	--	--	--	--	--	--
3rd Ave.	3.2	7/21	0810	33.2	17.0	7.8	230	8.15	87	2	9	0.02	1.1	0.10	460	530	120	0.4	<5	5	<1	<5	6
		7/22	0950	27.7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
24th Ave.	5.3	7/21	0845	21.1	17.1	7.9	250	8.30	89	2	<4	<0.01	0.67	0.09	560	450	110	0.4	<5	<5	<1	<5	<5
		7/21	Repl	--	--	--	--	--	--	2	7	<0.01	0.66	0.09	370	--	--	--	--	--	--	--	--
		7/22	1140	19.2	17.7	8.4	290	9.00	98	2	9	<0.01	0.70	0.09	340	--	--	--	--	--	--	--	--
48th Ave.	7.2	7/21	1045	15.9	17.5	8.4	240	10.30	111	2	7	<0.01	0.57	0.11	280	250	130	0.5	<5	<5	<1	<5	<5
		7/21	Repl	16.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
72nd Ave.	9.2	7/21	1130	11.9	18.3	8.9	230	10.45	115	4	10	0.02	0.25	0.10	92	--	120	0.4	<5	<5	<1	<5	<5
		7/21	Repl	--	--	--	--	--	--	3	<4	0.01	0.25	0.10	60	--	--	--	--	--	--	--	--
		7/22	1230	12.4	19.3	9.1	230	10.70	120	4	13	<0.01	0.30	0.08	100	--	--	--	--	--	--	--	--
Dazet Rd.	11.5	7/21	1215	3.8	19.6	8.5	360	9.90	112	2	18	0.01	0.06	0.17	300	--	--	--	--	--	--	--	--
Wide Hollow Rd.	13.7	7/21	1300	4.2	19.1	8.2	300	8.25	93	<1	12	<0.01	0.03	0.19	160	--	--	--	--	--	--	--	--
Tributaries																							
Unnamed Cr. at Pine St.***	(1.5)	7/21	0750	[0.7]	15.7	7.7	190	8.10	84	<1	5	0.01	1.1	0.08	1200	--	--	--	--	--	--	--	--
		7/22	0915	0.4	16.5	8.3	240	7.60	80	1	9	<0.01	0.95	0.08	1400	--	--	--	--	--	--	--	--
Randall Park Pond Outflow	(6.8)	7/21	0930	<0.1	21.8	8.3	170	6.50	76	15	66	0.06	0.02	0.43	2400	1800	120	<0.2	<5	<5	<1	<5	16
Cottonwood Cr. at Dazet Rd	(11.2)	7/21	1230	0.5	15.5	7.8	400	5.55	58	<1	<4	0.01	1.2	0.13	53	--	--	--	--	--	--	--	--
Pipes																							
Well overflow at Pine St.	(1.5)	7/22	0920	<0.1	13.9	8.3	310	--	--	<1	<4	<0.01	1.2	0.04	<1	--	--	--	--	--	--	--	--
Pioneer St. NE side of bridge	(3.7)	7/22	1020	[0.3]	13.9	7.8	650	6.10	61	3	8	<0.01	1.5	0.31	180	--	--	--	--	--	--	--	--
40th Ave. SE side of bridge	(6.6)	7/22	1430	[0.2]	18.1	8.4	300	--	--	1	9	0.01	0.63	0.13	220	--	--	--	--	--	--	--	--
Randall Park 50 meters east of 48th Ave.	(7.2)	7/22	1400	0.4	12.8	7.9	460	--	--	<1	7	<0.01	1.4	0.20	<3	--	--	--	--	--	--	--	--
48th Ave. NE side of bridge	(7.2)	7/21	1040	[1.3]	18.9	8.1	320	--	--	4	130	0.06	1.4	0.52	2200	--	--	--	--	--	--	--	--
		7/22	1415	[<0.1]	18.9	8.4	240	--	--	4	14	0.04	1.2	0.55	2100	--	--	--	--	--	--	--	--
64th Ave. N side of creek	(8.5)	7/22	1310	[2.2]	17.8	8.7	110	--	--	2	7	<0.01	0.20	0.02	66	--	--	--	--	--	--	--	--

*Parentheses indicate river mile where tributary or pipe joins Wide Hollow Creek.
**Brackets indicate flows are estimates.
***7/21 sample collected below well overflow; 7/22 sample collected upstream of overflow.

Appendix B. Partial list of Drainage Improvement District (DID) outfalls, storm sewer drains, and NPDES-permitted discharge sites along mainstem Wide Hollow Creek. Data from C. Buchanan (Yakima County Public Works Department), B. Thompson (Yakima Municipal Wastewater Treatment Plant), and J. Milton (CRO), respectively.

RM	Bank**	Site	Description
1.5*	L	4th & White Streets, Union Gap	Open-channel flow shown on historic maps as a natural stream; includes stormwater from 1st Street vicinity
1.6	L	BNRR bridge	Open-channel flow draining area to NW
1.6	L	UPRR bridge	Pipe or open-channel flow, drains stormwater from Mead Avenue vicinity
3.2	L	3rd Avenue bridge	DID outfall 24 L'2 (15-inch); includes stormwater drainage from 3rd Avenue, Mead Avenue, Nob Hill Boulevard, and Cornell Avenue vicinity
3.7*	L	Pioneer Street bridge	DID outfall 24 LL Line (18-inch)
4.0	L	10th Avenue bridge	New county storm drain (24-inch) with oil separator
4.2	L	Between 11th and 12th Avenues	DID outfall 4 Sub "A" (24-inch)
4.3	L	12th Avenue bridge	Storm sewer (24-inch) draining 12th Avenue, Mead Avenue, 14th Avenue, 16th Avenue, Nob Hill Boulevard, and Tieton Drive vicinity
4.9	R	Washington Avenue bridge	Stormwater runoff from small reach of Washington Avenue
4.9	L	Washington Avenue bridge	New city storm drain (42-inch, with oil separator) serving 20th Avenue and Nob Hill Boulevard vicinity
6.0	L	34th Avenue	Stormwater drainage from 34th Avenue vicinity
6.4	L	38th Avenue	Storm sewer draining 38th Avenue, 40th Avenue, Nob Hill Boulevard, and Tieton Drive vicinity; includes DID 40 Main (27-inch)
6.6*	R	40th Avenue bridge	12-inch corrugated pipe emerging from ground; source unknown
6.8*	L	Between 42nd and 44th Avenues	DID 48 Lat. 1 (15- and 36-inch) drains into pond at Randall Park (may include stormwater runoff); open-channel flow upstream and downstream of pond
7.2*	R	Randall Park, 50 miles E of 48th Avenue	12-inch pipe emerging from ground; source unknown
7.2*	L	48th Avenue bridge	Stormwater drainage (18-inch) from 48th Avenue, 50th Avenue, Chesnut Avenue, 56th Avenue, and Summitview Avenue vicinity; includes NPDES-permitted cooling water discharges from four orchards; may include some of DID 48 Lat. 1 (see 6.8 L, above)
8.2	L	0.3 mile E of 64th Avenue	Congdon Orchards NPDES-permitted cooling water discharge
8.5*	L	64th Avenue bridge	DID 38 Lat. D and 48 Lat. 5 (21-inch)
9.8	L	80th Avenue	Highland Fruit Growers NPDES-permitted cooling water discharge

*Sites marked with an asterisk were sampled in the present survey.
**Left or right bank, facing downstream.

Appendix C. Brief description of multivariate statistical techniques used in the present study as an aid to data interpretation.

Water quality is a multivariate concept--it is not defined by any single constituent (variable), but rather by a number of variables. Multivariate statistics are appropriate tools for analysis of water quality and biological data. Multivariate methods help clarify complex data sets to allow a better understanding of their underlying structure.

Most multivariate statistical techniques fall under the broad categories of ordination and classification. Ordination procedures reduce a multidimensional swarm of data points onto a two-dimensional graphic in such a way that any real pattern in the data may become apparent. Classification methods, or cluster analyses, formally divide entities (e.g., sampling sites) into groups on the basis of similarity in order to detect any natural groupings.

Principal components analysis (PCA) is an ordination technique that reduces the most important features of a data set to a few "principal components" which describe the intrinsic structure of the original data. These principal components may account for most of the variability in the original data set, allowing the remaining information to be discarded as noise. Mathematically, the principal components are essentially linear combinations of those parameters most responsible for the variation among different sampling sites. The first principal component is that linear combination of the original variables which best discriminates among the sites (i.e., accounts for the most variation).

Results of PCA are plotted on a two-dimensional graph, where each axis represents one principal component. Each sampling site is represented on the graph by a point whose coordinates are that site's first and second principal component scores. The relative position of sampling sites on the graph indicates their similarity: points (sites) close together are more similar than those far apart.

The relationship between the original water quality variables and the principal components can be superimposed on the graph as lines radiating outward from a central point. The length of each line is proportional to that variable's contribution to the principal components. Lines which parallel a component axis represent variables which are strongly correlated with that principal component. Similarly, the angle between any two lines is inversely proportional to the correlation between those two variables (i.e., lines pointing in the same direction indicate high correlation).

PCA was performed on the original water quality data set (Appendix A) using the microcomputer program "Statgraphics" (STSC Inc. 1986). The data were first edited to delete those parameters which were: 1) not measured at all sites (e.g., metals); 2) correlated with time of sampling (e.g., temperature); 3) a function of river mile (e.g., discharge); or 4) largely undetected (e.g., ammonia). Remaining parameters were standardized to _z_ scores to weight them equally.

Two-way indicator species analysis (TWINSPAN) is another multivariate statistical technique which reduces the complexity of a data set to clarify its underlying structure. TWINSPAN simultaneously performs an ordination (reciprocal averaging) and a classification (polythetic divisive clustering). With biological data, the resulting output is an ordered taxa-by-site table that groups similar sites together.

TWINSPAN was performed on the original benthic macroinvertebrate data set (Appendix H) using the Fortran program of Hill (1979). Only taxa detected at more than one site were treated statistically. In addition, individual organism occurrences were deleted because their presence was probably due to chance and thus lacked ecological significance. Remaining biota were then assigned the following categorical scores: R (Rare) = 2-4 organisms; C (Common) = 5-25 organisms; A (Abundant) = greater than 25 organisms.

Appendix D. Constituent loads measured in Wide Hollow Creek, July 21-22, 1987.

Sampling Site	River Mile*	Date	Time	COD	NH_3-N	NO_3-N + NO_2-N	Total Phos.	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Fecal Coliform	Enterococci
				Constituent Load in Lbs/Day**										Bacterial Load in Thousands/sec.**	
Mainstem															
Main Street	0.9	7/21	0730	600	1.4	140	15	<0.1	<0.7	<0.7	<0.1	<0.7	<0.7	2,100	--
		7/21	Repl	700	<1.4	140	15	--	--	--	--	--	--	2,200	--
		7/22	0850	700	<1.2	120	15	--	--	--	--	--	--	3,900	--
3rd Avenue	3.2	7/21	0810	2,000	3.6	200	18	<0.1	<0.9	0.9	<0.2	<0.9	1	4,300	5,000
24th Avenue	5.3	7/21	0845	<500	<1.1	76	10	<0.1	<0.6	<0.6	<0.1	<0.6	<0.6	3,400	2,700
		7/21	Repl	800	<1.1	75	10	--	--	--	--	--	--	2,200	--
		7/22	1140	900	<1.0	72	9.3	--	--	--	--	--	--	1,900	--
48th Avenue	7.2	7/21	1045	600	<0.9	49	9.4	<0.1	<0.4	<0.4	<0.1	<0.4	<0.4	1,300	1,100
72nd Avenue	9.2	7/21	1130	640	1.3	16	6.4	<0.1	<0.3	<0.3	<0.1	<0.3	<0.3	310	--
		7/21	Repl	<300	0.6	16	6.4	--	--	--	--	--	--	200	--
		7/22	1230	370	<0.7	20	5.4	--	--	--	--	--	--	350	--
Dazet Road	11.5	7/21	1215	370	0.2	1.2	3.5	--	--	--	--	--	--	320	--
Wide Hollow Road	13.7	7/21	1300	270	<0.2	0.7	4.3	--	--	--	--	--	--	190	--
Tributaries															
Unnamed Creek at Pine Street***	(1.5)	7/21	0750	[20]	[<0.1]	[4.2]	[0.3]	--	--	--	--	--	--	[240]	--
		7/22	0915	20	<0.1	2.0	0.2	--	--	--	--	--	--	160	--
Randall Park Pond Outflow	(6.8)	7/21	0930	<36	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<68	<51
Cottonwood Creek at Dazet Road	(11.2)	7/21	1230	<10	<0.1	3.2	0.4	--	--	--	--	--	--	8	--
Pipes															
Well overflow at Pine Street	(1.5)	7/22	0920	<2	<0.1	<0.6	<0.1	--	--	--	--	--	--	<1	--
Pioneer Street, NE side of bridge	(3.7)	7/22	1020	[10]	[<0.1]	[2.4]	[0.5]	--	--	--	--	--	--	[15]	--
40th Avenue, SE side of bridge	(6.6)	7/22	1430	[10]	[<0.1]	[0.7]	[0.1]	--	--	--	--	--	--	[13]	--
Randall Park, 50 meters east of 48th Avenue	(7.2)	7/22	1400	20	<0.1	3.0	0.4	--	--	--	--	--	--	<1	--
48th Avenue, NE side of bridge	(7.2)	7/21	1040	[910]	[0.4]	[9.8]	[3.6]	--	--	--	--	--	--	[810]	--
		7/22	1415	[<8]	[<0.1]	[<0.6]	[<0.3]	--	--	--	--	--	--	[<60]	--
64th Avenue, north side of creek	(8.5)	7/22	1310	[80]	[<0.1]	[2.4]	[0.2]	--	--	--	--	--	--	[41]	--

*Parentheses indicate river mile where tributary or pipe joins Wide Hollow Creek.
**Brackets indicate loads are based on estimated flows.
***7/21 sample collected below well overflow; 7/22 sample collected upstream of overflow.

Appendix E. Results of a dusk/dawn dissolved oxygen survey of Wildcat Creek, July 21-22, 1987.

Sampling Site	River Mile	Date	Time	Temp. (°C)	pH (S.U.)	Dissolved Oxygen as mg/L (% sat.) n=2 samples
Main Street	0.9	7/21	1755	19.2	8.4	9.35, 9.45 (104, 105)
		7/22	0650	16.6	8.4	7.70, 7.70 (81, 81)
3rd Avenue	3.2	7/21	1745	18.9	8.2	8.30, 8.40 (92, 93)
		7/22	0640	17.3	8.3	7.80, 7.85 (84, 84)
24th Avenue	5.3	7/21	1730	20.2	8.5	8.90, 8.90 (101, 101)
		7/22	0630	17.6	8.4	7.85, 7.85 (85, 85)
48th Avenue	7.2	7/21	1720	19.6	8.8	10.40, 10.50 (117, 118)
		7/22	0620	17.2	8.4	7.20, 7.30 (77, 78)
72nd Avenue	9.2	7/21	1710	22.3	9.2	9.40, 9.40 (112, 112)
		7/22	0610	15.8	8.5	8.10, 8.15 (85, 85)
Dazet Road	11.5	7/21	1650	23.4	8.4	8.00, 8.05 (97, 98)
		7/22	0600	15.5	8.3	6.70, 6.70 (70, 70)
Wide Hollow Road	13.7	7/21	1640	22.4	8.3	7.30, 7.30 (88, 88)
		7/22	0550	15.7	8.4	7.10, 7.10 (75, 75)

Appendix F. Results of an intensive fecal coliform survey of Wide Hollow Creek on July 22, 1987.

Sampling Site	River Mile	Time	Fecal coliform (#/100 mL) n=2 samples
3rd Avenue	3.2	0950	520,560
Pioneer Street	3.7	1010	600,710
10th Avenue	4.0	1030	410,560
12th Avenue	4.3	1040	240,300
16th Avenue	4.6	1050	260,270

Appendix G. Sediment quality at two sites in Wide Hollow Creek on July 23, 1987.

Parameter	Units	River Mile*		
		0.9	7.2	7.2-Repl
Total Solids	Pcnt wet wt	68.4	49.0	49.2
Total Organic Carbon	Pcnt dry wt	0.8	1.9	2.0
GRAIN SIZE				
Clay (<4um)	Pcnt dry wt	3.0	4.0	3.7
Silt (4um-62um)	"	15.5	22.6	22.8
Sand (62um-2mm)	"	64.8	70.5	71.6
Gravel (>2mm)	"	16.6	2.6	2.0
METALS				
Antimony	mg/kg dry wt	<0.1	<0.1	--
Arsenic	"	0.9	2.5	--
Beryllium	"	0.53	0.43	--
Cadmium	"	0.33	0.14	--
Chromium	"	15.0	10.3	--
Copper	"	25.6	28.6	--
Lead	"	11	32	--
Mercury	mg/kg wet wt	0.0243	0.0140	--
Nickel	mg/kg dry wt	13.9	5.8	--
Selenium	"	<0.1	<0.1	--
Silver	"	0.03	0.13	--
Thallium	"	<0.1	<0.1	--
Zinc	"	132.5	92	--
BASE-NEUTRAL/ACID EXTRACTABLES				
Acenaphthene	ug/kg wet wt	<500	<2,200	--
Acenaphthylene	"	<500	<2,200	--
Aniline, 2-nitro-	"	<2,400	<11,000	--
Aniline, 3-nitro-	"	<2,400	<11,000	--
Aniline, 4-nitro-	"	<2,400	<11,000	--
Aniline, 4-chloro	"	<500	<2,200	--
Anthracene	"	<500	<2,200	--
Anthracene, benzo(a)-	"	<500B	<2,200B	--
Anthracene, dibenzo(a,h)-	"	<500	<2,200	--
Benzene, 1,2-dichloro-	"	<500	<2,200	--
Benzene, 1,3-dichloro-	"	<500	<2,200	--
Benzene, 1,4-dichloro-	"	<500	<2,200	--
Benzene, 1,2,4-trichloro-	"	<500	<2,200	--
Benzene, hexachloro-	"	<500	<2,200	--
Benzene, nitro-	"	<500	<2,200	--
Benzidine, 3,3'-dichloro-	"	<1,000	<4,400	--
Benzoic acid	"	<2,400	<11,000J	--
Benzyl alcohol	"	<500	<2,200	--
Butadiene, hexachloro-	"	<500	<2,200	--
Chrysene	"	<130	<2,200B	--
Cyclopentadiene, hexachloro-	"	<500	<2,200	--
Dibenzofuran	"	<500	<2,200	--

Appendix G - continued.

Parameter	Units	River Mile*		
		0.9	7.2	7.2-Repl
BASE-NEUTRAL/ACID EXTRACTABLES - continued				
Ethane, hexachloro-	ug/kg wet wt	<500	<2,200	--
Ether, bis(2-chloroethyl)	"	<500	<2,200	--
Ether, bis(2-chloroisopropyl)	"	<500	<2,200	--
Ether, 4-bromophenyl-phenyl-	"	<500	<2,200	--
Ether, 4-chlorophenyl-phenyl-	"	<500	<2,200	--
Fluoranthene	"	65BJ	45BJ	--
Fluoranthene, benzo(b)-	"	130BJ	<2,200B	--
Fluoranthene, benzo(k)-	"	68BJ	<2,200B	--
Fluorene	"	<500	<2,200	--
Isophorone	"	11J	86J	--
Methane, bis(2-chloroethoxy)	"	<500	<2,200	--
Naphthalene	"	<500	<2,200	--
Naphthalene, 2-chloro-	"	<500	<2,200	--
Naphthalene, 2-methyl-	"	<500	<2,200	--
Nitrosodiphenylamine, n-	"	<500	<2,200	--
Nitroso-di-n-propylamine, n-	"	<500	<2,200	--
Perylene, benzo(g,h,i)-	"	<500	<2,200	--
Phenanthrene	"	28J	56J	--
Phenol	"	<500	<2,200	--
Phenol, o-chloro-	"	<500	<2,200	--
Phenol, 2,4-dichloro-	"	<500	<2,200J	--
Phenol, 2,4,5-trichloro-	"	<2,400	<11,000J	--
Phenol, 2,4,6-trichloro-	"	<500	<2,200J	--
Phenol, pentachloro-	"	<2,400	<11,000J	--
Phenol, 4-chloro-3-methyl-	"	<500	<2,200J	--
Phenol, 2-methyl-	"	<500	<2,200	--
Phenol, 4-methyl-	"	<500	3,000J	--
Phenol, 2,4-dimethyl-	"	<500	<2,200J	--
Phenol, 2-nitro-	"	<500	<2,200J	--
Phenol, 4-nitro-	"	<2,400	<11,000J	--
Phenol, 2,4-dinitro-	"	<2,400	<11,000J	--
Phenol, 4,6-dinitro-2-methyl-	"	<2,400	<11,000J	--
Phthalate, bis(2-ethylhexyl)	"	130BJ	80BJ	--
Phthalate, diethyl-	"	<500B	<2,200B	--
Phthalate, dimethyl-	"	<500	<2,200	--
Phthalate, di-n-butyl-	"	28BJ	53BJ	--
Phthalate, di-n-octyl-	"	64BJ	<2,200B	--
Phthalate, butylbenzyl-	"	<500B	<2,200B	--
Pyrene	"	<500	56J	--
Pyrene, benzo(a)-	"	<500	<2,200	--
Pyrene, indeno(1,2,3-c,d)-	"	<500	<2,200	--
Toluene, 2,4-dinitro-	"	<500	<2,200	--
Toluene, 2,6-dinitro-	"	<500	<2,200	--
Spike D5-phenol	Pcnt recov.	82	144	--
Spike D10-pyrene	"	69	100	--
Spike 2-fluorophenol	"	99	149	--
Spike D5-nitrobenzene	"	70	84	--
Spike 2-fluorobiphenyl	"	82	90	--
Spike D14-terphenyl	"	76	113	--

Appendix G - continued.

Parameter	Units	River Mile*		
		0.9	7.2	7.2-Repl
POLYCHLORINATED BIPHENYLS				
PCB-1016	ug/kg wet wt	<10	<10	--
PCB-1221	"	<10	<10	--
PCB-1232	"	<10	<10	--
PCB-1242	"	<10	<10	--
PCB-1248	"	<10	<10	--
PCB-1254	"	<10	<10	--
PCB-1260	"	<10	<10	--
ORGANOCHLORINE PESTICIDES				
Aldrin	ug/kg wet wt	<1	<1	--
BHC, alpha-	"	<1	<1	--
BHC, beta-	"	<1	<1	--
BHC, gamma- (Lindane)	"	<1	<1	--
BHC, delta-	"	<1	<1	--
Chlordane	"	<1	<1	--
DDT, 4,4'-	"	8	26	--
DDE, 4,4'-	"	27	260	--
DDD, 4,4'-	"	15	120	--
Dieldrin	"	<1	<1	--
Endosulfan, alpha-	"	<1	34	--
Endosulfan, beta-	"	<1	64	--
Endosulfan sulfate	"	17	67	--
Endrin	"	<1	<1	--
Endrin aldehyde	"	<1	<1	--
Heptachlor	"	<1	<1	--
Heptachlor epoxide	"	<1	<1	--
Toxaphene	"	<30	<30	--
Spike: Hexabromobenzene	Pcnt recov.	106	80	--
ORGANOPHOSPHORUS PESTICIDES				
Azinphos, methyl (Guthion)	ug/kg wet wt	<1	<1	--
Azinphos, ethyl	"	<1	<1	--
Carbophenothion	"	<1	<1	--
Coumaphos	"	<1	<1	--
DEF	"	<1	<1	--
Diazinon	"	<1	<1	--
Dichlorvos (DDVP)	"	<1	<1	--
Dimethoate	"	<1	<1	--
Dioxathion	"	<1	<1	--
Disulfoton (Di-Syston)	"	<1	<1	--
EPN	"	<1	<1	--
Ethion	"	<1	<1	--
Fenthion	"	<1	<1	--
Folex	"	<1	<1	--
Imidan	"	<1	<1	--
Malathion	"	<1	<1	--
Mevinphos	"	<1	<1	--

Appendix G - continued.

Parameter	Units	River Mile* 0.9	7.2	7.2-Repl
ORGANOPHOSPHORUS PESTICIDES - continued				
Monocrotophos	ug/kg wet wt	<1	<1	--
Parathion, methyl	"	<1	<1	--
Parathion, ethyl	"	<1	<1	--
Phencapton	"	<1	<1	--
Phorate	"	<1	<1	--
Phosphamidon	"	<1	<1	--
Ronnel	"	<1	<1	--
HERBICIDES				
2,4-D	ug/kg wet wt	<10	<10	--
2,4-DB	"	<10	<10	--
2,4,5-T	"	<10	<10	--
2,4,5-TB	"	<10	<10	--
2,4,5-TP (Silvex)	"	<10	<10	--
Bromoxynil	"	<10	<10	--
Dicamba	"	<10	<10	--
Dinoseb	"	<10	<10	--
Ioxynil	"	<10	<10	--
MCPA	"	340	2700	--
MCPB	"	<100	<100	--
MCPP	"	<100	<100	--
Phenol, pentachloro-	"	<1	<1	--
Phenol, tetrachloro-	"	<1	<1	--
Picloram	"	<10	<10	--

*Repl = Laboratory replicate for quality control.
-- = No analysis performed.
B = Detected in method blank.
J = Estimated value; value not accurate.

Appendix H. Macroinvertebrate community structure in Wide Hollow Creek, Washington, July 22 and 23, 1987.

Taxanomic Group	River Mile*						
	0.9	3.2	5.3	7.2	9.2	11.5	13.7
Turbellaria (flatworms)	--	--	--	19c	--	--	--
Hirudinea (leeches)	--	--	--	--	--	11	--
Oligochaeta (worms)	--	2	--	2	10	5	1
Ostracoda (ostracods)	--	3	--	2	--	24a	--
Amphipoda (amphipods)							
Talitridae	21c	--	--	--	4p	19	2
Hydracarina (mites)	--	--	1	--	1	--	--
Ephemeroptera (mayflies)							
Baetidae	--	1	1	--	19c	--	8p
Heptageniidae	--	--	--	--	--	--	1
Leptophlebiidae	--	--	--	--	--	--	7
Tricorythidae	--	--	--	--	19c	--	--
Trichoptera (caddisflies)							
Hydropsychidae	8	--	--	--	33c	4	19
Zygoptera (damselflies)							
Coenagrionidae	--	--	1	--	1	--	--
Hemiptera (true bugs)							
Corixidae	--	--	--	--	--	5p	1
Lepidoptera (moths)							
Pyralidae	1	--	--	--	--	--	--
Diptera (true flies)							
Chironomidae	20c	25p	26c	54a	58a	17	28p
Empididae	--	1	1	--	1	--	--
Simuliidae	--	--	--	1	--	--	--
Tipulidae	--	1	--	--	--	--	--
Gastropoda (snails)							
Ancylidae	1	--	--	--	--	1	--
Lymnaeidae	--	--	--	1	1	--	--
Physidae	1	--	--	33a	3	9	--
Planorbidae	--	--	--	--	2	1	--

*Abundance of organisms not picked in 10-minute span was estimated as: p = present (<10 remaining), c = common (10-25 remaining), or a = abundant (>25 remaining).

Appendix I. Qualitative assessment of invertebrate habitat quality in Wide Hollow Creek, July 22-23, 1987.

Parameter	Site						
	0.9	3.2	5.3	7.2	9.2	11.5	13.7
Date	7/22	7/22	7/22	7/22	7/23	7/23	7/23
Time	1600	1640	1715	1740	1430	0930	1400
Mean Width (ft)	15	20	15	15	15	8	6
Mean Depth (ft)							
Riffles/Runs	1.2	1.0	1.0	0.5	0.8	0.8	0.8
Pools	None	4	4	3	3	None	2
Substrate Composition*							
Fines (<1/4")	C	C	C	R	R	C	R
Gravel (1/4"-3")	R	R	R	R	C	R-C	R
Cobble (3"-12")	R	R	R	C	C	R	C
Boulder (>12")	R	R	R	R	N	R	R
Bedrock	C	N	N	N	N	N	N
Macrophytes	R-C	R	N	C	C	C	R
Clay	N	N	N	N	N	N	N
Canopy Cover (Shading) *	R	C	R-C	C	R	C	R
Bank Stability **	F	F	G	F-G	G	F	G
Bank Vegetation *	A	C	A	A	A	A	A
Aquatic Plants *							
Slimes	N	N	N	N	N	N	N
Periphyton	C	R	C	R	C	R	C
Filamentous Algae	N	N	N	N	N	N	N
Macrophytes	R-C	R	N	C	C	C	R
Aesthetics **	P-F	P-F	F	F-G	F-G	F	F-G
Predominant Land Use ***	C-I	A	C-R	A-R	A-R	A	A

* N = None (0%)
R = Rare (<10%)
C = Common (10-50%)
A = Abundant (>50%)

** P = Poor
F = Fair
G = Good
E = Excellent

*** A = Agricultural
C = Commercial
I = Industrial
R = Residential