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Portage Creek: Nonpoint Source Pollution Effects on Quality of the Water Resource

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ECOLOGY

Portage Creek: Nonpoint Source of Pollution Effects on Quality of the Water Resource

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ABSTRACT

Prevalent surface water quality problems in Portage Creek are probably exacerbated by land use in the watershed and by groundwater influences. Quantified land use and activity information for the Portage Creek watershed was useful in interpretation of patterns of pollution observed during this study. Land use types such as pasturing and cropland appeared to significantly influence water quality in Portage Creek. Total suspended solids and total inorganic nitrogen concentrations and loads were probably influenced by over-application of manure or commercial fertilizers during the wet season. Total phosphorus and fecal coliform concentrations were not found to be seasonally influenced.

Fecal coliform, turbidity, and dissolved oxygen concentrations violated Washington State Class A water quality standards during both the wet and dry season. Fecal coliform concentrations consistently violated the standard at all Portage Creek stations during the dry season (April-November). Dissolved oxygen concentrations violated the standard at mid- and lower-reach stations during both the wet and dry seasons. Turbidity exceeded the standard at mid- and upper-reach stations during both seasons. Exceedance of state water quality standards by these parameters was influenced by one or more of the following: manure spreading, cattle grazing, and instream decaying organics. Groundwater influences on surface water quality may have been prevalent at mid- and lower-reach regions of Portage Creek. Quantities of arsenic, chromium, copper, and nickel were detected in sediments at the mid-reach of Portage Creek. Benthic macroinvertebrate samples were collected at sites corresponding with sediment analysis. The benthic epifauna at the mid-reach of Portage Creek was highly impacted, possibly by the unstable organic substrate.

ACKNOWLEDGEMENTS

We wish to acknowledge the following personnel from the Surface Water Investigations Section (Department of Ecology) for their invaluable field assistance during segments of this project: Joe Joy, Will Kendra, Betsy Dickes, Ken Merrill, and Roger Willms. We are also grateful to private landowners in the Portage Creek watershed who allowed us access to the stream. This report was a component of the Portage Creek Pilot Project directed by Roberta Feins (Puget Sound Water Quality Authority) which was a larger interagency effort within this watershed to detail land use, growth, and activity. Information provided by Terry Nelson (Puget Sound Cooperative River Basin Team) and Bill Railton (Soil Conservation Service) regarding quantified land use information and land use activity assisted immensely in water quality data interpretation. Our gratitude is extended to Jennie Carruth, Kelly Carruth, Barbara Tovrea, and Kim Douglas for their invaluable assistance in preparing this document.

INTRODUCTION

Portage Creek is a tributary of the Stillaguamish River in northwest Washington and was identified as one of six "problem reaches" in the Stillaguamish River Basin (Snohomish County, 1974). Water quality problems in Portage Creek have been attributed to nonpoint source (PS) pollution related to agricultural land use (URS, 1977). In response to water quality problems, 205j and Referendum 39 grant monies have been used to fund implementation of agricultural best management practices (Snohomish Conservation District, undated). Most of the 13 dairies in the Portage Creek watershed have developed "conservation plans." Plans have been implemented to varying degrees at nine of the dairies (N. Jacobsen, personal communication).
Recently the Stillaguamish watershed was selected as an "Early Action Watershed", as described in the Puget Sound Water Quality Management Plan (PSWQA, 1989). As a result, Snohomish County received a grant from Ecology for development and implementation of an action plan for the control of nonpoint pollution. One of the grant requirements was to assess existing water quality and track long-term water quality trends. Baseline studies of important sub-watersheds such as Portage Creek are needed to provide data on existing conditions against which future trends can be compared. This study will provide some of the information required to meet the needs of the Stillaguamish Watershed Action Plan.

Various attributes in the Portage Creek watershed were examined through use of a Geographical Information System (GIS). The objective of a GIS project was to characterize and map current land use and resource data in the watershed. The information and water quality data collected as a part of this and other concurrent Portage Creek projects was used to evaluate relationships between land use and water quality. The Puget Sound River Basins Team compiled land use information and record agricultural activities in the Portage Creek watershed. The GIS database and records of actions taken to control NPS pollution will be used to assess the success of nonpoint planning efforts. The GIS pilot project participants included state, federal, and local entities.

Additionally, Ecology's effort will be used as an integral component of an interagency application and evaluation of GIS. The Stillaguamish River basin is targeted for GIS application by local government agencies in Snohomish County for environmental planning and resource management.

DESCRIPTION OF THE STUDY AREA

Portage Creek is located near the City of Arlington in northwestern Snohomish County, Washington (Figure 1). The Arlington airport is located along the southern boundary of the watershed, and the city of Arlington is located on the northern border. Interstate 5 bisects the drainage. The watershed covers approximately 19 square miles and contains nearly 45 miles of stream channel and tributaries. The mainstem of Portage Creek flows northwesterly from highlands south of Arlington through agricultural lowlands until its confluence with the Stillaguamish River at river mile 1.7 (Snohomish County, 1974). Fish Creek, a tributary to Portage Creek, drains the southwest portion of the watershed (six square miles), and enters Portage Creek about four river miles upstream of the mouth. Elevations in the watershed range from a maximum of 540 feet mean sea level (msl) in the highlands to 20 feet msl near the mouth. Portage Creek is rated as a "Class A" water in the state's water quality standards (WAC 173-201-045).

Land use in the watershed is predominantly agricultural with a forested perimeter. In general, the upper watershed is comprised of small, non-commercial farms and limited suburban development. Two small impounded reservoirs are located on Portage Creek approximately 7.3 miles upstream from the mouth. The majority of the lower watershed lies in the fertile Stillaguamish River floodplain and is farmed intensively for dairy and row crop production. Land use near Fish Creek is predominantly non-commercial farms, with the exception of residential development near Lake Ki. In general, the Fish Creek watershed appears to be undergoing some suburban development. This project is timely in providing baseline water quality data for future comparison of Fish Creek and Portage Creek watershed information.

Survey Objectives

1. Characterize existing water quality of Portage Creek and principal tributaries as related to state water quality standards.

2. Evaluate impacts on Portage Creek from the three predominant land uses in the basin:

    a. Non-commercial hobby farms and rural development in the upper watershed.

    b. Urban impacts from the City of Arlington and its commercial/industrial area.

    c. Commercial farming impacts to the lower mainstem.

3. Provide surface water quality information to the GIS pilot project conducted by the Puget Sound River Basins Team for the Stillaguamish River watershed.

4. Evaluate sample collection methods and pollutant contributions to Portage Creek during storm events.

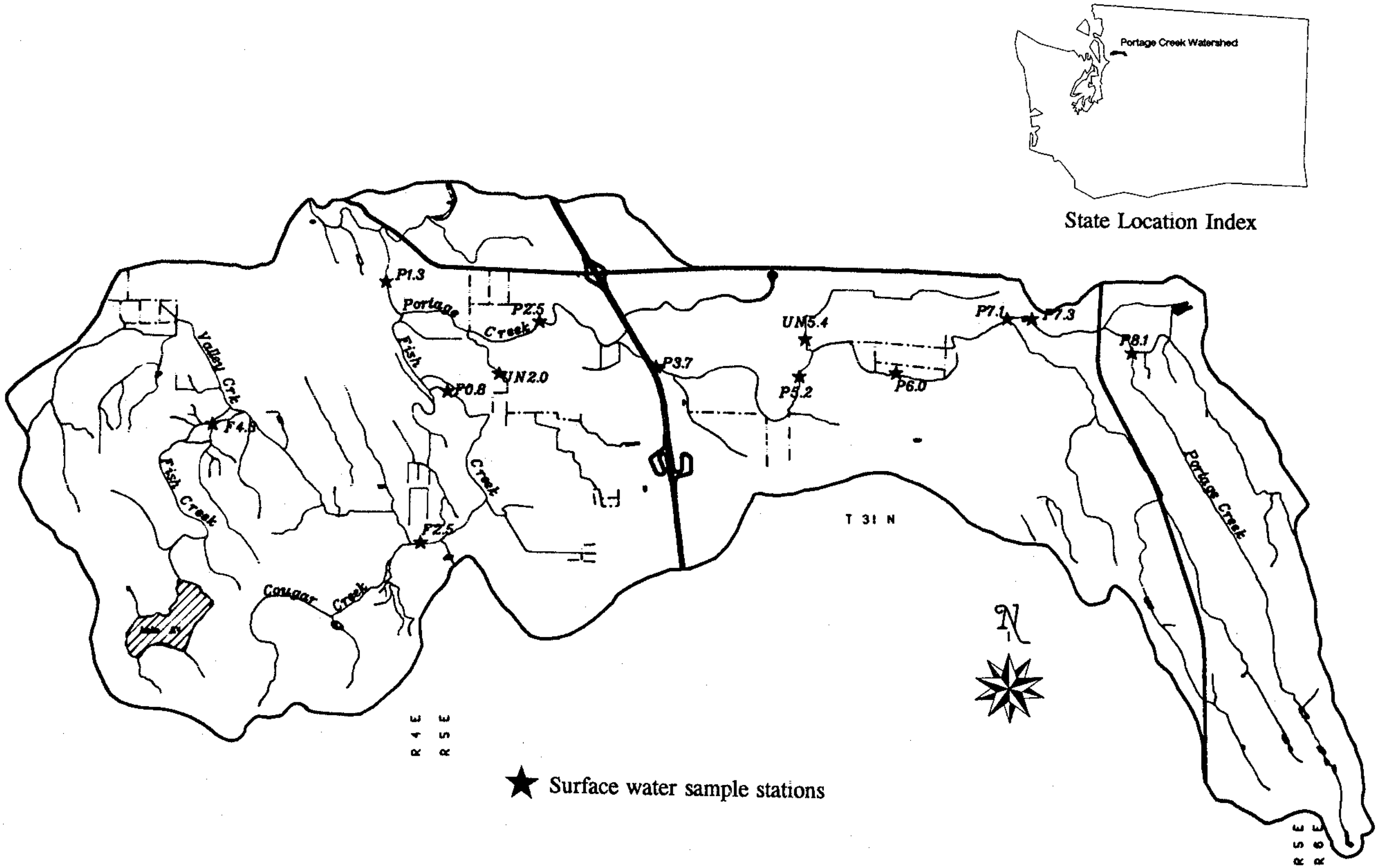


Figure 1. Sample station locations in the Portage Creek watershed.

5. Evaluate the effectiveness of the nonpoint monitoring guidance (Michaud, 1989) developed for Puget Sound Action Plan watersheds in terms of characterizing water quality conditions during wet and dry weather.

METHODS

Survey Plans

To meet the objectives of the study and those stated in the nonpoint monitoring guidance (Michaud, 1989), the following were performed and are described below:

- Routine Monitoring
- Runoff-Event Monitoring
- Special Studies

Routine Monitoring

Routine monitoring concentrated on the wet-weather period at the 13 stations shown in Figure 1. The variability of pollutant contributions during the wet-weather period was greater. Monitoring occurred on 14 occasions; once in December, bi-weekly in January and February, and monthly from March through November. Table 1 summarizes parameters measured at each station. Analytical methods used to determine constituent concentrations are referenced in Table 2.

Runoff-Event Monitoring

Four key routine monitoring stations (P1.3, P3.7, P7.1, F0.8) were emphasized during 3 runoff events. Two were monitored during the January through March period and one in November, 1989. Stage recorders were placed at each of these stations to record stream height for the January-through-March period. During runoff-event monitoring, sequential samplers placed at the four stations collected one sample every hour for a 24-hour period. These 24 samples were hand-composited into 12 samples for each station by combining bi-hourly samples.

During routine and runoff events, stage and flow were measured to calibrate stage recorder data. Additionally, parameters analyzed for in grab samples were: oil and grease, conductivity, fecal coliform, and BOD from the four key stations to determine the impact of urban and highway runoff.

Table 1. Water quality parameters measured at Portage Creek sample stations. Numbers indicate sample size.

Parameter	P1.3	UN2.0	P2.5	P3.7	P5.2	UN5.4	P6.0	P7.1	P7.3	P8.1	F0.8	F2.5	F4.3	QA/QC
	Station*													
	Routine Monitoring													
Flow	1	1		1	1			1	1		1			1
Temperature	1	1	1	1	1	1	1	1	1	1	1	1	1	1
pH	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Conductivity	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D.O.	1	1		1	1				1		1			
TSS	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Turbidity	1	1		1	1			1	1	1	1			1
Nutrients	1	1		1	1			1	1	1	1			1
Fecal Coliform	1	1	1	1	1	1	1	1	1	1	1	1	1	2
BOD	1			1					1		1			0
	Runoff-Events													
Flow	1			1				1			1			1
Temperature	1			1				1			1			1
pH	1			1				1			1			1
Conductivity	1	1	1	1	1	1	1	1	1	1	1	1	1	1
TSS[1]	12	1	1	12	1	1	1	12	1	1	12	1	1	6
Nutrients[1]	12			12				12			12			5
Fecal Coliform	1	1	1	1	1	1	1	1	1	1	1	1	1	2
BOD	1			1				1			1			0
Oil and Grease	1			1				1			1			0
	Dissolved Oxygen Study													
D.O.	1			1				1			1			1
	Sediment Sampling													
Priority Pollutants	1			1				1			1			1
	Benthic Macroinvertebrate Study													
Macroinvertebrates	1			1				1			1			0

* Station numbers coded as follows:

P=Portage Creek mainstem
F=Fish Creek
UN=Unnamed Creek
QA/QC=Quality Assurance/Quality Control

Numeral denotes river miles upstream from mouth

[1] Parameters analyzed in bi-hourly composited runoff-event sampling over a 24-hour period.

Table 2. Sampling and analytical methods used in the Portage Creek monitoring program.

Parameter	Analytical Method	Method Reference(1)
Flow	Swoffer Meter	
Temperature	Thermometer	
pH	Field Probe	SM 423
Specific Conductance	Field Probe	SM 205
Dissolved Oxygen	Winkler (iodometric)	SM 421A
BOD_5	Bioassay	SM 507
TSS	Gravimetric	SM 209C
Turbidity	Nephelometric	SM 214A
Ammonia-N	Phenate	EPA 350.1
Nitrate + Nitrite-N	Cadmium Reduction	EPA 353.2
Total P	Ascorbic Acid	EPA 365.1
Fecal Coliform	Membrane Filter	SM 909C
Oil and Grease	Gravimetric	EPA 413.1

(1) SM: APHA, 1989
EPA: EPA, 1983

Special Studies

Dissolved Oxygen Studies

A dissolved oxygen (D.O.) study was conducted during the late summer period. Late summer was selected because increased temperature and decreased mixing during low flow periods can be critical for D.O. Sampling occurred during pre-dawn hours when D.O. levels usually reach a diurnal minimum. Dissolved oxygen was measured at the four key stations.

Sediment Sampling

Sediments were sampled in August 1989 from depositional areas at the four key stations. Collection was consistent with the nonpoint monitoring guidance (Michaud, 1990). A pollutant analysis of the samples included the following compound groups:

- Acid extractable compounds
- Base-neutral extractable compounds
- Pesticides
- Herbicides
- Metals
- Polychlorinated biphenyls (PCBs)

Grain size, total organic carbon, and percent solids were measured for each sample to aid data interpretation. Exact parameter coverage is presented in Appendix C.

Benthic Macroinvertebrates

Instream biota are indicators of long-term water quality conditions due to their continual presence at a particular stream reach. A water sample represents water quality information for a discrete period in time and may not adequately represent daily and seasonal variation. Sampling locations were selected to minimize differences in habitat (i.e., stream velocity, substrate, stream cover). The invertebrates were keyed to at least the family level and to the generic level, where possible (Pennak, 1978; Merritt and Cummins, 1984).

Benthic macroinvertebrates were sampled at the four key stations in the Portage Creek drainage. Three D-Net kick samples were taken at sites P1.3, P7.1, and F0.8. Substrate was a mixture of gravel, cobble, and pebble. The collection area for each sample was one square foot. Three Eckman Grab samples were taken at site P3.7 due to the unstable organic detrital nature of the substrate. The mainstem Portage Creek sample sites were characterized as "runs", whereas the Fish Creek site was considered a "riffle/run" water type. Sampling depth at site P1.3 varied from between 20 cm and 45 cm. Site P3.7 sampling was accomplished at approximately 45 cm and the two remaining sites (P7.1 and F0.8) were sampled at depths of 10 to 20 cm.

Samples were emptied into one gallon freezer bags and preserved in a 70 percent ethanol solution. The Eckman Grab samples were thoroughly mixed and divided into six equal volumes in order to expedite the sorting and identification process. Benthic macroinvertebrates from each replicate sample from all four sites were picked, sorted and identified. This information is located in Appendix D of this document.

Land Use

Land use information was collected and stored by the Puget Sound River Basins Team in a geographical information system (GIS) using Arch.Info software. The Portage Creek drainage was further divided into sub-watersheds based on location of mainstem surface water sample sites (P1.3, P3.7, P5.2, P7.1, P7.3). Land uses were expressed as percentages within four consecutive distances from the stream (250 ft, 500 ft, 1000 ft, >1000 ft). Use of percentages to describe land use within a sub-watershed eliminated direct comparison problems due to unequal sub-watershed sizes.

Quality Assurance/Quality Control (QA/QC)

Ten percent of all field samples were randomly replicated. All field and laboratory measurements met QA/QC requirements described in the Puget Sound freshwater protocols (PSEP, 1988).

Considerations in Data Analysis

The sample period December 21, 1988, through March 22, 1989, represented a period with high monthly precipitation totals and was thus considered the wet season. Runoff event monitoring was carried out on March 6 and March 22, 1989, with a third runoff event sample collected on November 7, 1989, during a heavy rain event near the end of the dry season.

The routine monitoring data was grouped for wet and dry seasonal comparisons. The dry season included samples from April through November 1989. Data analyses were performed in two ways. First, between-season comparisons were made for each sample station. The between-season comparison was used to gauge the effects of seasonal variables (e.g., temperature, precipitation) on water quality within the drainage. Knowledge of seasonal variation allows evaluation of worst-case events throughout the year. The second analysis used between-station comparisons to identify spatial water quality differences within the drainage. One of the objectives of this monitoring project was to evaluate land use impacts, and to identify sources in finer detail using station comparisons.

Pollutant loads are calculated by multiplying concentration by flow and correcting to yield mass per unit time. Load calculations are reported in Appendix A. Pollutant loads can be used to quantify diffuse pollution sources and compare sites/sub-drainages. Best management practicesimplemented to control nonpoint source pollution may be measured by comparison of pollutant loads before and after BMP implementation.

RESULTS AND DISCUSSION

Land Use

Forest land distribution is most dense around the perimeter of the Portage Creek watershed and away from the creek proper (Figure 2). In addition, there is an increased amount of forest land near the mouth of Portage Creek. The central region of this watershed contains very small quantities of this land use type.

Grazed pasture is the major land use in the central portion of the watershed covered primarily by low growing grasses (Figure 3). Much of this activity is contiguous with the stream from river mile P7.3 downstream to river mile P1.3. Nutrient and total suspended solids contributions may occur from grazed pasture land activities. Grazed pasture land experiences a declining representation near the mouth of Portage Creek (Figure 3).

Ungrazed cropland was distributed centrally in the Portage Creek watershed, similar to grazed cropland, but at a much smaller proportion by comparison (Figure 4). Ungrazed cropland increased in percent representation at the lower end of Portage Creek and is predominant from streamside to 1000 feet from the stream.

Management of some ungrazed cropland can be the same as grazed pasture land including the type of fertilizer application and absence of streamside riparian zone vegetation. Contributions to surface waters from ungrazed cropland would primarily be limited to nutrients, with some suspended solids entering the stream more frequently through surface runoff from tilled land.

Urban land use distribution for the Portage Creek watershed is displayed in Figure 5. A major portion of the urbanized region in the watershed is located along the outer boundary (>1000 feet) and a small percentage is contiguous with the stream in the upper-reaches. Urban zones are characterized by impervious surfaces that promote conveyance of oil and grease residues and metals associated with transportation vehicles (Novotny and Chesters, 1986). The Portage Creek watershed does not contain an exceedingly high proportion of urban areas in relation to other land use types. A land use category related to the urban environment is classified as "utilities" and consists of highways, railroads, and high voltage cable corridors. Most of the utilities are concentrated more than 1000 feet away from the stream, and at the mid- and lower reaches toward the mouth (Figure 6).

Wetlands in the Portage Creek watershed are primarily distributed close to the stream (Figure 7). Land classified as wetlands is present throughout the length of Portage Creek drainage, but predominantly at mid-reach stations. Much of the mid-reach is bordered by a plateau where ground water discharge is suspected. Wetlands may function as "filters" of contaminated surface water. Alternately, organics and humic acids may be contributed from wetlands to receiving water.

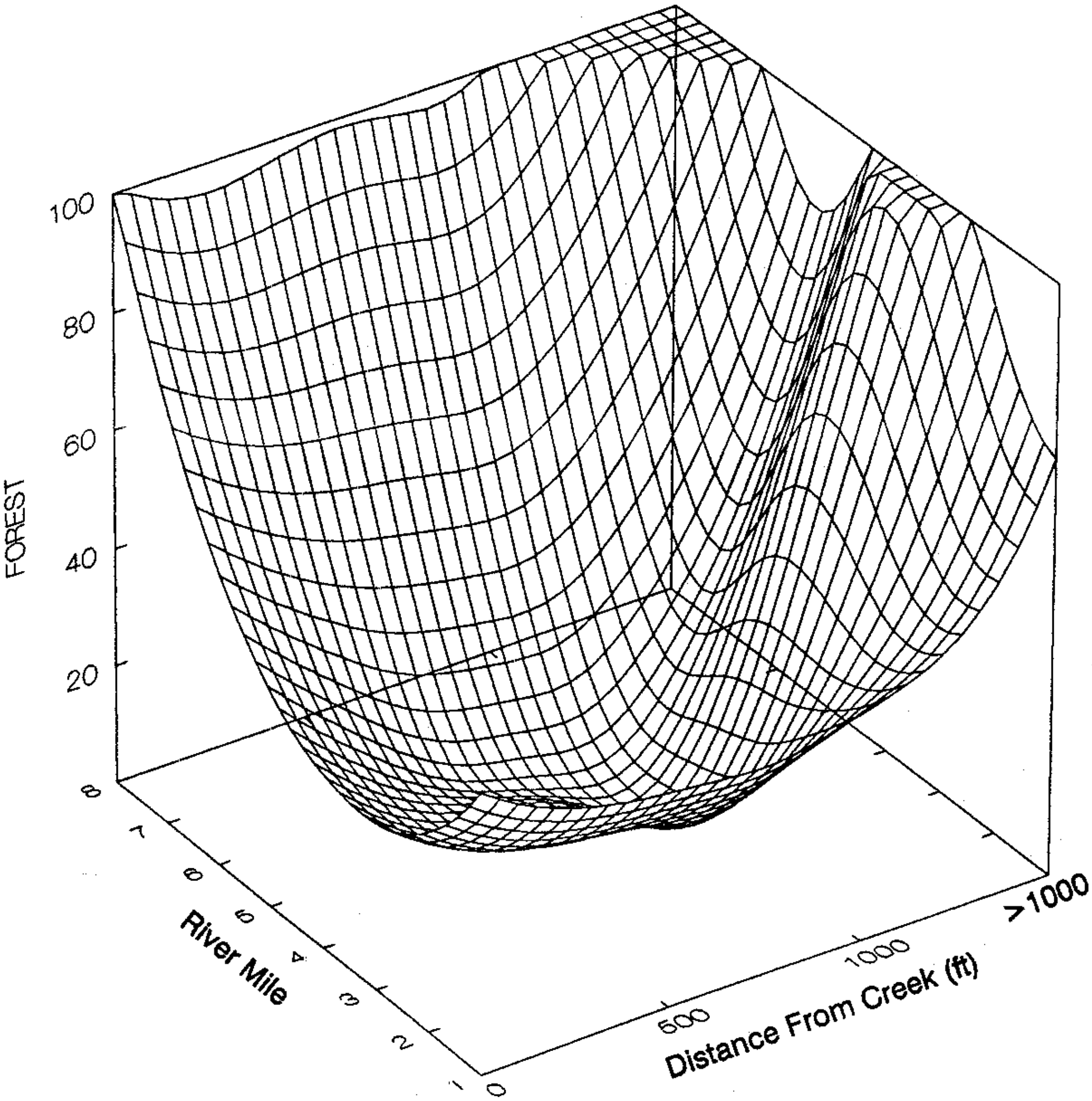


Figure 2. Forested land distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

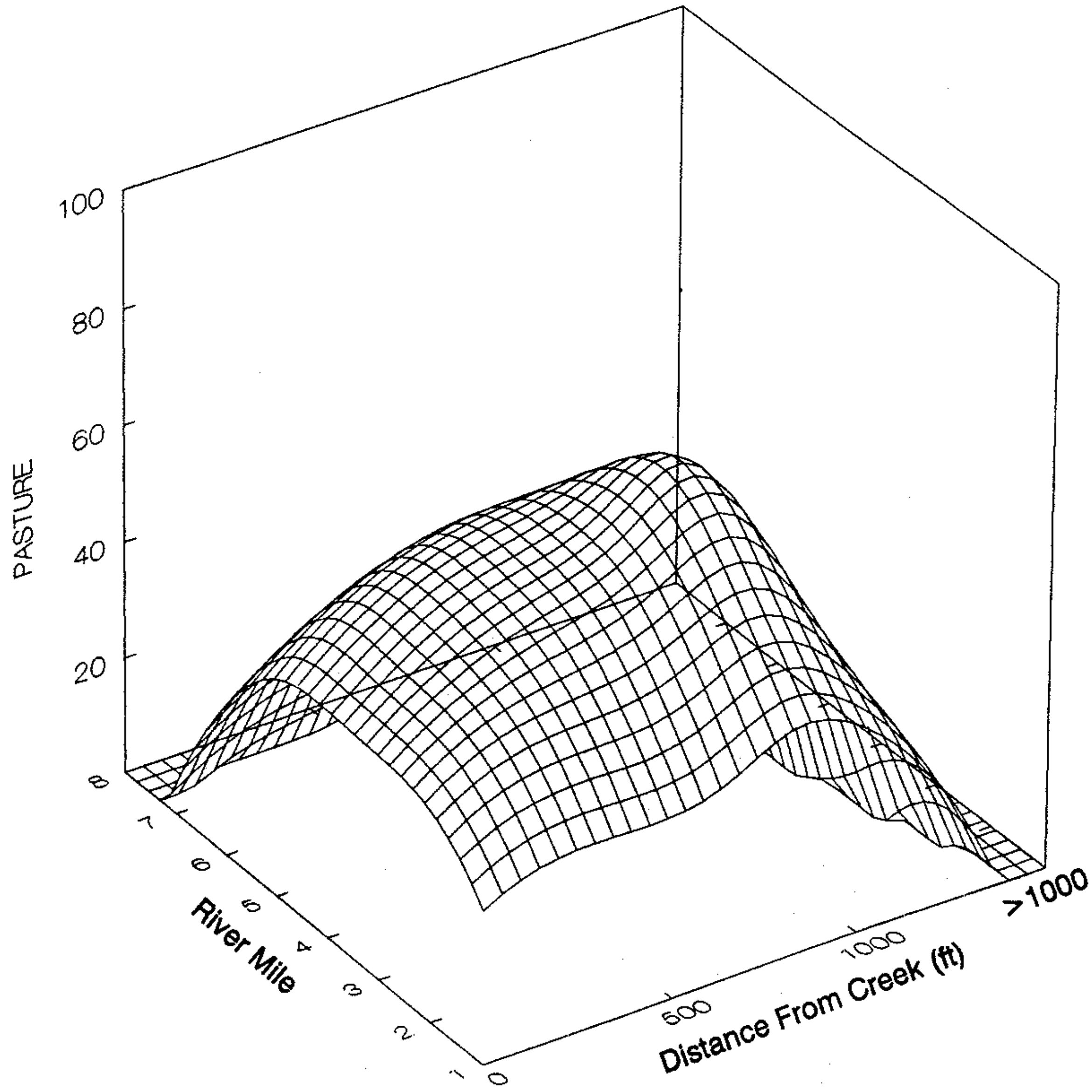


Figure 3. Pasture land distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

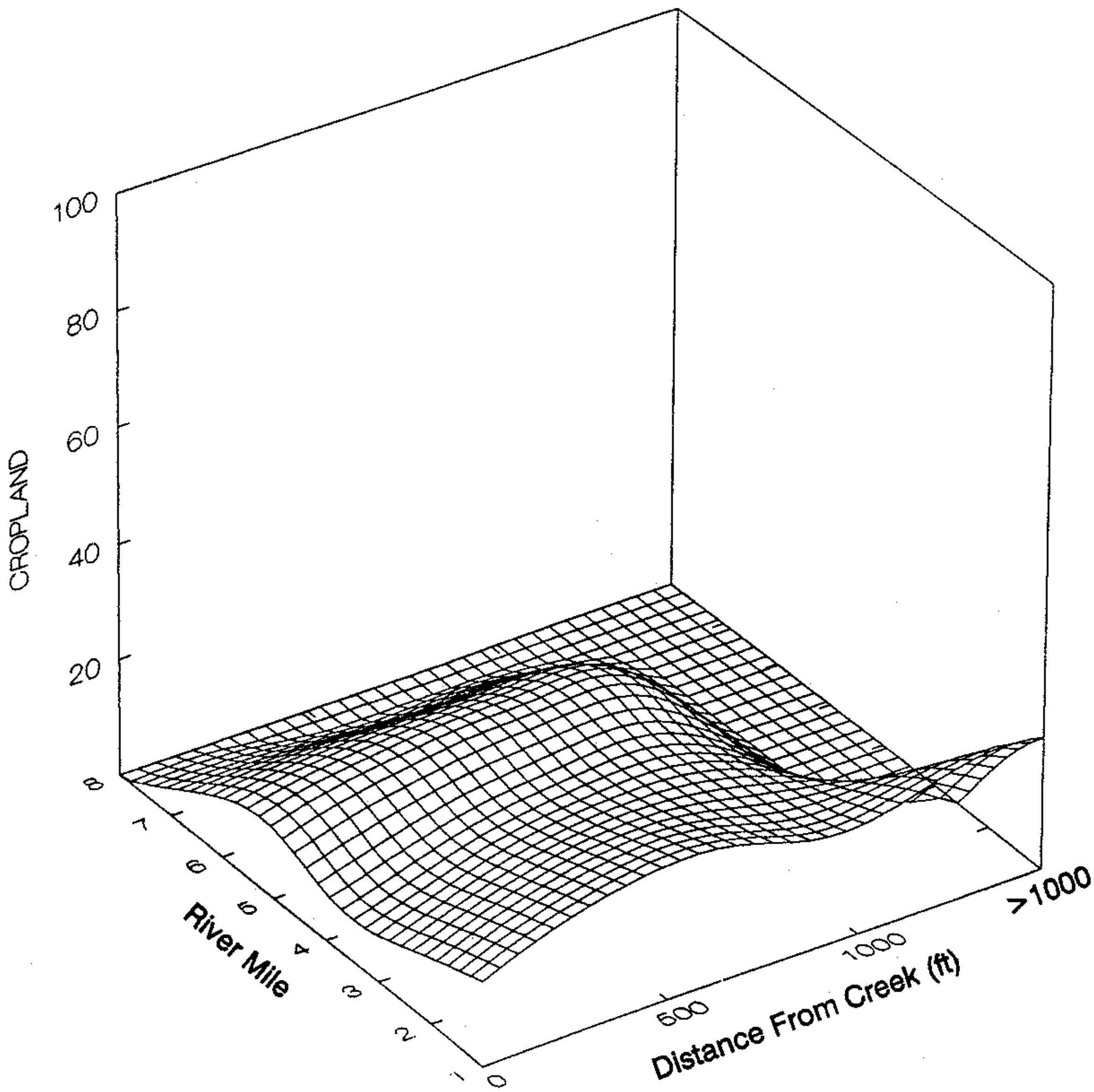


Figure 4. Cropland distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

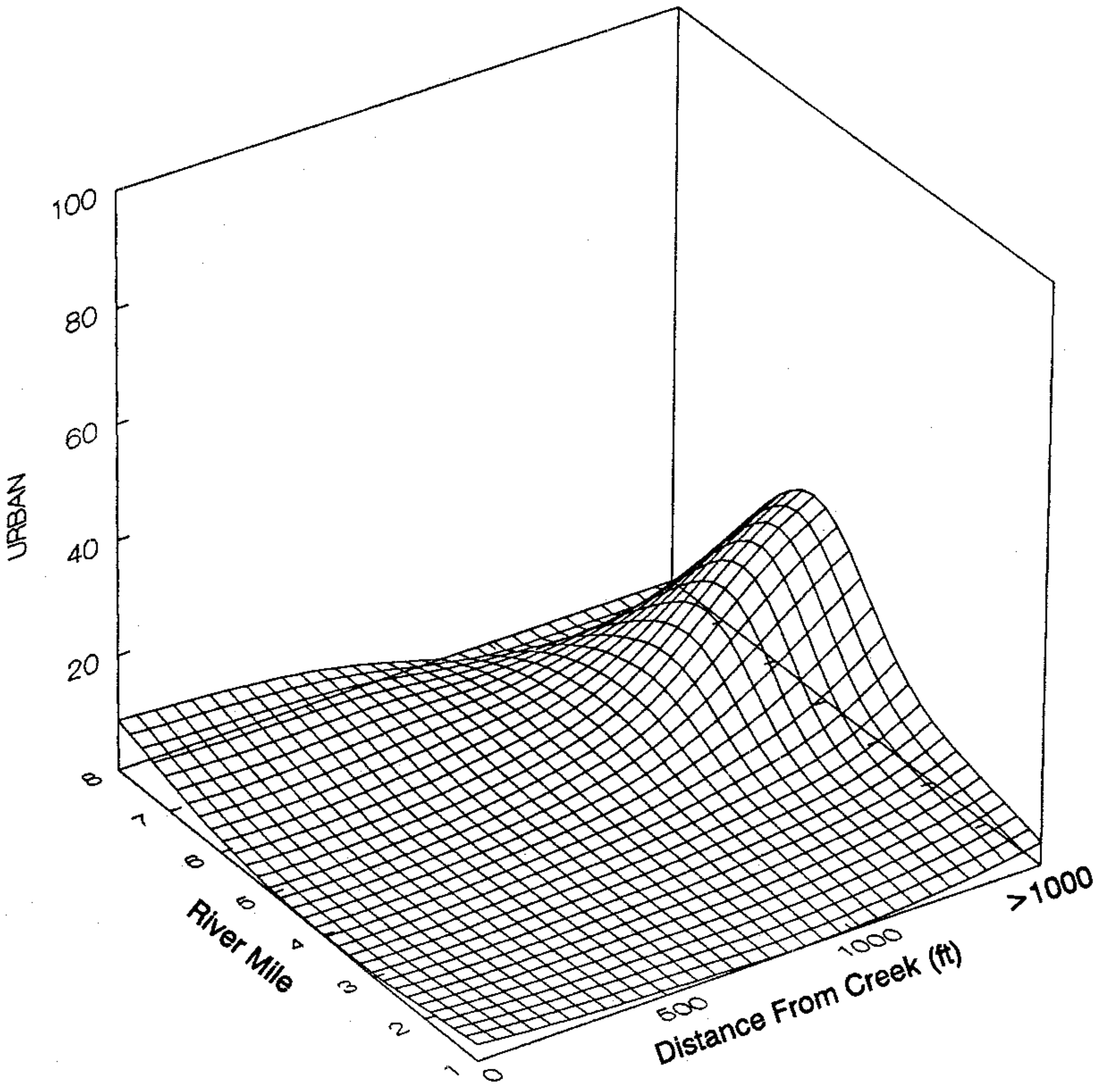


Figure 5. Urban land distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

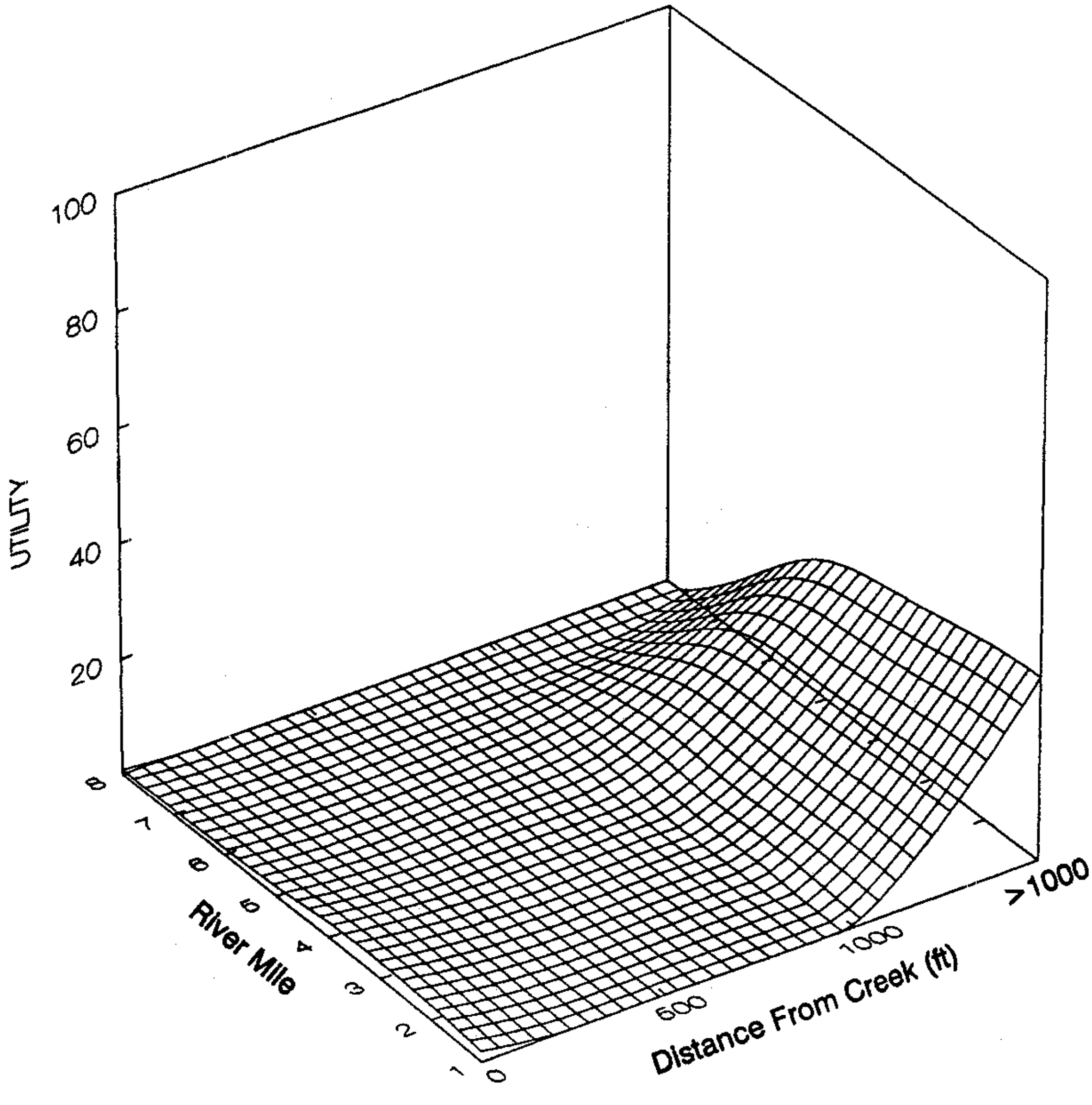


Figure 6. Distribution of Utility land use in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

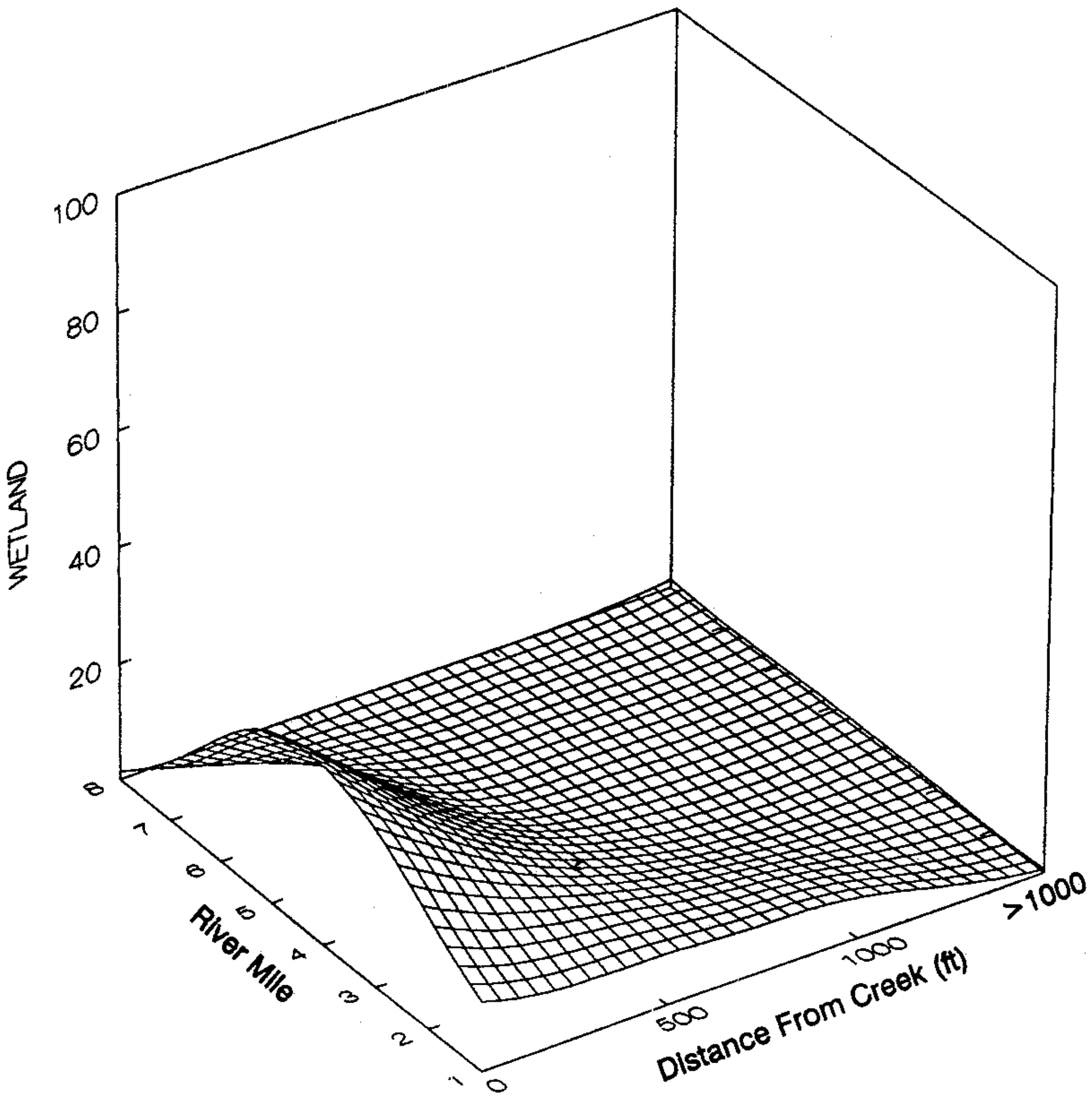


Figure 7. Wetland distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

A recognizable portion of land type termed "grass" is ubiquitous in the Portage Creek watershed (Figure 8). Land classified in this category is mainly comprised of fallow fields and semi-forested regions dominated by grass. The largest quantity of this land type is found in the same watershed region as was urban development. Much of the stream perimeter is dominated by grass land, primarily as a component of the riparian zone.

Water Quality Characteristics

Seasonal Discharge Comparisons

Rates of discharge varied substantially at each mainstem Portage Creek station during wet season and dry season months. Mean discharge rates during the wet season were between two and three times higher than during the dry season (Figure 9). The largest discharge increase during the wet season was between sites P1.3 and P3.7. This was primarily due to the Fish Creek contribution.

Discharge rates influence the concentration of substances (including pollutants) in streams. Concentrations are influenced through either dilution when discharge is high, or conversely, concentration when discharge is low. The concentration/dilution effect is pronounced if loading is constant where concentrations are inversely related to flow. The load calculation for a particular parameter describes the mass of pollutant passing a given point per unit time. Load accounts for flow, thereby providing a standardized measure for comparison among all stations.

Load calculations are useful for identifying sources of chemical input to a stream and identifying areas where losses occur. A net increase of a particular constituent load relative to an upstream site is termed a "gain" and conversely, a decrease in constituent load is a "loss". Sources of chemical input include groundwater, point sources, and nonpoint sources. These contributing sources or sinks, may classify a stream reach between two consecutive stations as gaining or losing a chemical pollutant load, respectively.

Seasonal Water Quality Comparisons

Four water quality parameters were examined to characterize nonpoint sources: total suspended solids, total inorganic nitrogen, total phosphorus, and fecal coliform.

Mean total suspended solids (TSS) concentrations were generally greater during the wet season (Figure 10). The exception was at station P7.3 during the dry season. The total suspended solids observation on October 10, 1989, was responsible for the higher mean during the dry season (Appendix A, Table A7). Manure spreading activity on a crop field was prevalent upstream of this sample station and adjacent to the creek. Other parameters such as total inorganic nitrogen, fecal coliform bacteria, and total phosphorus also showed high concentrations on October 10, 1989. The highest mean value for total suspended solids was recorded at Station P3.7 during the wet season (Figure 10). Investigations observed continuous suspension of organic debris at this station. Suspended solids in surface waters originate either from the

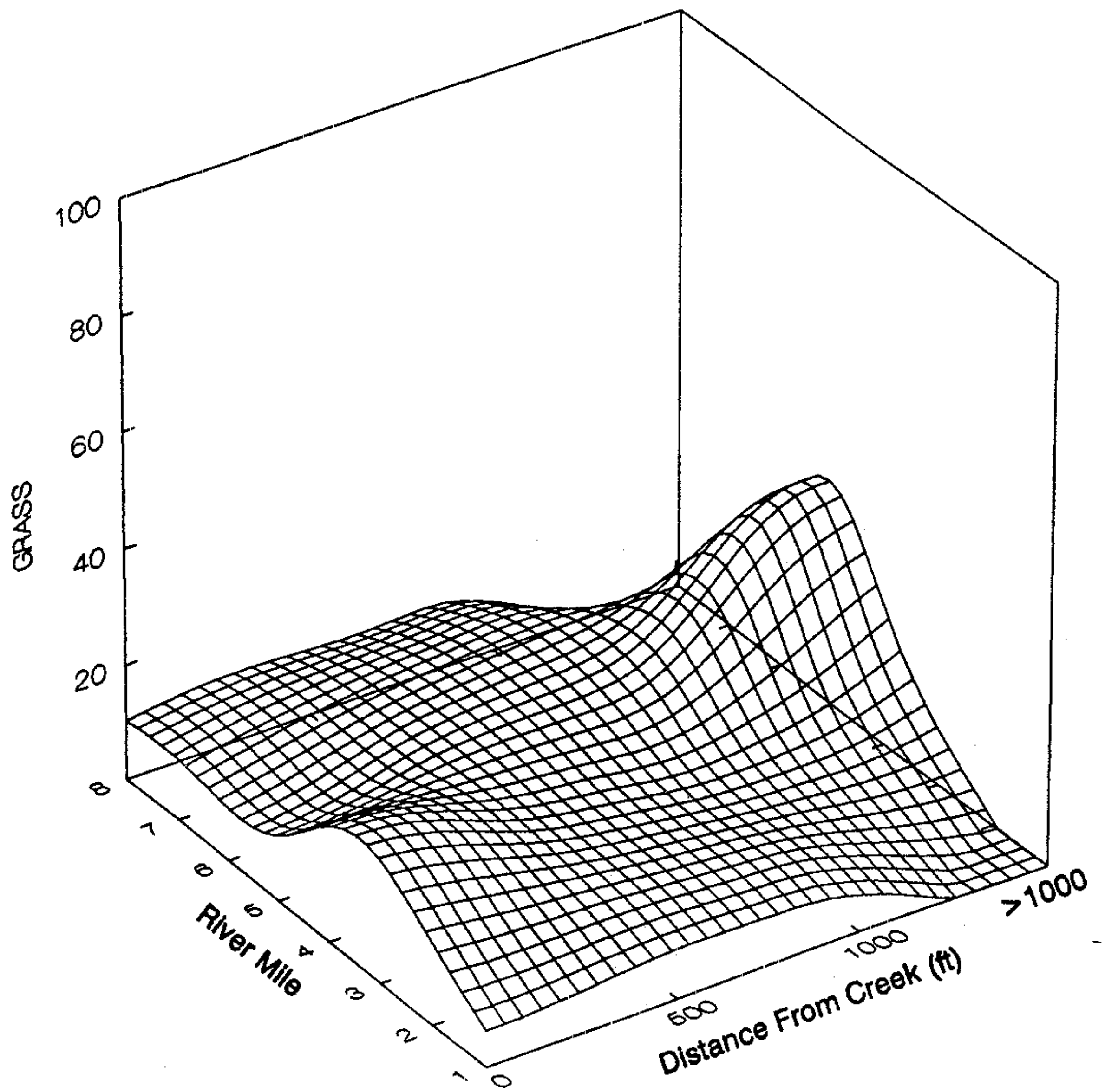


Figure 8. Grass land distribution in the Portage Creek watershed expressed as percent representation by river mile distance and linear distance from the creek.

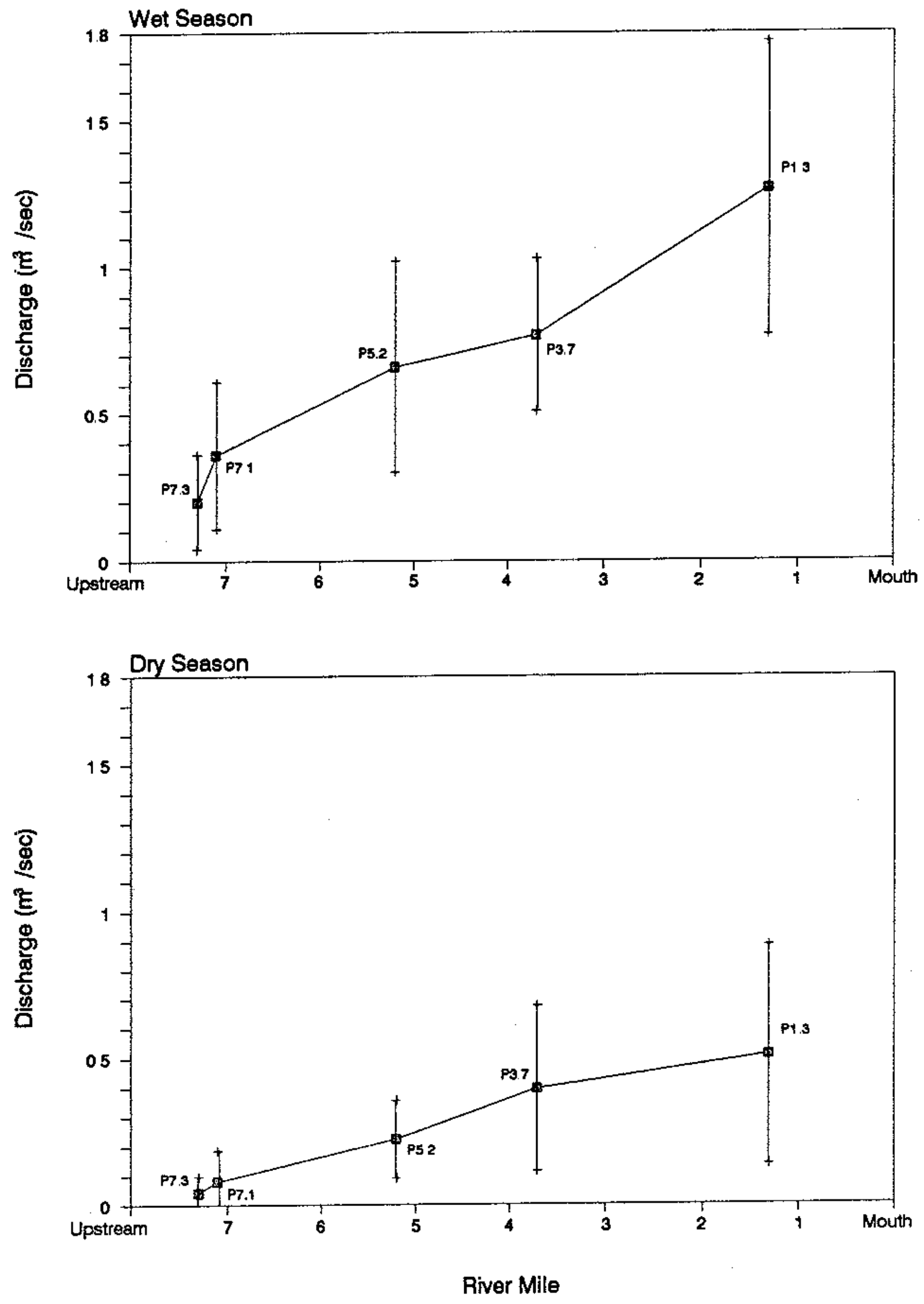


Figure 9. Mean discharge rates (m³/sec) and standard deviations at Portage Creek stations during the wet season (21 December 1988-13 March 1989) and the dry season (10 April 1989-14 November 1989).

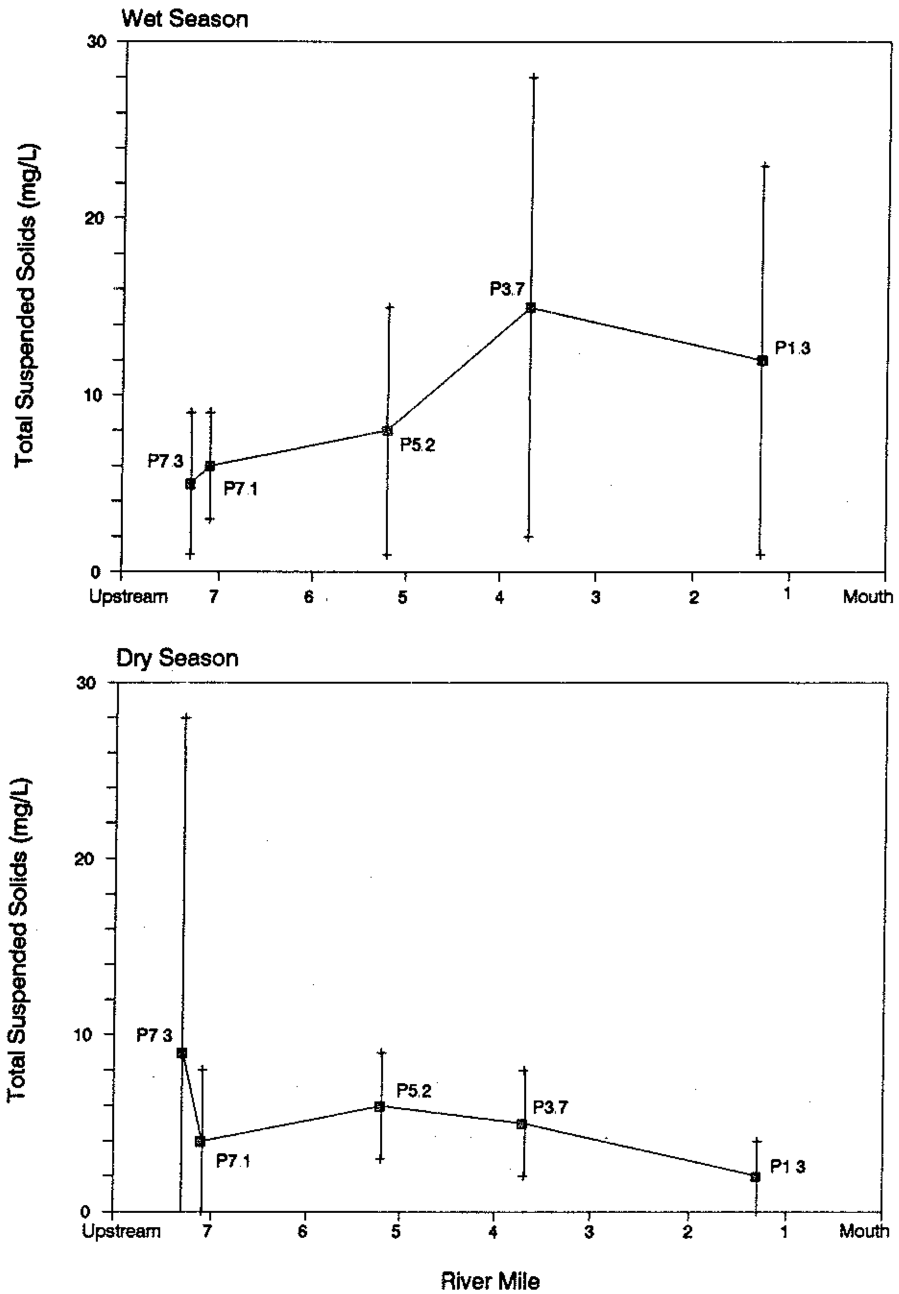


Figure 10. Mean concentrations for total suspended solids (mg/L) and standard deviations at Portage Creek stations during the wet season (21 December 1988-13 March 1989) and the dry season (10 April 1989-14 November 1989).

resuspension of settled solids during turbulent flow or through the introduction of runoff material. Certain land use activities mobilize these materials by destroying the integrity of soils (e.g., land development), adding nutrient-laden materials (e.g., agricultural activity) or by removing overhead canopy which can increase surface soil transport on hill slopes (forest practices).

Total inorganic nitrogen is the sum of ammonia-nitrogen and nitrate+nitrite-nitrogen. In this study, animal waste, fertilizers, and groundwater were the suspected sources of nitrate+nitrite-nitrogen in surface waters. Ammonia is usually released from proteinaceous organic matter and urea, which are components of manure (EPA, 1986). Mean total inorganic nitrogen (TIN) concentrations were higher at all Portage Creek stations during the wet season (Figure 11). The largest mean value was 6.48 mg/L at Station P7.3 and the lowest mean value (0.86 mg/L) was also observed at this station during the dry season. Pasture land use is dominated adjacent to Station P7.3 and downstream from this site. Animal grazing activities contribute to higher instream nitrogen loading when frequent runoff occurs, especially during the wet season.

Mean total phosphorus (TP) concentrations were highest at mid-reach stations on Portage Creek during the wet season and at upper-reach stations during the dry season (Figure 12). Station P5.2 had the highest mean total phosphorus concentration (0.34 mg/L) during the wet season. This site was possibly influenced by manure lagoon flushing through an upstream tributary where station UN5.4 was located. Station P7.3, located below the impounded reservoir on Portage Creek, had a substantially increased mean total phosphorus concentration (0.78 mg/L). This elevated concentration may have been influenced by upstream manure spreading adjacent to the creek which occurred on October 10, 1989. Small contributions by senescing aquatic vegetation in the impoundment may have contributed, to a lesser extent, during the fall (Table A7). Another phosphorus contribution is decaying plant materials found on crop lands (EPA, 1986). Instream processes that facilitate removal of phosphorus from the water column are linked with heavy macrophyte growth. The presence of heavy macrophyte growth reduces water velocity which increases sedimentation and adsorption of suspended particulates (Riemer, 1984).

Fecal coliform (FC) bacteria were generally more concentrated in surface waters during the dry season than in the wet season (Figure 13). Contaminated groundwater contributions during the low discharge period may have contributed additional fecal coliform colonies to surface waters. Increased fecal coliform counts such as at Station P7.3 coincided with high total inorganic nitrogen levels. Many investigations regarding the effects of nutrients on fecal coliform populations have shown a direct relationship. It is believed that the increased nutrient in the water column adsorbs trace metals and toxins. The metals are no longer bioavailable which eliminates toxic effects and allows fecal coliform colonies to proliferate (EPA, 1985a).

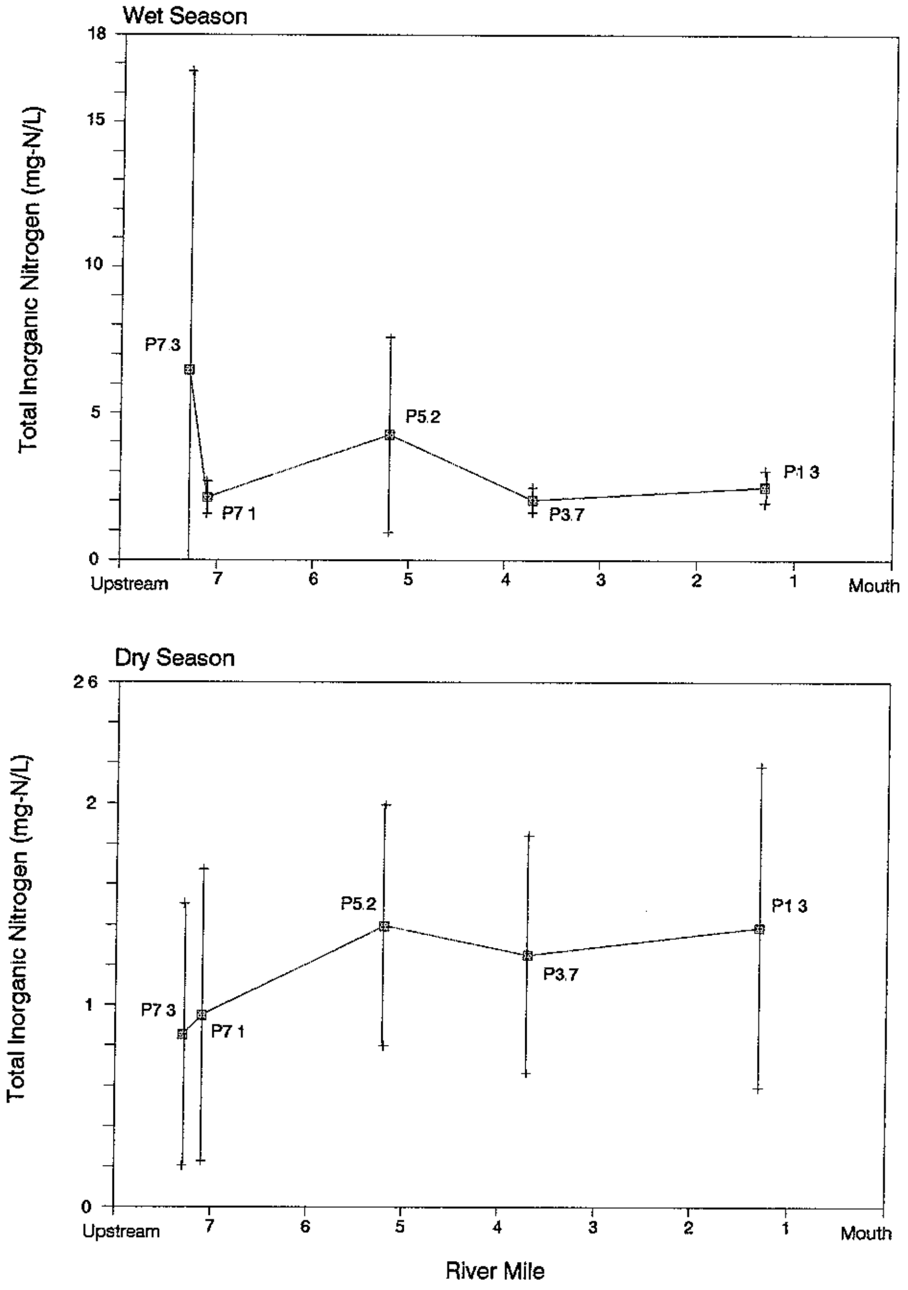


Figure 11. Mean concentrations for total inorganic nitrogen (mg/L) and standard deviations at Portage Creek stations during the wet season (21 December 1988-13 March 1989) and the dry season (10 April 1989-14 November 1989)

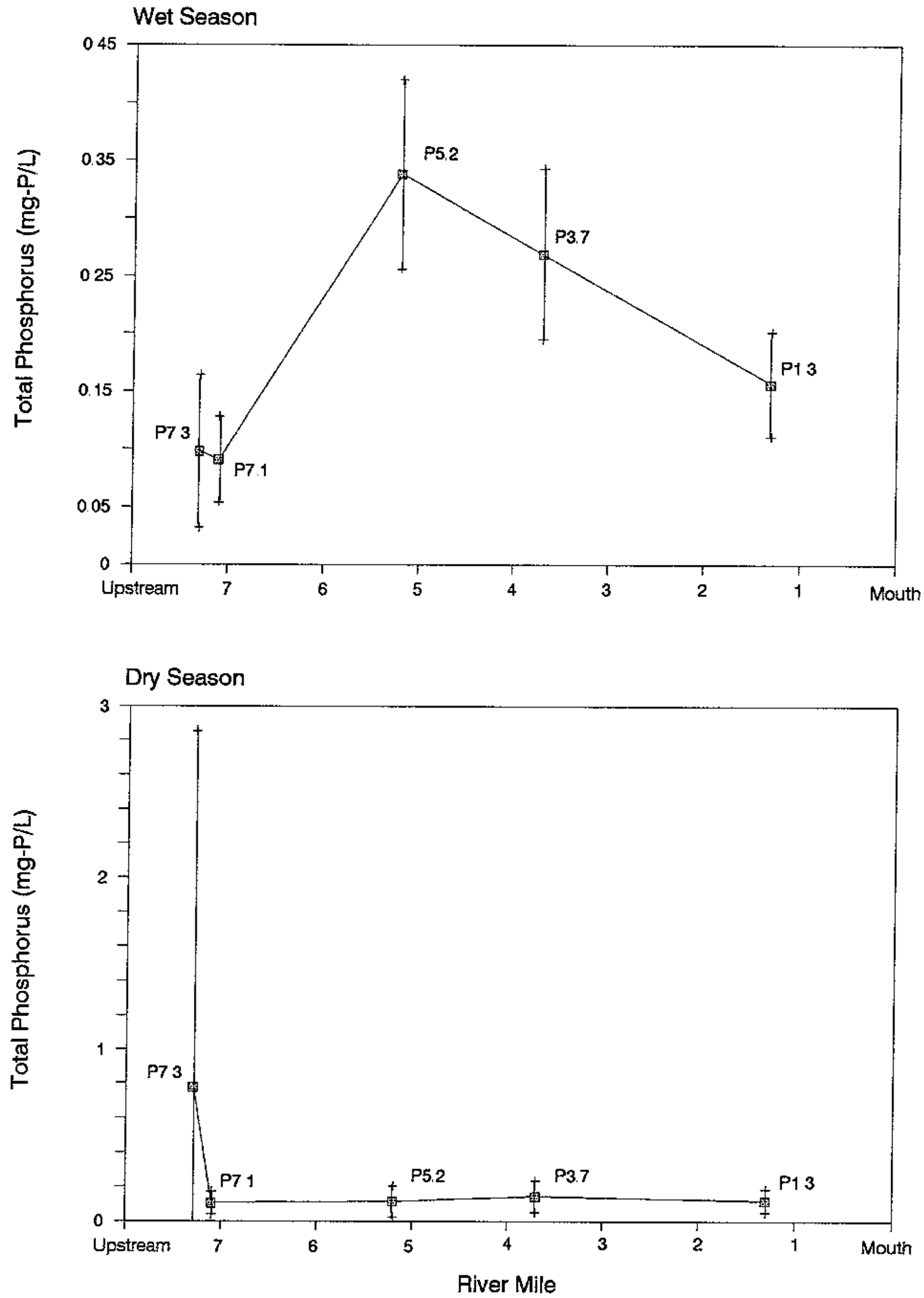


Figure 12. Mean concentrations for total phosphorus (mg/L) and standard deviations at Portage Creek stations during the wet season (21 December 1988-13 March 1989) and the dry season (10 April 1989-14 November 1989).

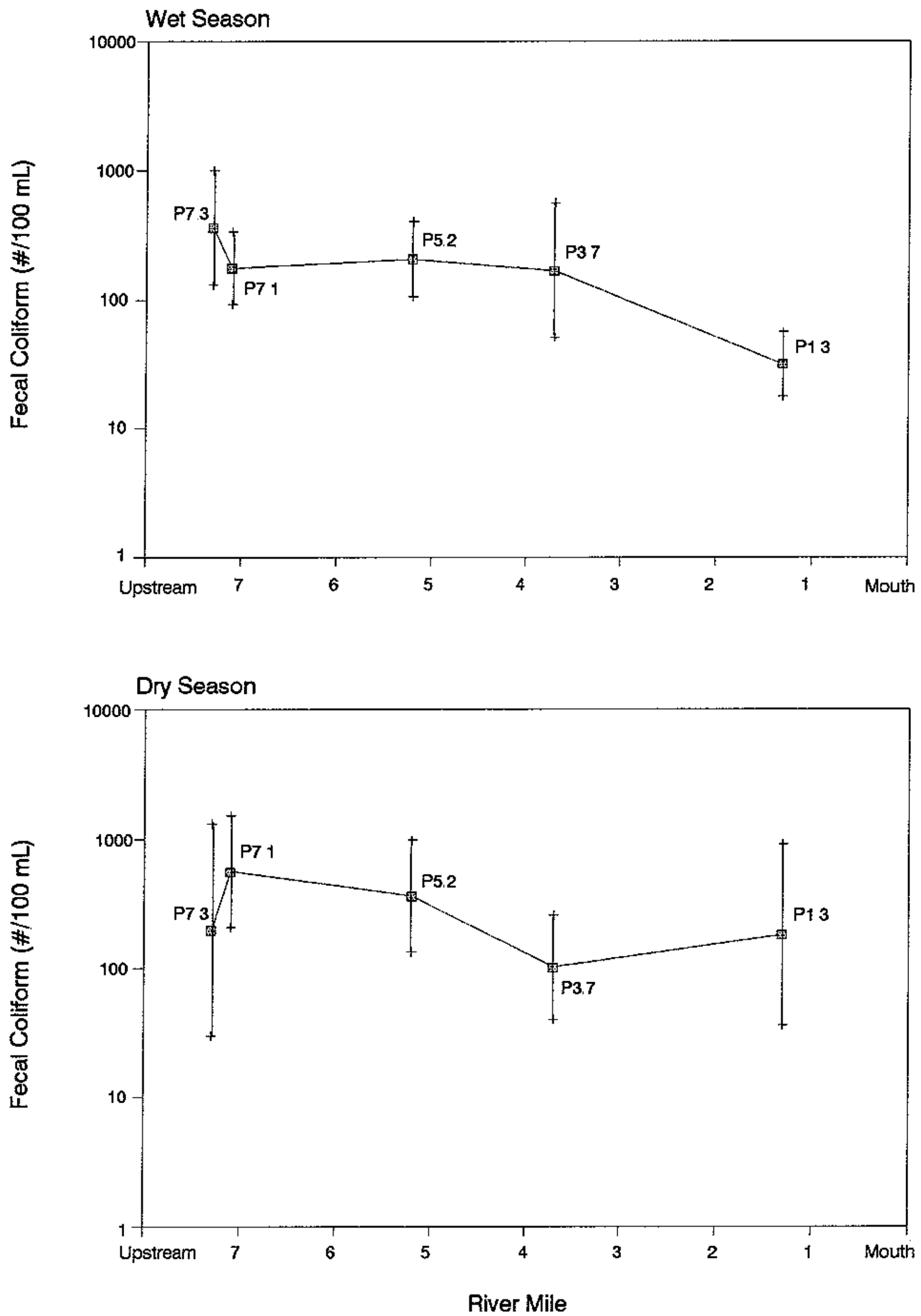


Figure 13. Geometric mean concentrations for fecal coliform (#/100 mL) and standard deviations at Portage Creek stations during the wet season (21 December 1988-13 March 1989) and the dry season (10 April 1989-14 November 1989).

Analysis of Spatial and Seasonal Effects

The data collected for total suspended solids, total inorganic nitrogen, total phosphorus, and fecal coliform were analyzed using multivariate analysis of variance (SYSTAT 1988). A two-factor fixed-effects model was constructed by using the wet and dry seasons as factors and the five Portage Creek sample stations as levels. Graphical results of the analysis are displayed in Figures 14 and 15 for each variable tested (STSC 1987).

There was a significant difference in total suspended solids (TSS) concentration between the wet and dry season (Figure 14). A $\log_{10}$-transformation of the TSS data was required to satisfy the normality assumption of the analysis. The wet season maintained a significantly higher concentration for this parameter in Portage Creek due to increased runoff of solids and greater tributary contributions. Significant site differences occurred between station pairs P7.3 and P5.2, and P7.3 and P3.7. The higher mid-reach total suspended solids concentrations (P5.2 and P3.7) were attributed to the change in land use contiguous with stream areas. Cropland and pastured land activities typically contribute total suspended solids, nutrients, and bacteria to the water column through grazing, manure spreading, and cultivation practices. Cropland and pastured land were most prevalent in the mid-reach region of Portage Creek.

Total inorganic nitrogen (TIN) also showed significant site and seasonal differences (Figure 14). Higher concentrations of inorganic nitrogen were introduced into Portage Creek during runoff events. Site differences were found between upper-reach stations (P7.3 and P7.1) and the mid-reach (P5.2) and lower-reach (P1.3) stations. The increase in total inorganic nitrogen at mid- and lower-reach stations indicates the presence of a change in land use from upper-reach sites. The land use change from a suburban/small farm environment to agricultural activities was indicated by the water quality alterations observed at mid- and lower-reach stations. Station P3.7 was not statistically different from upper-reach stations. Reduced TIN concentration at this station may be attributed to: 1) settling of inorganic nitrogen components; and 2) smaller contributions of groundwater that contained higher nitrogen concentrations (Wetzel, 1983).

Un-ionized ammonia is a component of total inorganic nitrogen and is toxic to aquatic life when occurring in substantial quantities. A water sample collected at Station P7.3 on October 10, 1989, was determined to contain an un-ionized ammonia concentration exceeding the chronic (4-day) criterion established by the EPA (1986). Manure spreading at an upstream site bordering the creek during this sample date was likely a major contributor to a potentially toxic un-ionized ammonia condition.

Non-continuous trends (interaction effects) were found between site and season following analysis of the total phosphorus (TP) data. Total phosphorus data were $\log_{10}$-transformed prior to statistical analysis. The seasonal pattern of total phosphorus showed high concentrations during the wet season and low concentrations during the dry season (Figure 15). An exception (i.e., the interaction) to this trend occurred at Station P7.1 where the dry season mean was slightly higher than the wet season mean.

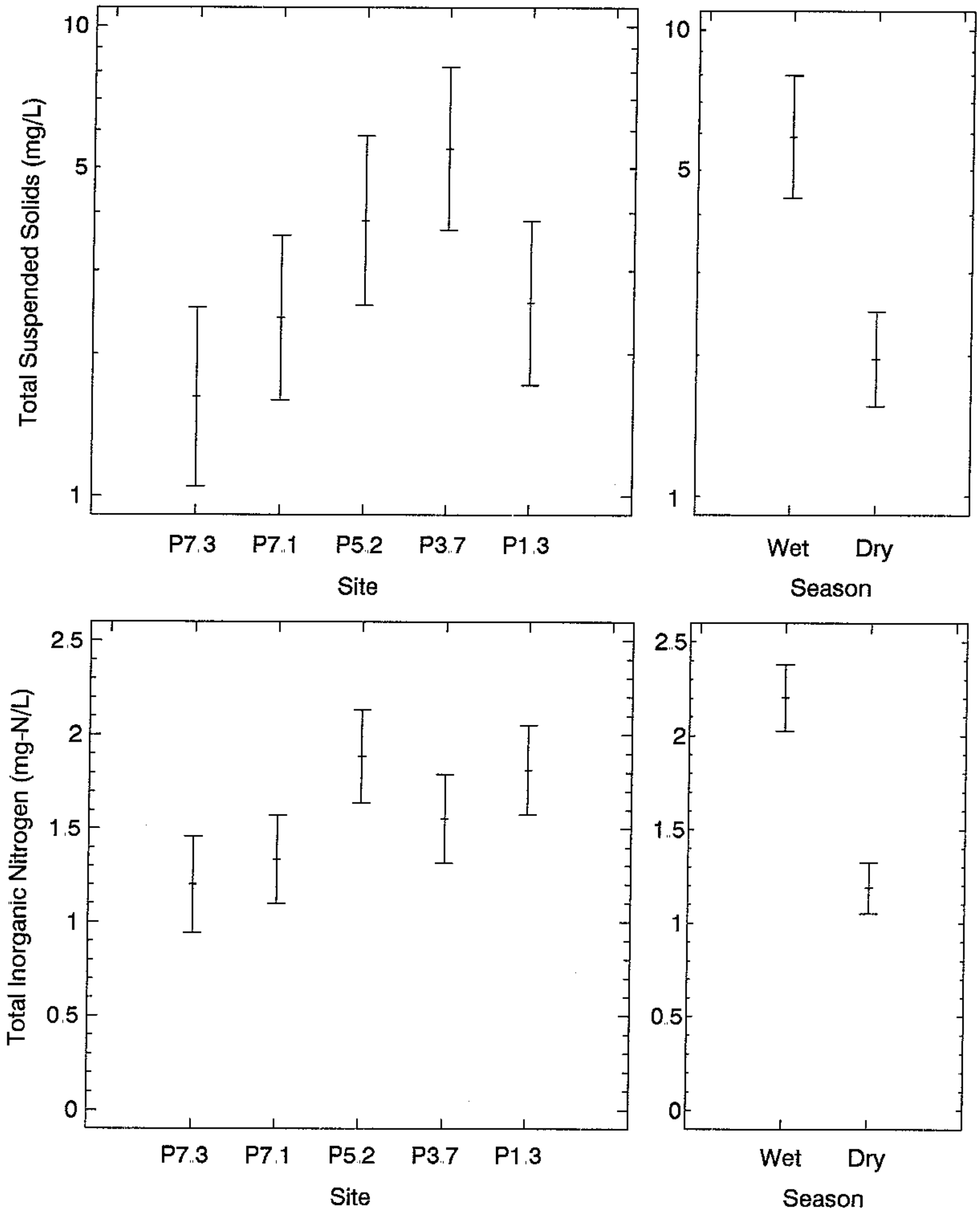
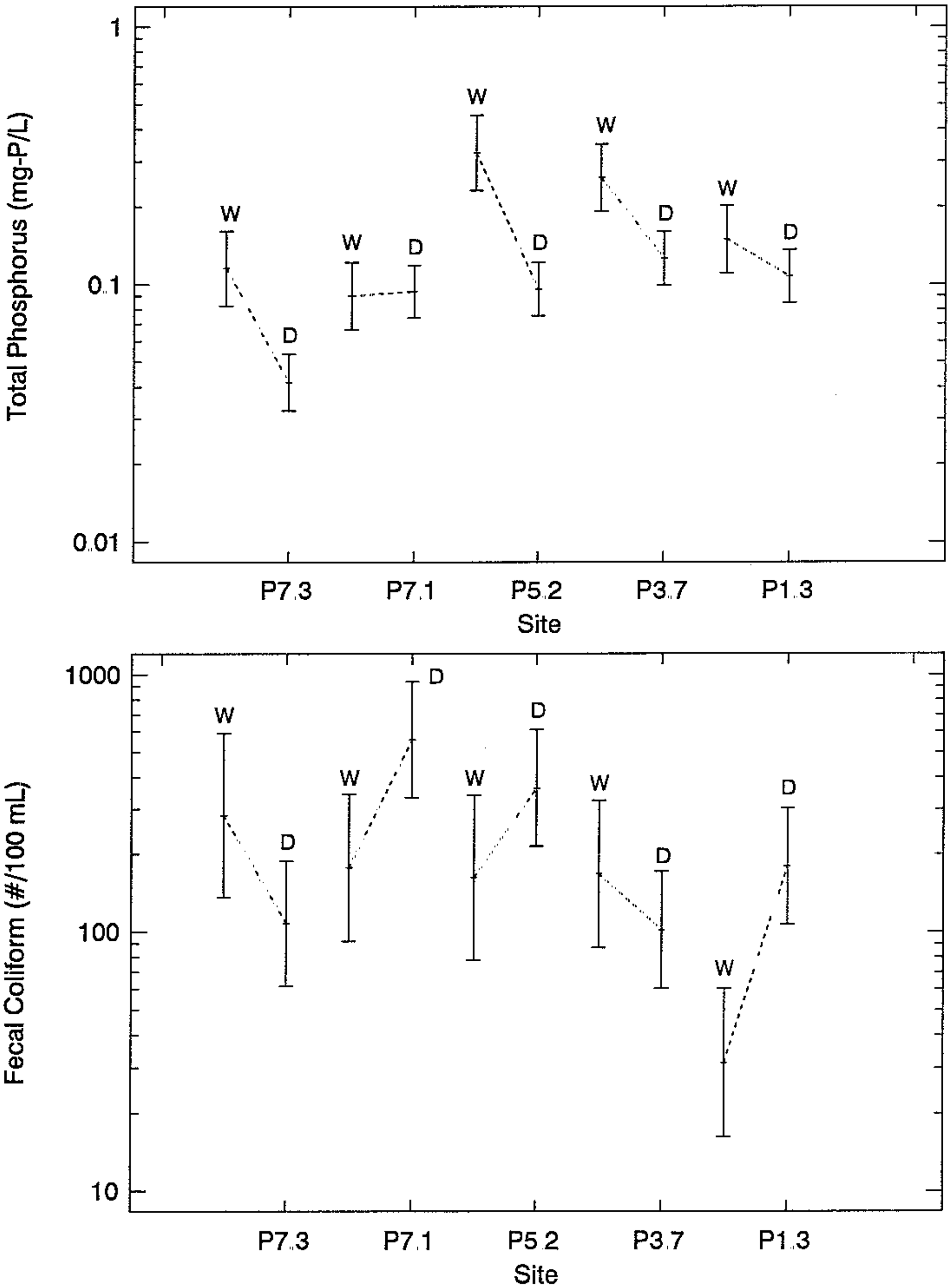


Figure 14 Means plot for total suspended solids (mg/L) and total inorganic nitrogen (mg-N/L) illustrating site differences and seasonal trends. Least significant differences at p=0.05 were used to determine confidence intervals.



W=Wet Season D=Dry Season

Figure 15. Means plot for total phosphorus (mg/L) and geometric means for fecal coliform (#/100 mL) illustrating seasonal trends and spatial differences among Portage Creek sample sites. Least significant differences at p=0.05 were used to delineate sample site and seasonal interactions.

Variable(s) not accounted for by site and season in the analysis of total phosphorus concentration data were partially responsible in explaining the anomalous pattern. Cattle were allowed direct access to the stream at P7.1 during most of the dry season months. Manure containing higher levels of phosphorus was the most probable path of introduction.

Multivariate ANOVA of fecal coliform (FC) data also produced a significant interaction between site and season (Figure 15). The general trend for fecal coliform was from a lower mean value in the wet season and higher means at sites during the dry season. The interaction was between three sites showing increasing seasonal trends (P1.3, P5.2, P7.1) and two sites showing a decreasing seasonal trend (P3.7, P7.3). Wet season means were found to be higher at the latter two sites in contrast to the general trend. Manure spreading and cattle grazing are suspected of occurring on contiguous streamside zones at site P3.7 during the wet season.

The same multivariate analysis of variance model was used to analyze mainstem loads of these four pollutants. Further analysis using parameter loads revealed the relative physical quantity of each parameter at stream reaches. This approach indicates sources and proportionate contributions of each parameter. The total suspended solids (TSS) load was possibly influenced by livestock access to the stream and manure spreading during both the wet and dry seasons. The TSS load was significantly greater during the wet season from surface water runoff contributions. Fish Creek contributed large quantities of TSS and TIN during the wet season which significantly increased TSS and TIN loads at Station P1.3. Fish Creek is a sub-watershed of Portage Creek and predominantly contains small farms. The dry season TSS load declined from Station P3.7 to P1.3 and was probably influenced by substantially smaller contributions from Fish Creek and by an increased rate of sedimentation. An increased TIN and total phosphorus (TP) load at Station P5.2 during the wet season was probably contributed by excess application of manure and fertilizers on cropland fields adjacent to Portage Creek. Fecal coliform (FC) loads did not show differences between stations or seasons. TSS, TIN and TP loads at Station P1.3 were significantly higher than at other upstream Portage Creek sites during the wet season. The higher loads were attributed to a cumulative contribution of loads from upstream tributaries and runoff into the creek.

Comparison to State Water Quality Standards

Water quality values obtained from Portage Creek sites and tributaries were compared with Washington State Class A standards. Comparisons with state standards at five mainstem sites are shown in Table 3; remaining sites are shown in Table 4.

Although water temperatures did not violate state standards repeatedly, it is appropriate to note that groundwater influence seemed prevalent on some portions of Portage Creek surface water. Water temperatures at site P5.2 were cooler than at upstream sites during the dry season with this trend continuing at sites below this station (Table 3). The presence of streamside wetland areas in mid- and lower reaches of Portage Creek suggests influence by a ground water source (Figure 7). The wetlands are located adjacent to an extensive cut bank. Another factor that may have influenced the unexpected lower water temperatures in mid- and lower reaches of

Table 3. Range of parameter values from Portage Creek Stations compared with Washington State Water Quality Standards during wet and dry seasons. Numbers in parenthesis indicate the number of standards violations recorded during a season.

Parameter	Units	Stations P1.3	P3.7	P5.2	P7.1	P7.3	Class A Standards
Wet Season	(n = 6)						
Temperature	(°C)	2.20-8.03 (0)	3.30-8.44 (0)	4.40-8.70 (0)	3.50-7.90 (0)	2.10-7.70 (0)	<18°C
pH	(S.U.)	6.75-7.02 (0)	6.72-7.66 (0)	6.60-7.20 (0)	7.09-7.62 (0)	6.68-7.15 (0)	6.5-8.5
D.O.	(mg/L)	6.5 -9.7 (1)	5.5 -8.3 (3)	7.6 -9.6 (1)	10.5-13.2 (0)	10.9-13.3 (0)	>8.0 mg/L
D.O.	(% sat.)	55.5-77.4 (0)	47.5-67.3 (0)	65.5-75.2 (0)	86.9-104.0 (0)	87.6-103.4 (0)	<110 %
Turbidity	(NTU)	2	7	4	2	5	<5 above background
Fecal Coliform	(#/100 mL geo. mean)	70 (1)	209 (4)	210 (5)	177 (5)	437 (6)	100,200*
Dry Season	(n = 8)						
Temperature	(°C)	7.80-14.50 (0)	7.24-14.30 (0)	8.29-14.00 (0)	8.28-19.65 (4)	7.96-19.00 (3)	<18°C
pH	(S.U.)	6.86-7.37 (0)	6.87-7.41 (0)	6.94-7.52 (0)	6.87-8.80 (2)	6.81 -8.76(2)	6.5-8.5
D.O.	(mg/L)	4.7 -10.9 (6)	5.2 -7.9 (7)	7.4 -9.4 (2)	9.4 -11.7 (0)	5.5 -14.0 (1)	>8.0 mg/L
D.O.	(% sat.)	46.9-104.4 (0)	43.2-76.3 (0)	52.2-91.8 (0)	70.9-114.3 (1)	53.3-154.1 (1)	<110 %
Turbidity	(NTU)	2	2	1	2	24	<5 above background
Fecal Coliform	(#/100 mL geo. mean)	180 (5)	102 (4)	362 (7)	560 (8)	198 (4)	100,200*

* Concentrations shall not exceed 100 organisms/100 mL with not more than 10% of the samples exceeding 200 organisms/100 mL.

Table 4. Range of parameter values from Portage Creek Stations and Tributaries with Washington State Water Quality Standards during wet and dry seasons. Numbers in parenthesis indicate the number of standards violations recorded during a season.

Parameter	Units	Stations P2.5	P6.0	P8.1	F0.8	UN2.0	Class A Standards
Wet Season	(n = 6)						
Temperature	(°C)	3.20-8.46 (0)	5.20-9.50 (0)	2.60-7.30 (0)	1.30-7.88 (0)	2.00-8.23 (0)	<18°C
pH	(S.U.)	6.75-7.31 (0)	6.90-7.45 (0)	6.50-7.29 (0)	6.50-7.47 (0)	6.07-6.80 (3)	6.5-8.5
D.O.	(mg/L)	2.1-6.3 (3)	8.4-8.8 (0)	10.8-13.1 (0)	10.9-13.0 (0)	8.4-10.0 (0)	>8.0 mg/L
D.O.	(% sat.)	18.1-49.5 (0)	69.4-72.2 (0)	88.3-101.3(0)	79.3-100.2 (0)	67.6-79.8 (0)	<110 %
Fecal Coliform	(#/100 mL geo. mean)	120 (4)	76 (1)	281 (4)	80 (2)	28 (1)	100,200*
Dry Season	(n = 8)						
Temperature	(°C)	8.18-14.10 (0)	8.66-17.19 (0)	7.70-16.70 (0)	7.80-15.40 (0)	8.99-17.90 (0)	<18°C
pH	(S.U.)	6.84-7.38 (0)	7.27-7.67 (0)	6.84-7.74 (0)	6.83-7.83 (0)	6.51-6.96 (0)	6.5-8.5
D.O.	(mg/L)	4.0-7.1 (7)	8.5-11.1 (0)	8.9-11.7 (0)	9.9-10.9 (0)	6.7-9.3 (3)	>8.0 mg/L
D.O.	(% sat.)	34.4-67.9 (0)	77.5-117.5 (4)	91.4-99.1 (0)	91.4-103.5 (0)	63.7-92.3 (0)	<110 %
Fecal Coliform	(#/100 mL geo. mean)	149 (4)	114 (5)	3051 (8)	121 (5)	145 (3)	100,200*

* Concentrations shall not exceed 100 organisms/100 mL with not more than 10% of the samples exceeding 200 organisms/100 mL.

Portage Creek was the quality of overhead canopy. The riparian vegetation seemed to provide a greater quantity of shade to portions of Portage Creek below site P5.2.

Violation of the fecal coliform (FC) criterion for Class A waters was generally consistent during the wet and dry seasons at mainstem Portage Creek sample stations (Table 3). The highest geometric mean for fecal coliform bacteria at a mainstem station was found at site P7.1 (560 #/100mL) during the dry season. Fecal coliform concentrations violated Class A water quality standards at all remaining Portage Creek stations and tributaries during the dry season (Table 4). FC criteria were not violated at Portage Creek sites P1.3 and P6.0 during the wet season presumably due to streamside inactivity and/or dilution effects. Site P6.0 was located in a region of the watershed surrounded by wetlands which possibly buffered adverse runoff effects by contributing to sedimentation and removal of fecal coliforms associated with particulates. Site P1.3 contained a high rate of discharge with a substantial contribution from the Fish Creek drainage. Wet season FC concentrations at the mouth of Fish Creek did not violate Class A standards and, therefore, did not contribute to an FC violation in surface water downstream of the confluence with Portage Creek. Individual FC concentrations reached 52,000 #/100 mL at Station P8.1 and 14,000 #/100 Ml at Station P7.3 during October 10, 1989. These elevated concentrations coincided with observed manure spreading activity in the upper-reach of Portage Creek.

The turbidity criterion for Class A waters in Washington was violated at site P3.7 during the wet season and at site P7.3 during the dry and wet season (Table 3). Site P3.7 is located in a region of Portage Creek with adjacent commercial farms. Site P7.3 experienced high turbidity levels on October, 10 1989 which influenced the elevated observed value. Turbidity levels at P7.3 were extraordinarily high during the dry season and coincided with manure spreading activity on cropland at an upstream site.

Dissolved oxygen (D.O.) concentrations fell below the Class A standard for freshwater at sites P2.5 and P3.7 during the wet season (Tables 3 and 4). Dry season D.O. violations occurred at sites P1.3, P2.5, P3.7, P5.2, P7.3, and UN2.0. Decaying organics such as manure may have been one source of oxygen depletion at these lower Portage Creek stations. Sediment oxygen demand (SOD) occurs when organic solids are deposited and decay, which consumes oxygen. Cattle grazing and manure spreading were continuously prevalent throughout the year adjacent to Station P3.7. Accumulated organics are decomposed through chemical and biological processes. The consumption of oxygen in the water column is influenced primarily by biological respiration and chemical oxidation processes as components of SOD (EPA 1985b; Hatcher, 1986). Review of the sediment analysis conducted at Station P3.7 revealed a high organic content in comparison with sediments collected upstream and downstream on Portage Creek (Appendix C). Low D.O. levels in surface waters is a "traditional" characteristic of nonpoint source pollution (Novotny and Chesters 1986). Lower D.O. concentrations at Station P1.3 during the dry season may have been influenced by groundwater input. The low stream discharge during this season is more easily influenced by oxygen deficient groundwater inputs.

Percent saturation D.O. generally increased from the wet season to the dry season (Tables 3 and 4). Wet season runoff containing particulates may have created an oxygen demand. Lower- and mid-reach stations on Portage Creek contained lower oxygen saturation levels than at upper-reach stations. Groundwater influences at lower- and mid-reach sites may have contributed to this condition. Percent oxygen saturation in the water column reached maximums at Station P7.3 during the July 11, 1989, and August 8, 1989, sample dates (142.5% and 154.1%, respectively). These were instances of single event water quality standard violations and were probably influenced by oxygenation of water through photosynthetic activity in the impoundment. Conversely, extreme low D.O. concentrations (Table A9) were measured at an unnamed tributary (station UN5.4) which entered Portage Creek immediately above station P5.2. The D.O. concentrations measured at UN5.4 ranged from 0.7 mg/L to 3.0 mg/L. Manure lagoon flushing occasionally occurred through this channel which deposited oxygen depleting sediments. All D.O. concentrations estimated at this station violated the Class A standards, but did not seem to significantly influence the receiving water at Station P5.2; possibly due to a large dilution factor.

Mass Balance Analysis

Mass balances are the relative parameter load changes between any two successive sample sites. The area of a stream between two sample sites may be a gaining reach where input from surface water runoff, groundwater recharge, tributaries or other external sources to the stream contribute to an increased downstream load. Conversely, a losing reach features sedimentation, sediment adsorption, water withdrawal, or plant uptake within a reach. Mass balance analysis attempts to define inputs/outputs of constituent loads through an accounting process between two nodes in a stream segment.

Wet season mass balances for three parameters are displayed in Figure 16. Total suspended solids (TSS) experienced a load gain in all stream segments except Segment III. The loss of TSS from the water column between site P7.1 and P5.2 was attributed to inactivity of land uses suspected to be major contributors, namely streamside cattle grazing and crop cultivation and instream deposition. The large increase of TSS in Stream Segment IV was probably due to inappropriate management practices of small hobby farm operators with regard to waste disposal and stream access by livestock. Dissolved nutrient loads increased in Stream Segments IV and III as the suspended solids component settled out of the water column (Figure 16). Decrease of total inorganic nitrogen and total phosphorus loads occurred in Stream Segment II. Land use activities contributing to the introduction of these nutrients to the water column were also suspected of being absent during the wet season. Stream Segment I showed an increased TSS load and total inorganic nitrogen load contributed by the Fish Creek tributary and activities such as manure spreading. The total phosphorus load declined in this segment, possibly due to adsorption to suspended particulates (Figure 16).

Mass balances for nutrient and total suspended solids loads during the dry season are displayed in Figure 17. The total inorganic nitrogen and total phosphorus loads decreased in Stream Segment IV. The loss of nutrient loads may indicate that runoff contributions originating from sources such as manure storage had subsided. Wet season nutrient load contributions increased in Segment IV which suggested that nutrients from observed streamside manure storage was primarily transported by surface runoff during precipitation events (Figure 16). The smaller quantity of total suspended solids load gained in this segment during the dry season possibly indicated that minimal quantities of precipitation easily mobilized the transport of solids. Cropland and pasturing activity were prevalent in Stream Segment III during the dry season. Nutrient loads increased, as did the total suspended solids load, contrary to the wet season condition. Cultivated cropland activities coupled with fertilizer application contribute significantly to total suspended solids, inorganic nitrogen and total phosphorus loads (Coote, *et al.*, 1979). Stream Segment II followed the same loading pattern as Stream Segment III; additional contributors of nutrients and solids may have originated from increased farm activity in this segment. Total inorganic nitrogen load conditions gained in Stream Segment I during both the wet and dry seasons. Factors such as macrophyte growth and stream gradient may have decreased water velocity in the lower reach and increased the sedimentation of total suspended solids during the dry season. Total phosphorus load may have partially been lost to macrophyte uptake and adsorption to sedimented particulates (Figure 17).

Effectiveness of the Department of Ecology Guidance

One of the objectives in this investigation was to evaluate the effectiveness of the nonpoint water quality monitoring guidance developed by Ecology (Michaud, 1989). Routine monitoring and runoff-event surveys are the major components of the guidance. The guidance suggests at a minimum: four sampling events during the wet season (December-March), the "runoff-event" monitoring and two sampling events during the dry season (August and September). The purpose of developing methods guidance for conducting water quality surveys was to promote a standard approach. This would provide various entities that conduct water quality surveys, either under Ecology-funded projects or those seeking independent guidance, a beginning point in implementing the project. Studies conducted in keeping with the guidance should adequately estimate physical and chemical conditions during the season of concern. Histograms of pollutant concentrations were used to compare minimum sampling effort outlined in the guidance with the level of effort (monthly sampling) applied to this investigation.

Mean total suspended solids (TSS) concentrations during the wet season were comparable between the two sampling frequencies for all stations except P1.3 (Figure 18). The consistency in TSS concentrations was probably due to the uniformity of hydrologic conditions during the wet season. The frequency of wet season precipitation events allowed for adequate estimation of parameter concentrations with fewer samples over time. A larger difference between the sampling schemes occurred at Station P1.3, possibly due to Fish Creek contributions. The dry season TSS concentrations showed larger differences between sampling frequencies (Figure 18). Lower discharge rates during the dry season were probably more sensitive to TSS input and were exaggerated through a "concentrating" effect. A smaller number of samples would probably not account for variability in TSS at the stations.

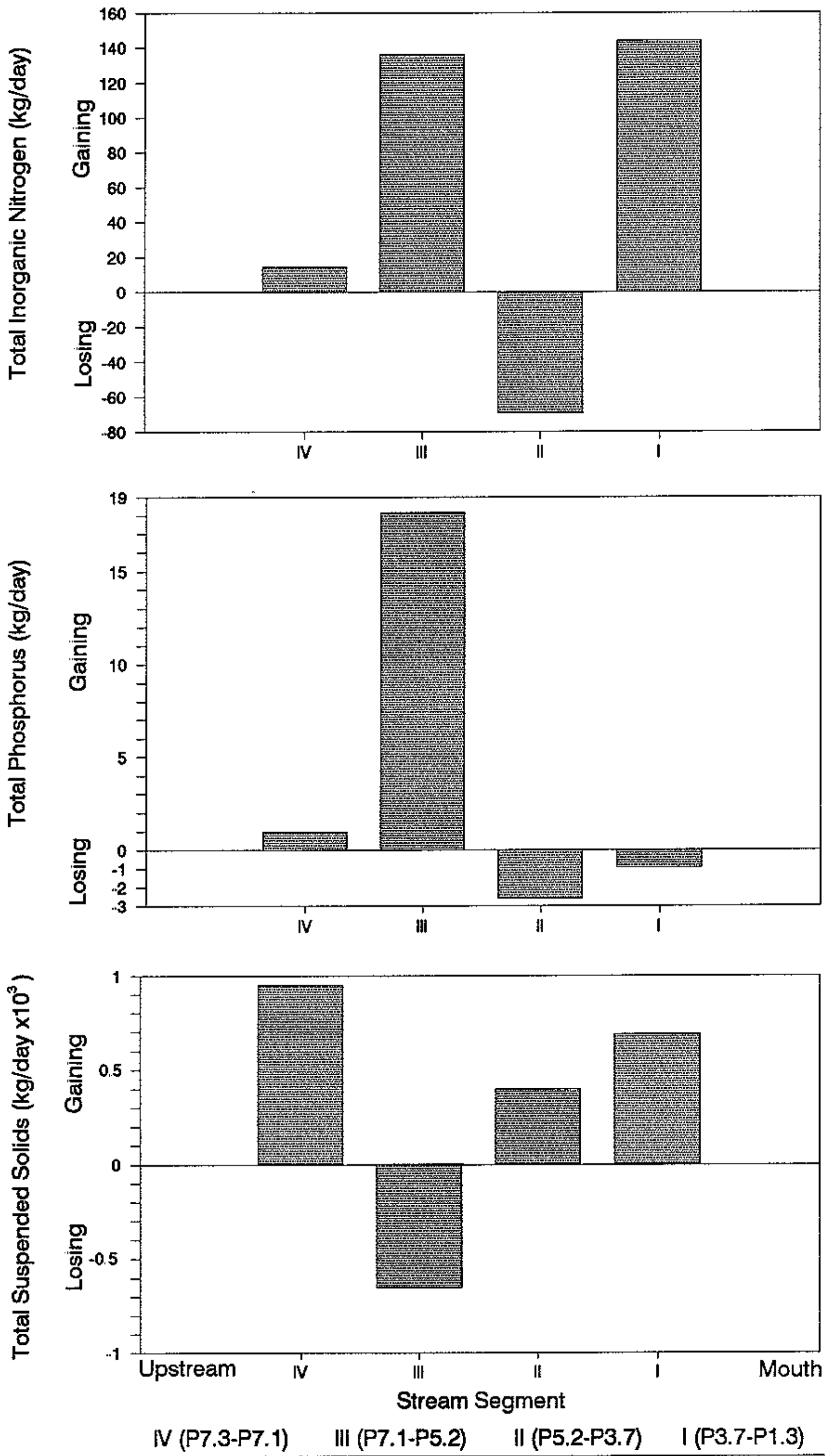


Figure 16 Wet season (21 December 1988-13 March 1989) mass balance analysis: total inorganic nitrogen, total phosphorus, and total suspended solids at four Portage Creek stream segments.

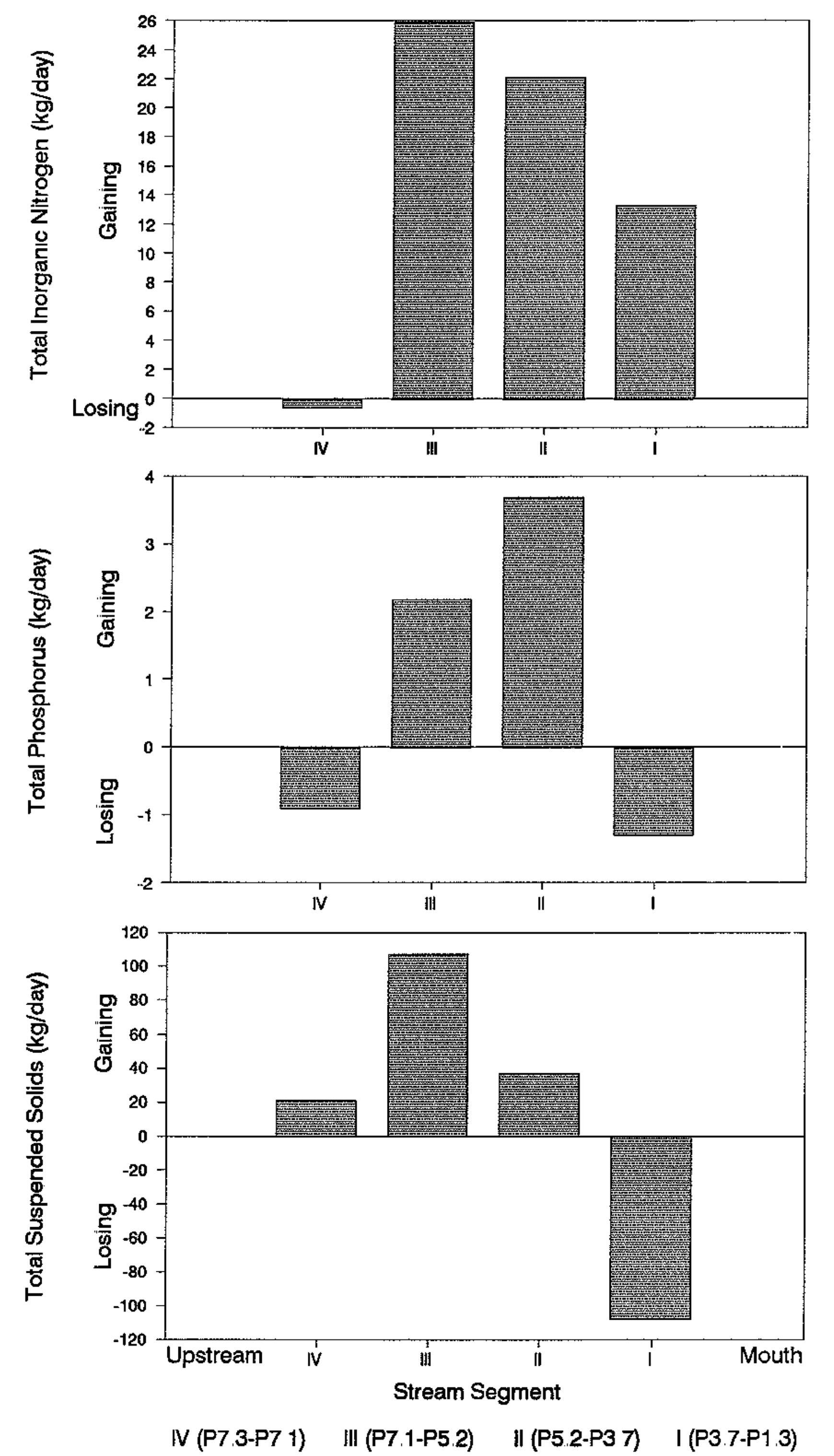


Figure 17. Dry season (10 April 1989-14 November 1989) mass balance analysis: total inorganic nitrogen, total phosphorus, and total suspended solids at four Portage Creek stream segments.

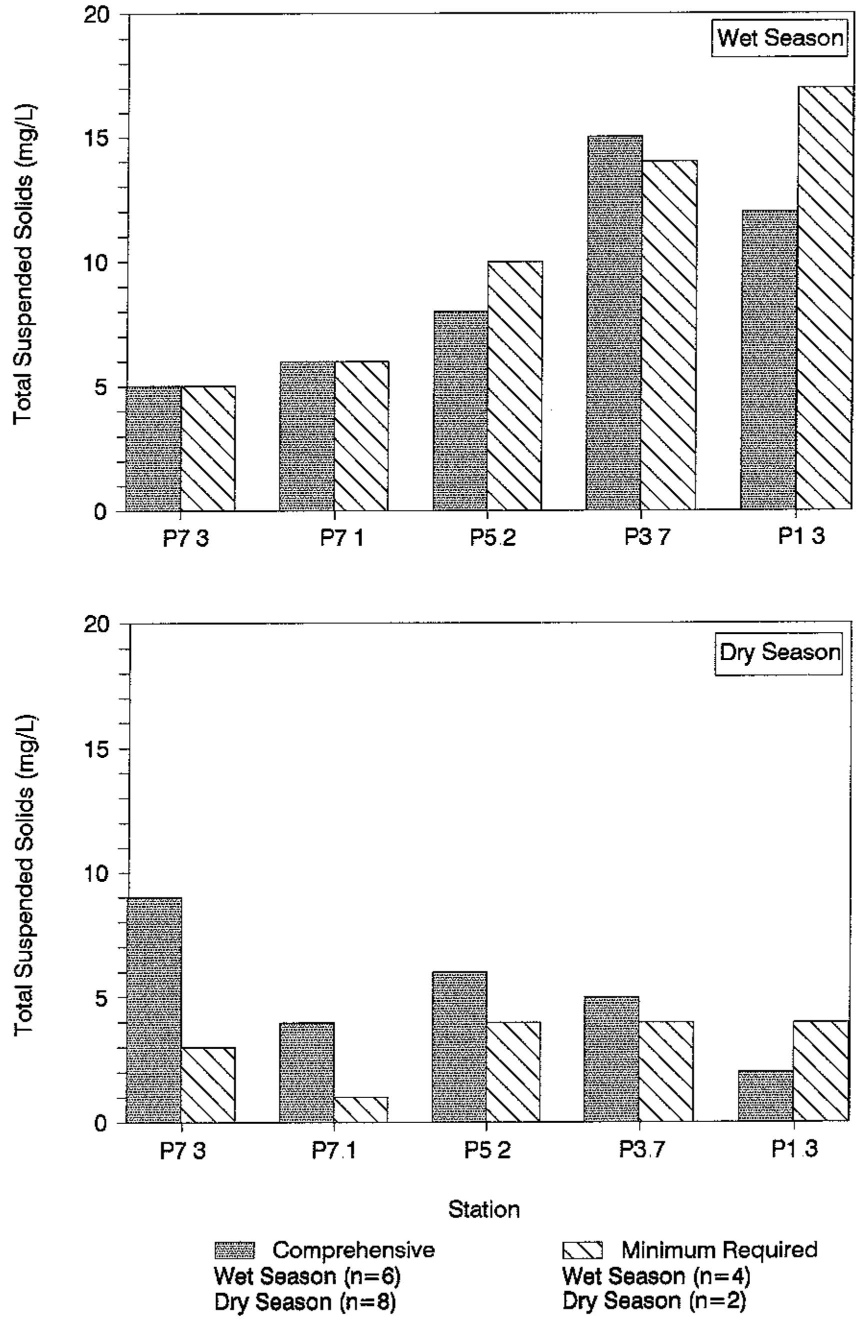


Figure 18. Comparison of mean total suspended solids (mg/L) concentrations collected on a comprehensive monthly basis versus following the minimum required number as outlined by Michaud (1989).

Wet season total inorganic nitrogen (TIN) concentrations as estimated by comprehensive sampling and minimum required sampling were comparable (Figure 19). A larger difference between the two means occurred at station P7.3, which was probably influenced by the impoundment on Portage Creek directly above this station. TIN variability may have been introduced through infrequent or pulsing releases from this impoundment. Dry season TIN showed larger differences between the two sampling frequencies at all stations (Figure 19). The minimum required number of samples appeared to underestimate the mean TIN concentrations. Higher variability for TIN in the water column may be a result of a greater variety of sources, both instream and terrestrial. Periodic introduction of nitrogen containing material such as particulate organics or fertilizers may reduce uniformity of parameter concentrations among individual samples.

Total phosphorus (TP) during the wet season had comparable mean concentration estimates for all stations except P7.3 (Figure 20). The impoundment above this station was thought to have the same influence on TP concentrations as it did on the TIN data set. Dry season TP concentrations were very low with little difference between the two sampling frequency methods except at P7.3. The high mean TP concentration at P7.3 was an anomaly resulting from a single high value on October 10, 1989. Phosphorus is often a limiting nutrient in the water column and probably exhibits low variability due to the demand for it by plants. An increased sampling frequency in this instance would not be necessary.

Geometric mean fecal coliform concentrations were equally estimated by both sampling frequency methods during each season (Figure 21). Individual sample variability was normally high within both the comprehensive monthly- and minimum required sampling frequency data sets. Fecal coliform estimations at a site can be highly variable over time, but the mean FC values between the two sampling methods were favorably comparable. Physical, chemical and biological factors in the environment may influence abundance and distribution of the coliform bacteria (EPA, 1985a).

Wet season means for parameters were comparable as estimated by the two sampling schemes because sample sizes were nearly equal. Dry season means were based on sample sizes that were much less similar between the two sampling schemes.

Runoff-Event Monitoring

The purpose of collecting water samples during a storm event was to evaluate sample collection methods, and to document contributions of pollutants through surface runoff. A mean concentration for each parameter was obtained from bi-hourly composited sequential samples at three sites on Portage Creek (P1.3, P3.7, P7.1) and Fish Creek (F0.8). This concentration was compared with a grab sample that would have been collected at the end of the 24-hour sequential sampling event. The Ecology guidance (Michaud, 1989) recommended completion of two or three storm surveys during the investigation. The objectives for sampling during a storm event were to: 1) determine the value of obtaining sequential sample data on a bi-hourly basis for a set of parameters and compare these results to a single surface water grab at the end of the storm

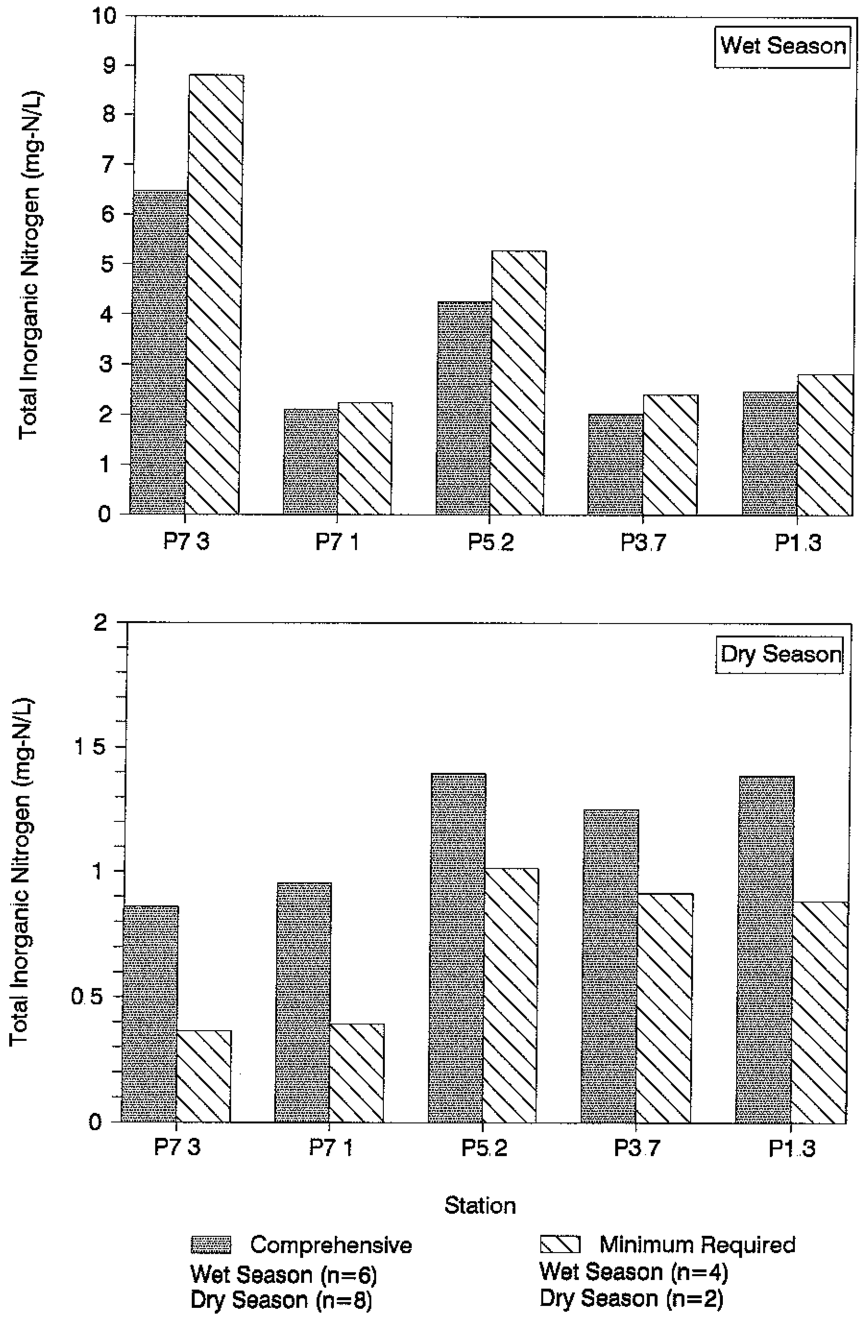


Figure 19. Comparison of mean total inorganic nitrogen (mg-N/L) concentrations collected on a comprehensive monthly basis versus following the minimum required number as outlined by Michaud (1989).

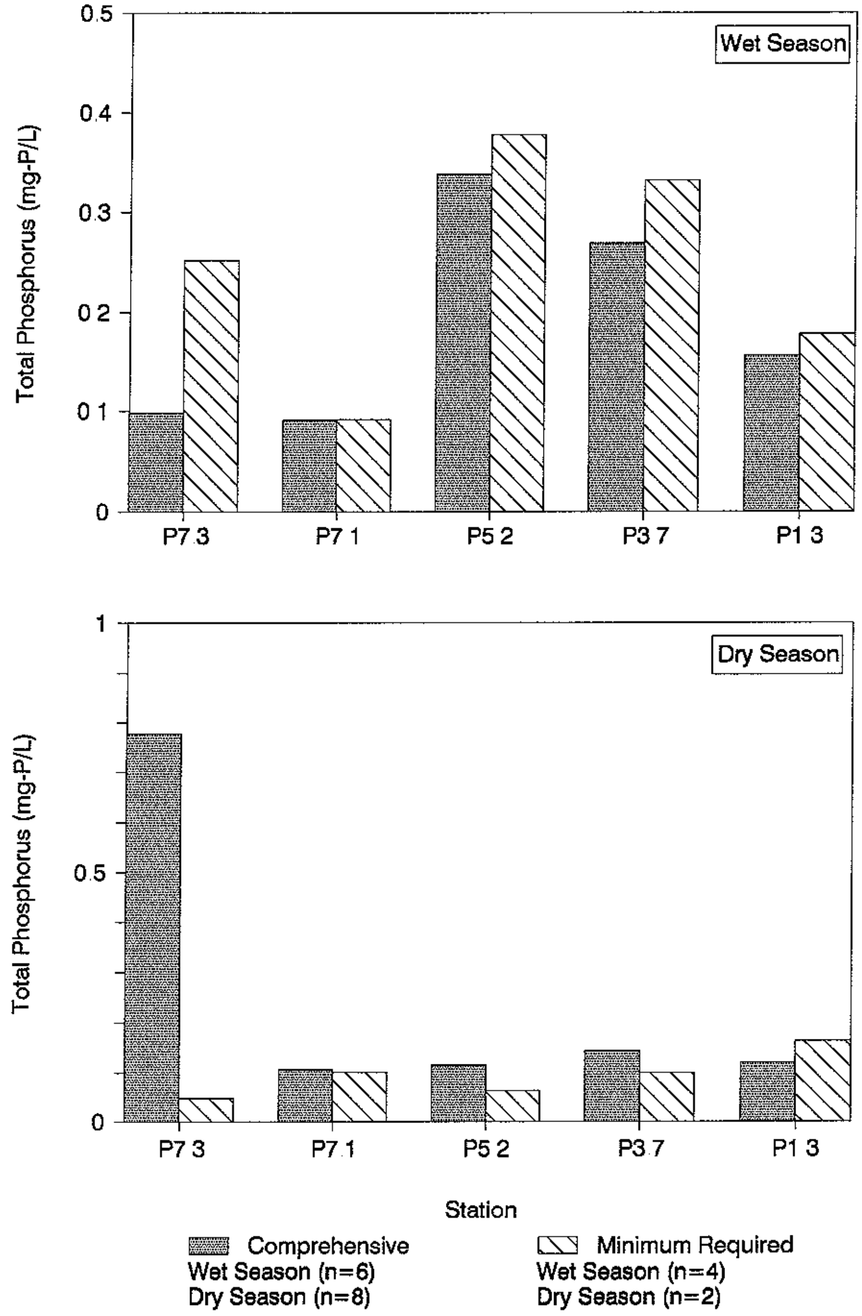


Figure 20. Comparison of total phosphorus (mg-P/L) concentrations collected on a comprehensive monthly basis versus following the minimum required number as outlined by Michaud (1989).

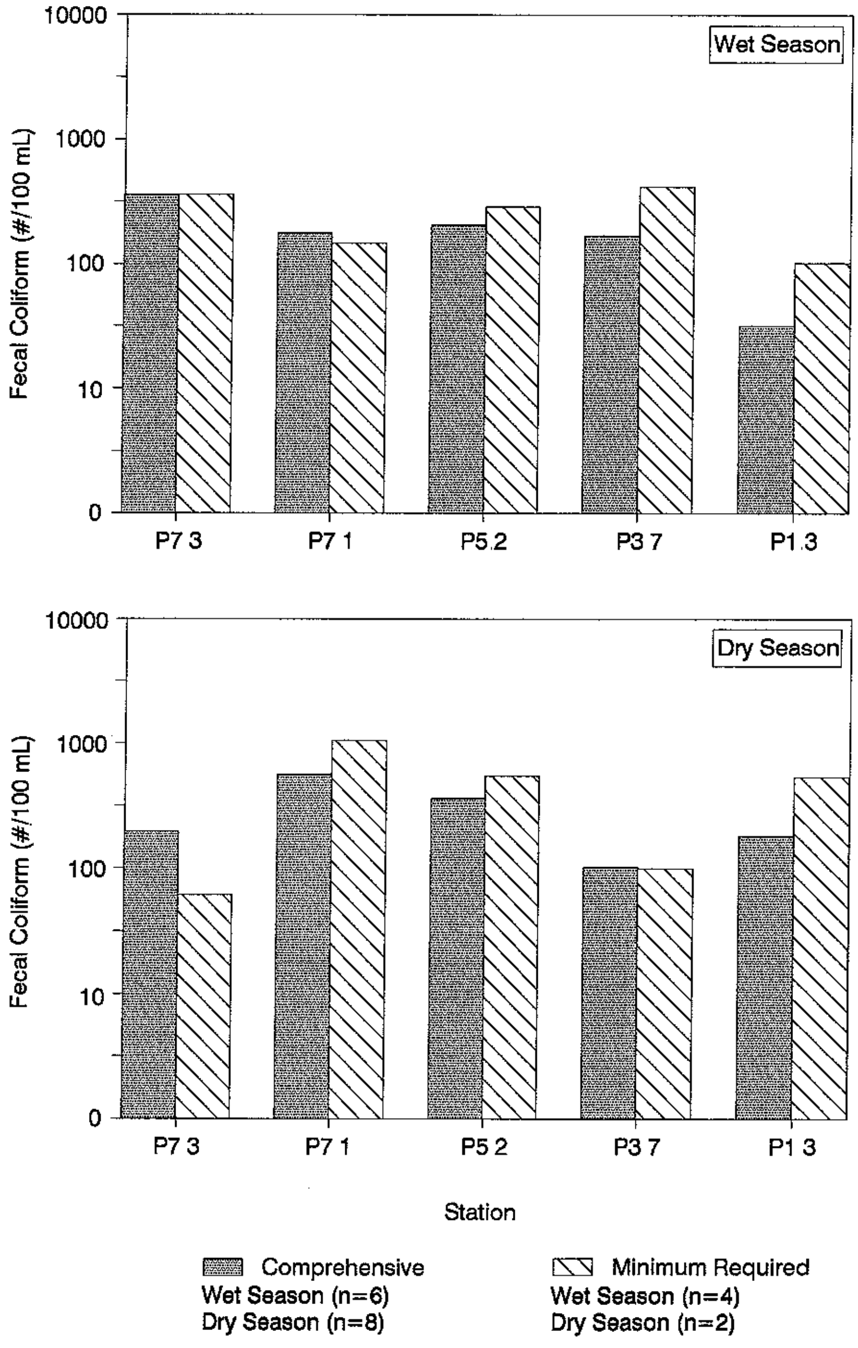


Figure 21. Comparison of geometric means for fecal coliform (#/100 mL) samples collected on a comprehensive monthly basis versus following the minimum required number as outlined by Michaud (1989).

event, and 2) determine moderate worst case pollutant loading conditions. Data for the 24-hour sequential sampling at sites surveyed during three different storm events are listed in Appendix B.

The largest discrepancy between results for grab and sequential samples at individual sites was for TSS concentrations (Figure 22). The mean composited TSS concentration at site P1.3 was consistently higher than the grab sample estimate. This site may have been influenced by flood waters from the South Slough of the lower Stillaguamish River during storm events. Water from the Stillaguamish River was turbid during storm events in which sequential sampling was conducted and probably carried large TSS loads. High discharge rates from major tributaries on lower Portage Creek (e.g. Fish Creek) were another possible source of TSS (Appendix B).

Differences between mean concentrations calculated from the sequential sampling data and grab sample data may be attributable to the timing of storm event monitoring. If at the end of the 24-hour storm monitoring period the storm event had continued, the grab sample estimate may be biased toward a higher concentration than if the grab sample was collected during some other point after the storm that did not reflect a worst-case condition.

Composite sampling revealed parameter concentrations on a bi-hourly basis for purposes of defining worst case pollutant contributions. The nutrients generally displayed subtle concentration changes over the storm survey period (Figures 23, 24, and 25). There were some distinct concentration increases, such as a nitrate + nitrite-nitrogen peak (29.34 mg/L) at site P1.3 on March 6, 1989, (Appendix B, Table B1). TSS concentrations were useful in identifying the magnitude of nonpoint source contributions at the runoff event monitoring sites. Schlosser and Karr (1981) determined that suspended solids contributions to a stream channel may be a function of riparian zone quality. TSS may be the most appropriate indicator of erosion potential of certain land uses near Portage Creek.

Special Studies

Sediment Analysis

Sediments were collected at four key stations within the Portage Creek drainage to determine potential toxic contamination. Urban and agricultural areas have sources that can be known contributors of metals and organic toxicants to streams (Novotny and Chesters, 1981).

Particle size distribution varied at the four sample sites (Table C1). Particle size is a major determinant of the adsorption and accumulation potential of toxicants. Fine sediments such as total organic carbon possess the greatest affinity for binding these toxicants. Particle size distribution of stream sediments is influenced by stream gradient, water velocity, and sediment source.

Site P3.7 contained the largest percentage of silt and clay. The sediment sample from P1.3 also contained a predominance of silt and clay. High total organic carbon (TOC) of sediments at

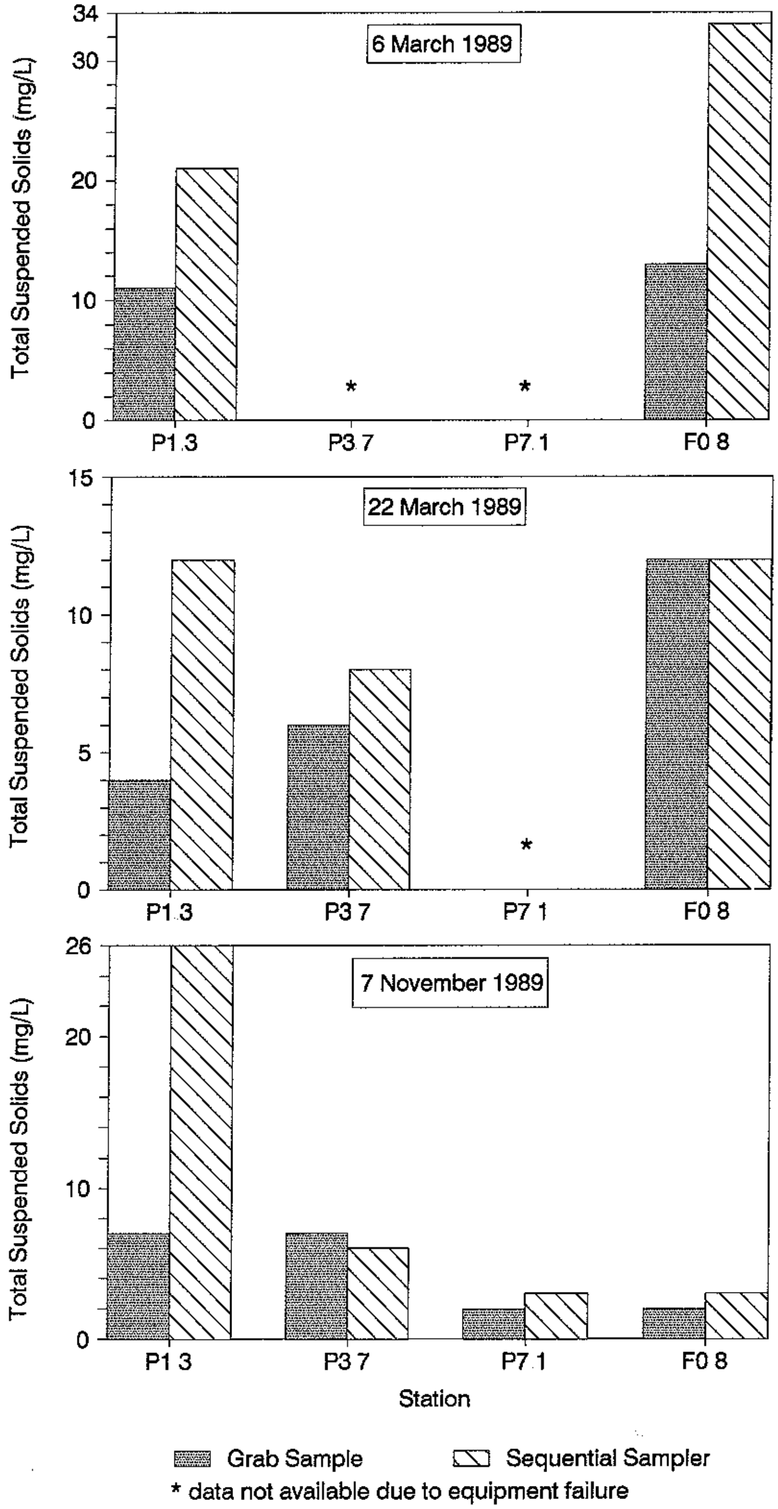


Figure 22. Comparison of grab sample concentrations versus sequential sample mean concentrations derived from a 24-hour sample period.

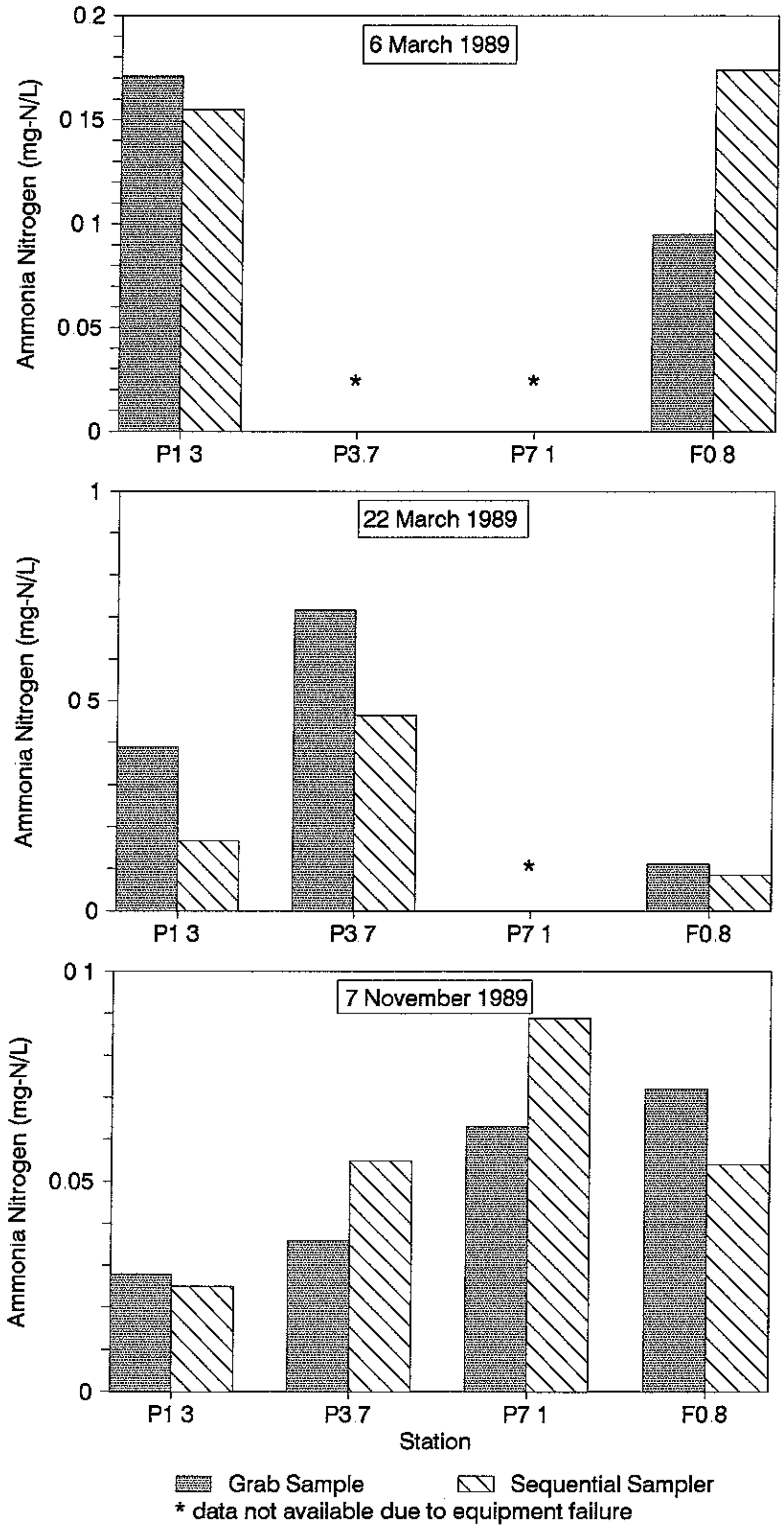


Figure 23. Comparison of grab sample concentrations versus sequential sample mean concentrations derived from a 24-hour sample period.

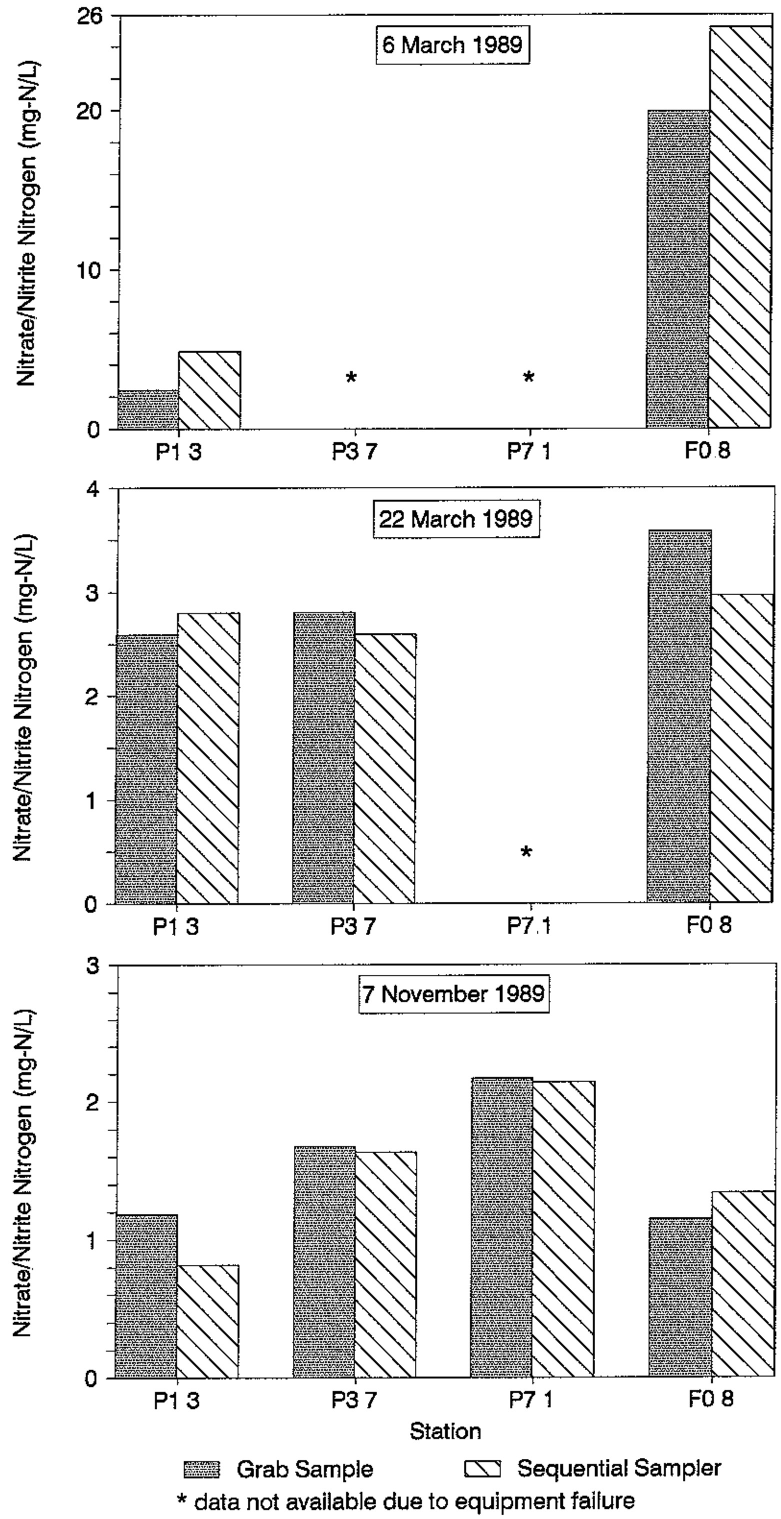
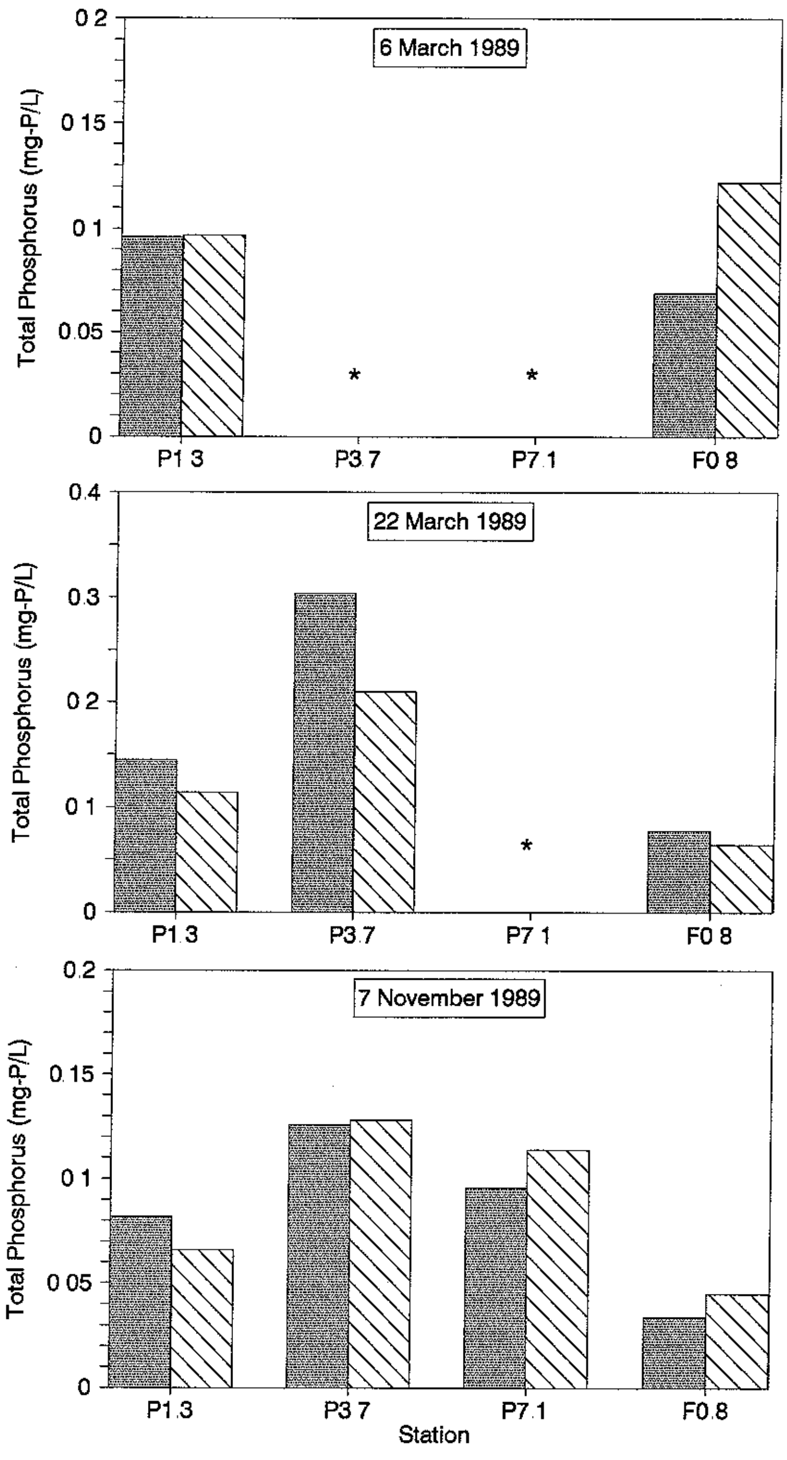


Figure 24. Comparison of grab sample concentrations versus sequential sample mean concentrations derived from a 24-hour sample period.



Grab Sample   Sequential Sampler

* data not available due to equipment failure

Figure 25. Comparison of grab sample concentrations versus sequential sample mean concentrations derived from a 24-hour sample period.

P1.3 and P3.7 suggested that the two sites may have similar contributing sources (Table C1). Low water velocities coupled with manure transport via surface runoff into the stream would contribute to increased TOC levels. Higher percentages of coarse sand and gravel comprised sediment samples collected at sites P7.1 and F0.8.

No semi-volatiles (Base/Neutral/Acids) or pesticide/herbicide compounds were detected in sediments from the Portage Creek watershed (Tables C2 and C3). However, priority pollutant metals were detected at all sites (Table C4). Of those metals detected, arsenic, chromium, copper and nickel were high relative to sediment quality guidelines (Persaud *et al.*, 1990). Metal accumulation in sediments was a function of sediment size. The largest accumulations of metals were found at site P3.7, as expected given the predominance of silt and clay. Smaller sediment accumulation of metals was found at the Fish Creek site (F0.8), where substrate was predominantly gravel.

The concentrations of metals in sediments in the Portage Creek watershed were indicative of contributions from either stormwater runoff, historical pesticide application comprised by arsenicals, or naturally high background concentrations. Chromium, copper, and nickel may also be contributed by motor vehicle operation, where pollutants are transported to the stream by runoff from paved surfaces (Novotny and Chesters, 1981). The metals concentrations found in Portage Creek sediments would have to be compared with background levels before identification of problem areas were possible.

Dissolved Oxygen Profiles

A special study of diurnal dissolved oxygen (D.O.) fluctuation was conducted at three Portage Creek sample sites (P1.3, P3.7, P7.1) and one Fish Creek site (F0.8) (Figure 26). The objective was to compare D.O. concentrations among the four sites and describe the minimum and maximum concentrations at each site.

Daily D.O. concentrations were lowest at sample site P3.7 and highest at P7.1. Daily D.O. concentrations remained above water quality standards (8.0 mg/L) at sites P7.1 and F0.8 due to stream turbulence and possibly low organic input. Both of these sites were characterized as riffle reaches with higher water velocities. Sample sites P1.3 and P3.7 were characterized by slow moving water with deep channels that were predominantly sedimented with finer particulates. Lower daily oxygen concentrations at these sites reflected the possible increase in oxygen demand by sediments. Surface water analysis indicated increased inorganic nitrogen concentrations at these lower- and mid-reach sections of Portage Creek. Nitrogenous biochemical oxygen demand (NBOD) may also have been a contributor to the lower ambient dissolved oxygen condition. Water temperatures were similar at all of the sample sites and were not considered an influential factor in D.O. water column concentrations. The largest temperature difference among sites during an individual sampling interval was 1.9 °C.

Dissolved oxygen minima occurred at approximately 0800 hours for sample sites P1.3 and P3.7. The D.O. maxima occurred near 1400 hours at these same two stations. The D.O. profiles at

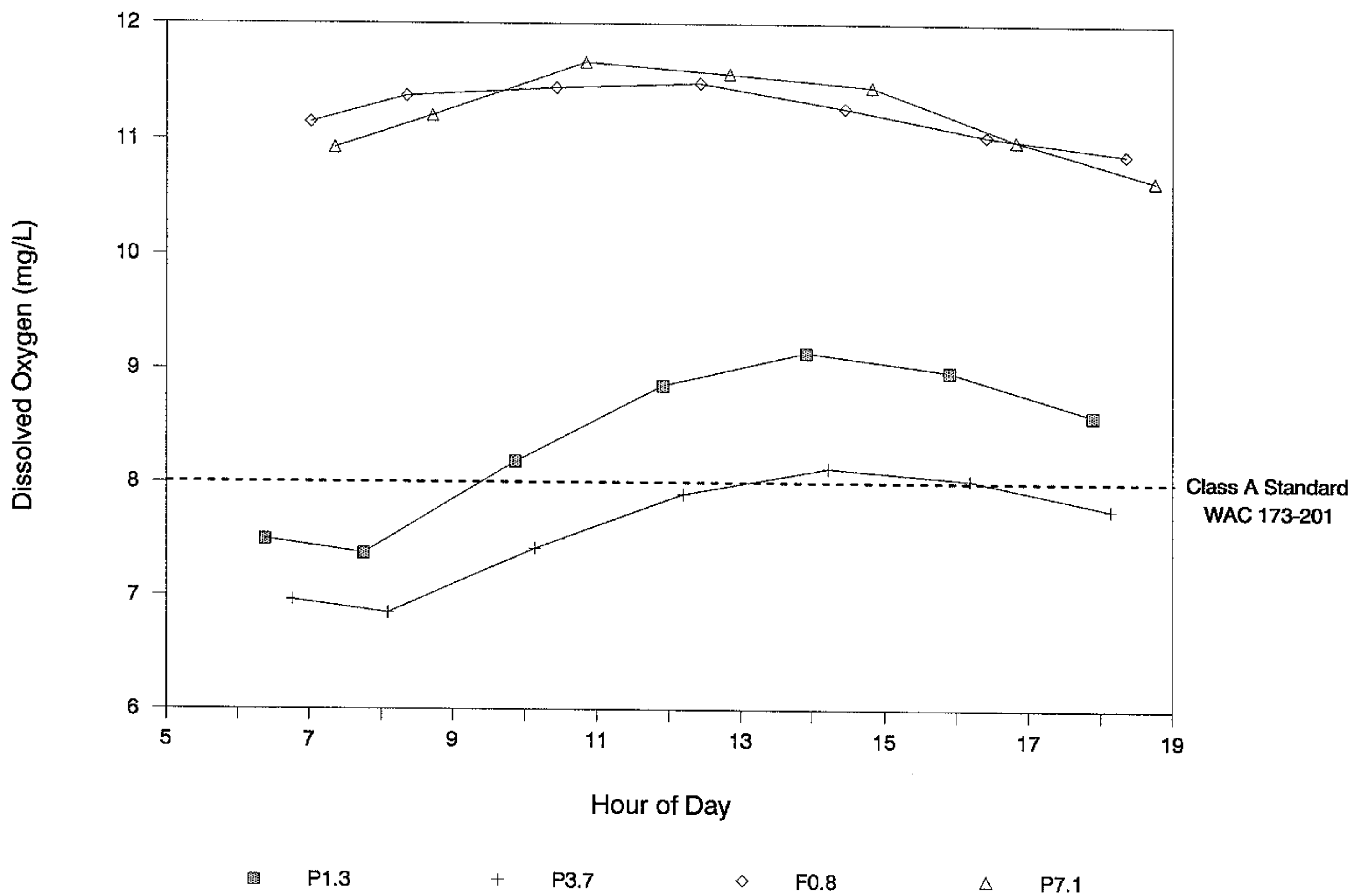


Figure 26. Diurnal dissolved oxygen curves for Portage Creek at three mainstem stations and near the mouth on Fish Creek, 4 October 1989.

sites P1.3 and P3.7 were almost identical, which indicated similar stream conditions at each site. One significant observation that should be noted is that almost all D.O. concentrations at site P3.7 violated the Class A water quality standard. Decaying organic particulates may have created an oxygen demand in the water column which influenced initial D.O. concentrations to decline below the criterion.

Benthic Macroinvertebrates

The objective for benthic macroinvertebrate sampling in this study was to define characteristic assemblages at each site and relate structural and functional attributes of the invertebrate community to possible stream degradation.

Water quality monitoring established that Portage Creek is adversely affected by nonpoint pollution. Nonpoint contributions included eroding soils and organic materials that can settle on depositional areas of the stream. Quantification of stress experienced by the benthic macroinvertebrate community was determined using a modified version of Chandler's (1970) Biotic Score (CBS). The CBS was originally developed for use on the River North Esk in Britain as a means to address sampling anomalies associated with benthic macroinvertebrate abundance estimates. Modifications of this index included additions of some taxa to the list and a restructuring of the taxa abundance categories based on available literature (Gaufin, 1958; Hynes, 1970; Pennak, 1978) (Table 5). Appendix D contains relative taxa abundance information, including a corresponding trophic status for each taxon. The CBS for the sites are listed at the bottom of the Abundance Table. Higher scores indicate abundant populations and a stable community while a lower score indicates possible pollution impact. This score was calculated by first determining a mean value among the three CBS values assigned to a taxon for the replicate samples. The sum of mean CBS values for each taxon present at a site comprised the CBS reported at the bottom of the macrobenthic abundance tables in Appendix D.

The highest CBS (1268) was found at site P7.1, which also had the greatest species richness (25 taxa). This was the most upstream site sampled and had the largest variety of functional groups. Functional groups describe populations at various "feeding" levels (e.g. algal consumption vs. animal consumption). The river continuum concept (Vannote *et al.*, 1980) provides a comparative example of functional attributes nearer headwaters of drainages that parallel those found at site P7.1 on Portage Creek. Biota in this portion of the stream are driven by both autochthonous and allochthonous energy input, as indicated by the presence of scrapers and collector-gatherers (Appendix D3). The larger variety of functional groups at this site indicates the heterogeneity in habitat.

The benthic macroinvertebrate sampling sites at P1.3 and F0.8 had a CBS of 770 and 742, respectively (Appendix D1 and D4). These two sites were similar in functional organization and had comparable species richness. The functional groups present were indicative of a larger stream size where specialization in feeding habits occurred. It is interesting to note that the lowermost sampling stations on each stream attained similar modified Chandler Biotic Scores. This further validates the CBS method as a viable indicator of relative stream condition. The

Table 5. A modified list of Chandler's biotic index scoring system (Chandler, 1970).

		Increasing abundance				
		Points scored*				
	Groups present in sample	P	F	C	A	V
Each species of:	Planaria alpina Taeniopterygidae Perlidae Perlodidae Isoperlidae Chloroperlidae	90	94	98	99	100
Each species of:	Leuctridae Capniidae Nemouridae (excluding Amphinemura)	84	89	94	97	98
Each species of:	Ephemeroptera (excluding Baetis)	79	84	90	94	97
	Cased Caddis, Megaloptera	75	80	86	91	94
	Ancylus	70	75	82	87	91
	Rhyacophila (Trichoptera)	65	70	77	83	88
Each Species of :	Dicranota, Limnophora	60	65	72	78	84
	Simulium	56	61	67	73	75
	Coleoptera, Nematoda	51	55	61	66	72
	Amphinemura (Plecoptera)	47	50	54	58	63
	Baetis (Ephemeroptera)	44	46	48	50	52
	Odonata	42	44	46	48	50
	Gammarus, Hyallela azteca, Ostracoda	40	40	40	40	40
Each species of:	Uncased Caddis(excluding Rhyacophila	38	36	35	33	31
	Tricladida (excluding P. alpina)	35	33	31	29	25
Genera of:	Hydracarina	32	30	28	25	21
Each species of:	Mollusca (excluding Ancylus)	30	28	25	22	18
	Chironomids (excluding C. riparius)	28	25	21	18	15
Each species of:	Glossiphonia	26	23	20	16	13
	Asellus	25	22	18	14	10
	Leech(excluding Glossiphonia,Haemopsis)	24	20	16	12	9
	Haemopsis	23	19	15	10	7
	Tubifex sp.	22	18	13	12	9
	Chironomus riparius	21	17	12	7	4
	Nais (Naididae, Lumbriculidae)	20	16	10	6	2
Each species of:	Air breathing species	19	15	9	5	1
	No animal life			0		

*Abundance Rating:

P=present (1-5 organisms)
F=few (6-10 organisms)
C=common (11-25 organisms)
A=abundant (26-50 organisms)
V=very abundant (>50 organisms)

note: the modified Chandler Biotic Index was based on information from various studies relating taxon tolerance to organic pollution.

observed trophic structure at sites P1.3 and F0.8 were indicative of habitat tending toward homogeneity, much like conditions found in larger lower reach portions of a drainage. A predominance of collectors (gatherers and filterers) was found at these two sites, which also indicated the presence of depositional detrital and suspended transport materials (Appendix D1 and D4).

The CBS was 81 at site P3.7, which indicated that habitat at this site may be highly modified relative to other sites in the drainage (Appendix D2). The only functional groups present were collectors. These benthic macroinvertebrates are sustained by heavy input and deposition of organic particulates. The substrate was highly unstable and generally composed of fine organic particulates.

Diversity of a benthic macroinvertebrate community and behavior of individuals have been used to describe disturbance and its frequency. The intermediate disturbance hypothesis proposed by Connell (1978) outlined possible diversity levels along a disturbance gradient. Diversity in natural communities has a tendency to be lower in frequently disturbed areas and in undisturbed areas. This is because taxa comprised by opportunists rapidly colonize frequently disturbed sites while specialists will develop in relatively undisturbed sites. Moderately disturbed sites will normally contain the highest level of taxonomic diversity.

The intermediate disturbance hypothesis would be appropriate for analysis of the community structures sampled in the Portage Creek drainage. Site P3.7 was regarded as physically modified by nonpoint pollution sources and showed little diversity (Townsend and Hildrew, 1976). The highest diversity was found at site P7.1, which was represented by a variety of functional groups that formed a more stable community. This upstream site was not exposed to large fluctuations in discharge or excessive stream disturbance. Site P3.7 exemplified a degraded condition for an expected benthic macroinvertebrate community when compared with the favorable habitat conditions found at site P7.1.

RECOMMENDATIONS AND CONCLUSIONS

1. Spatial distribution of land use appeared to explain significant statistical differences between the Portage Creek stations examined. Grazing and manure/fertilizer applications in the central portion of the watershed contributed to increases in total suspended solids and total inorganic nitrogen, respectively. Wetlands were well represented in the mid-reach of Portage Creek and were contiguous with the stream. Wetlands, when present, may have provided some natural filtration of organics and other pollutants in the mainstem Portage Creek water column. Urban land use is contiguous with the upper reach of Portage Creek. Urban impacts seemed to be minimal due to the concentration of such land use nearer the periphery of the watershed.

2. Seasonal trends were analyzed in Portage Creek for concentrations of total suspended solids (TSS), total inorganic nitrogen (TIN), total phosphorus (TP) and fecal coliforms (FC). Significant seasonal differences were found for surface water concentrations of TSS and TIN; wet season concentrations were significantly higher than dry season concentrations. Site differences were also found and assisted in identifying sources of contamination. Total suspended solids and total inorganic nitrogen concentrations were likely influenced by streamside manure spreading practices and cattle grazing. Manure spreading was conducted during the wet season which probably increased contributions to the stream through surface runoff.

   Riparian soils destabilized by grazing cattle increased the concentration of TSS during the wet season. Manure spreading was prevalent in regions near station P3.7 and P5.2 while cattle grazing occurred near station P3.7. Particulates that may have been contributed by pasturing of cattle appeared at station P3.7 as TSS in the water column. Station P3.7 water quality was influenced primarily by contributions from pasture land. Land contiguous with station P5.2 was used for cropland and was heavily fertilized with both manure and commercial fertilizers. Substantial TIN loads were found at station P5.2.

   Total phosphorus and fecal coliform concentrations did not show seasonal trends at Portage Creek sample sites. TP was contributed to surface water through manure introduction and from senescing aquatic macrophytes in an upstream impoundment on Portage Creek at river mile 7.3. Inconsistencies in wet and dry season trends for TP and FC may have been due to instream processes. Available phosphorus in the water column is often cycled quickly through biological uptake or adsorption. The presence of fecal coliform colonies are related to sources of input. It is evident that TP and FC were related to specific streamside agricultural activities, but were not conserved in the water column as were TSS and TIN.

3. Individual concentrations for fecal coliform (FC), turbidity and dissolved oxygen (D.O.) violated Washington State Class A water quality standards during both wet and dry seasons. The FC standard was consistently violated during the dry season at all mainstem Portage Creek sites; the highest value measured was 560/100 mL at site P7.1. Manure storage and manure spreading near upper reach stations (P7.1 and P8.1, respectively) at the end of the dry season were partially responsible for the FC violations. FC criteria were not violated at Portage Creek sites P1.3 and P6.0 during the wet season, presumably due to streamside inactivity and dilution effects. Site P6.0 was located in a region of the watershed surrounded by wetlands which possibly contributed to sedimentation and removal of fecal coliforms associated with particulates. High discharges were recorded at site P1.3 with substantial contribution from the Fish Creek drainage. Wet season FC concentrations at the mouth of Fish Creek did not continuously violate Class A standards and, therefore, did not contribute to FC violations in surface water downstream of its confluence with Portage Creek.

   Turbidity values violated the Class A criterion at site P3.7 in the wet season and at site P7.3 during the dry season. Commercial farming activities, including cattle grazing and manure spreading during the wet season, increased the turbidity of surface water at site P3.7. Exceedance of the turbidity criterion at upstream site P7.3 was influenced by a high value recorded during the October routine monitoring date. Both turbidity and fecal coliform were extraordinarily high in October 1989, which coincided with manure spreading activity on cropland near the streamside at this site.

Dissolved oxygen concentrations violated the Class A water quality standard at station P1.3, P2.5, P3.7, and P5.2 during the wet season. Dissolved oxygen violations for the same stations continued in the dry season, with the addition of station P7.3. Decaying organics such as manure may have been one source of oxygen depletion in the surface water at these lower Portage Creek stations. Sediment oxygen demand (SOD) often occurs where decaying organics are deposited; SOD removes D.O. from the overlying surface water. Cattle grazing and manure spreading were prevalent throughout the year adjacent to station P3.7. Lower D.O. concentrations at station P1.3 during the dry season may have been influenced by groundwater input. The low stream discharge during this season is probably more easily influenced by the oxygen deficient groundwater input near the mouth of Portage Creek.

4. Pollutant inputs in Portage Creek were best analyzed through mass balances between stream segments. TSS load in the water column was influenced by livestock access to the stream and manure spreading during both wet and dry seasons. The TSS load was significantly greater during the wet season from surface water runoff contributions. In stream segments that contained higher TSS loads, dissolved nutrient loads were concurrently lower, presumably due to adsorption on suspended material. Fish Creek contributed large quantities of TSS and TIN during the wet season, which significantly increased TSS and TIN loads at station P1.3. Fish Creek drains a sub-watershed of Portage Creek that predominantly contains small farms. The extensive macrophyte community on the lower reach of Portage Creek probably modified water velocity (which increased sedimentation) and removed dissolved nutrient from the stream. The dry season TSS load declined from station P3.7 to P1.3, likely due to smaller contributions from Fish Creek and by an increased rate of sedimentation. An increased TIN load at station P5.2 during the wet season was probably contributed by excess application of manure and fertilizers on cropland fields adjacent to Portage Creek.

5. Sediment samples were analyzed at stations P1.3, P3.7, P7.1 and F0.8 for semi-volatiles, pesticides/herbicides, and metals. The substrate composition at stations P1.3 and P3.7 was comprised predominantly of silt and clay. Stations P7.1 and F0.8 contained higher percentages of coarse sand and gravel. No semi-volatiles or pesticides/herbicides were detected. A priority pollutant scan of the same sediment samples for metals resulted indetectable quantities of arsenic, chromium, copper and nickel at station P3.7. Sediment concentrations of chromium and nickel at P3.7 may be sufficiently high to create pronounced disturbance of the benthic community.

6. Benthic macroinvertebrates were sampled at stations P1.3, P3.7, P7.1 and F0.8. The abundance data for each taxon at a sample station was analyzed using a modified version of

Chandler's Biotic Scoring (CBS) method. A higher score indicates a balanced benthic macroinvertebrate community, which was found at station P7.1. This upper stream reach station was supported by a variety of food sources for benthic macroinvertebrates, which was reflected by the functional groups present within the community. Stations P1.3 and F0.8 attained similar scores, but were lower than that determined for site P7.1. Specialization of taxa at each of these stations occurred due to increased uniformity of habitat characteristic of a larger stream size. The lowest biotic score was found at station P3.7, which was considered an extremely disturbed site due to sedimentation and possibly metals toxicity.

7. The information obtained in this investigation forms some well defined observations regarding nonpoint pollution contributions to Portage Creek and the quality of habitat available for aquatic life. Water quality problems were exacerbated by total suspended solids (TSS) and total inorganic nitrogen (TIN) contributions from cropland and pasture land activities, including manure spreading and cattle grazing. Many of the water quality problems occurred at mid-reach sites P3.7 and P5.2, where the largest concentration of commercial farms are found in the Portage Creek watershed. Occasionally, water quality criteria were not met at upper-reach and lower-reach Portage Creek stations, but habitat impact as indicated by the benthic macroinvertebrate community was most severe at the mid-reach site, P3.7. High metals concentrations and shifting organic sediments (manure contribution) at site P3.7 may have led to the small, non-diverse benthic macroinvertebrate community found there. The upper-reach and lower-reach sites were probably able to assimilate (site P1.3) or transport (site P7.1) nonpoint source pollutants that may have been detrimental to endemic intolerant benthic macroinvertebrate taxa. Physical and chemical analyses were successful in determining the type of pollution and where it was contributed, while the biological information was useful in determining the cumulative impacts of the pollutants on the aquatic life at select Portage Creek sites.

8. It is recommended that cattle access points at Portage Creek be fenced, with a buffer strip left between the stream and fence. The stream banks, especially in the central portion of the Portage Creek drainage, have experienced excessive erosion which has degraded surface water quality and benthic habitat. Grazing on stream banks will only exacerbate the present condition of Portage Creek water quality. Manure spreading should be conducted away from the stream; the buffer strip should be wide enough to decrease runoff potential into the stream or tributaries. This activity occurred too close to the stream in the upper portion of the watershed and was reflected in surface water grab samples downstream. Manure spreading should be conducted during the dry season. Correct timing in manure spreading should minimize present nutrient and suspended solids contributions.

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APPENDIX A

Routine Monitoring Data

Table A1. Water quality monitoring data at Station P1.3 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	BOD (mg/L)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]	Oil/ Grease (mg/L)
Routine Survey															
12/21/88	1.32	5.25	6.99	171	8.7	69.2	3U	6	3	0.530	0.660	2.600	0.200	20	
[Load]								680		60.45		296.52	22.81	264,000	
01/09/89	2.07	4.44	6.77	140	9.4	73.2	3K	26	3	0.080	0.056	2.900	0.170	75	
[Load]								4,750		14.31		518.66	30.40	1,552,500	
01/30/89	1.10	8.03	7.02	162	6.5	55.5	3U	2	3	0.060	0.100	2.100	0.170	31	
[Load]								190		5.70		199.58	16.16	341,000	
02/13/89	0.71	2.20	6.99	176	9.4	68.9	3U	23	5	0.099	0.058	1.778	0.160	36	
[Load]								1,400		6.07		109.07	9.82	255,600	
02/27/89	1.14	5.40	6.75	142	9.7	77.4	3U	5	2	0.060	0.044	2.200	0.080	18 S	
[Load]								490		5.91		216.69	7.88	205,200	
03/13/89	*	--	6.80	100	9.6	66.2	3K	13	6	0.36	2.95	0.18	--	2,000 L,S	
[Load]															
04/10/89	1.36	9.60	6.98	156	--	--	3U	1 K	2	0.060	0.103	1.600	0.100	29 S	
[Load]								120		7.05		188.01	11.75	394,400	
05/08/89	0.59	13.00	7.11	179	6.5	62.6	3U	1	3	0.100	0.302	0.960	0.090	250	
[Load]								51		5.10		48.94	4.59	1,475,000	
06/06/89	0.49	14.50	6.98	190	6.5	64.8	3U	1	3	0.050	0.126	0.810	0.110	390	
duplicate			6.99					1 U	3	0.050	0.128	0.820	0.110	380	
[Load]								42		2.12		34.50	4.66	1,886,500	
07/11/89	0.31	12.80	7.37	180	10.9	104.4	3U	1 U	2	0.020	0.108	0.890	0.080	390	
[Load]								27		0.54		23.84	2.14	1,209,000	
08/08/89	0.25	14.50	7.23	237	4.7	46.9	3U	6	5	1.500	6.686	0.910	0.260	4,000	
[Load]								130		32.40		19.66	5.62	10,000,000	
09/19/89	0.27	10.00	7.13	208	7.2	64.5	3U	1 U	1	0.021	0.053	0.681	0.068	74	
[Load]								23		0.49		15.89	1.59	199,800	
10/10/89	0.24	11.30	7.22	200	6.5	60.2	3U	1	1.5	0.020	0.068	0.790	0.070	31	
[Load]								21		0.41		16.38	1.45	74,400	
11/14/89	0.58	7.80	6.86	155	7.0	59.7	3U	4	5	0.320	0.363	2.420	0.180	110	
[Load]								200		16.04		121.27	9.02	638,000	
Runoff Events															
03/06/89	--	5.50	7.27	146	--	--	3U	--	--	--	--	--	--	610	1U
[Load]															
03/22/89	--	10.00	--	120	--	--	3U	--	--	--	--	--	--	3,400	2
[Load]															
11/07/89	--	8.80	6.96	158	--	--	3U	--	--	--	--	--	--	120	<1.4
[Load]															

* flow meter malfunction
"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"L" Total plate count greater than 200
"S" Spreader

Table A2. Water quality monitoring data at station P3.7 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	BOD (mg/L)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]	Oil/ Grease (mg/L)
Routine Survey															
12/21/88	1.04	5.62	6.94	172	6.0	48.2	3	6	2	0.370	0.423	2.200	0.340	530 S	
[Load]								540		33.25		197.68	30.55	5,512,000	
01/09/89	0.98	4.71	6.72	155	7.2	56.4	3K	9	3	0.200	0.128	2.200	0.320	450	
duplicate								5	2					430	
[Load]								640		16.93		186.28	27.10	4,312,000	
01/30/89	0.52	8.44	7.09	175	5.5	47.5	3U	11	3	0.050	0.101	1.700	0.240	88	
duplicate								15	2	0.050	0.101	1.700	0.270	110	
[Load]								580		2.25		76.38	11.46	514,800	
02/13/89	0.48	3.30	7.32	190	8.0	60.4	3U	37	11	0.285	0.646	1.387	0.280	200	
[Load]								1,500		11.82		57.52	11.61	960,000	
02/27/89	0.84	6.00	7.66	166	8.3	67.3	3U	11	3	0.080	0.493	1.700	0.150	29	
[Load]								800		5.81		123.38	10.89	243,600	
03/13/89	*	--	7.00	130	8.3	57.2	3K	8	5	0.590	--	2.430	0.390	620 S	
[Load]															
04/10/89	0.86	10.60	6.93	184	--	--	3U	6	2	0.110	0.183	1.500	0.150	66 S	
duplicate								7	2	0.100	0.166	1.500	0.170	52 S	
[Load]								480		7.80		111.46	12.26	507,400	
05/08/89	0.47	12.60	7.41	161	7.0	66.8	3U	7	4	0.070	0.408	1.000	0.130	240	
[Load]								280		2.84		40.61	5.28	1,128,000	
06/06/89	0.24	14.30	6.88	200	6.4	63.5	3U	6	5	0.060	0.118	0.960	0.130	190	
[Load]								120		1.24		19.91	1.87	648,000	
07/11/89	0.24	13.10	7.34	187	7.9	76.3	3U	1 U	1	0.020	0.103	0.960	0.090	270	
[Load]								21		0.41		19.91	2.70	456,000	
08/08/89	0.21	13.70	7.26	200	6.9	67.6	3U	6	2	0.030	0.135	0.880	0.100	230	
[Load]								110		0.54		15.97	1.81	483,000	
09/19/89	0.20	10.85	7.30	231	7.0	63.8	3U	1 U	2	0.014	0.055	0.903	0.090	43	
[Load]								17		0.24		15.60	1.56	86,000	
10/10/89	0.16	10.80	7.28	206	6.3	57.5	3U	8	4	0.020	0.075	0.910	0.080	60	
[Load]								110		0.27		12.42	1.09	94,800	
11/14/89	0.79	7.24	6.87	177	5.2	43.2	3U	5	3	0.600	0.665	1.990	0.360	27	
[Load]								340		40.95		135.83	24.57	213,300	
Runoff Events															
03/06/89	--	6.10	7.21	183	--	--	3U	--	--	--	--	--	--	820	1 U
[Load]															
03/22/89	--	9.00	--	165	--	--	4	--	--	--	--	--	--	--	2
[Load]															
11/07/89	--	9.10	6.91	130	--	--	3U	--	--	--	--	--	--	69	<1.5
[Load]															

*flow meter malfunction
"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"S" Spreader

Table A3. Water quality monitoring data at station P7.1 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	BOD (mg/L)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]	Oil/ Grease (mg/L)
Routine Survey															
12/21/88	0.32	4.77	7.23	81	12.7	99.7	3U	3	2	0.020	0.042	2.000	0.120	45	
duplicate								4	2	0.020	0.042	2.000	0.120	53	
[Load]								97		1		55.30	3.32	156,800	
01/09/89	0.53	4.21	7.09	76	12.9	99.8	3K	6	3	0.010	0.014	2.100	0.120	210	
[Load]								280		0.46		96.16	5.50	1,113,000	
01/30/89	0.18	7.90	--	87	10.5	89.4	3U	2	1	0.010U	--	1.800	0.130	270	
[Load]								31		0.16		27.99	2.02	486,000	
02/13/89	0.09	3.50	7.62	103	13.1	99.4	3U	5	2	0.014	0.064	1.638	0.070	260	
[Load]								39		0.11		12.74	0.54	234,000	
02/27/89	0.28	4.90	--	83	13.2	104.0	3U	8	3	0.010	--	1.900	0.050	210	
duplicate								7	3	0.020		1.900	0.040	280	
[Load]								5,200		0.36		45.96	1.09	686,000	
03/13/89	0.77	--	7.10	58	12.6	86.9	--	11	5	0.020	--	3.160	0.060	180	
[Load]								730		1.33		210.23	3.99	1,386,000	
04/10/89	0.22	13.00	7.32	80	--	--	--	5	1	0.010	0.049	1.300	0.050	160	
[Load]								95		0.19		24.71	0.95	352,000	
05/08/89	0.03	18.50	8.80	155	10.5	114.3	--	1	1	0.010	1.833	0.510	0.100	500	
[Load]								3		0.03		1.32	0.26	150,000	
06/06/89	0.02	18.60	7.36	135	9.7	105.6	3U	1	1	0.020	0.162	0.580	0.090	730	
[Load]								2		0.03		1.00	0.16	146,000	
07/11/89	0.02	19.65	8.30	158	9.4	104.9	--	1 U	1	0.010U	0.717	0.460	0.100	460	
[Load]								2		0.02		0.79	0.17	92,000	
08/08/89	0.02	19.40	8.60	159	9.7	107.7		1 U	1	0.010	1.314	0.380	0.100	1,300	
duplicate					10.3	114.3		1 U	1	0.010	1.314	0.380	0.100	1,400	
[Load]								2		0.02		0.66	0.17	270,000	
09/19/89	0.02	14.25	8.43	174	10.4	71.7	--	1 U	1	0.011	0.716	0.387	0.101	830	
[Load]								2		0.02		0.67	0.17	149,400	
10/10/89	0.04	13.20	8.03	188	10.3	70.9	--	11	3	0.720	17.961	0.860	0.260	2,400	
[Load]								38		2.49		2.97	0.90	960,000	
11/14/89	0.28	8.28	6.87	85	11.7	80.9	--	7	2	0.020	0.024	2.360	0.050	140	
duplicate					11.7	80.9		8	2	0.020	0.024	2.310	0.050	120	
[Load]								180		0.48		5.66	1.21	364,000	
Runoff Events															
03/06/89	--	5.10	7.68	74	--	--	3U	--	--	--	--	--	--	220	1U
[Load]															
03/22/89	--	7.40	--	70	--	--	3U	--	--	--	--	--	--	410	1
duplicate														390	
[Load]															
11/07/89	--	9.10	7.58	147	--	--	3U	--	--	--	--	--	--	77	2.2
[Load]															

"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

Table A4. Water quality monitoring data at station F0.8 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	BOD (mg/L)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]	Oil/ Grease (mg/L)
Routine Survey															
12/21/88	0.42	4.32	7.18	109	12.3	95.4	3U	8	3	0.030	0.054	2.500	0.150	170	
[Load]								290		1.09		90.72	5.44	714,000	
01/09/89	0.83	3.54	6.84	97	12.4	94.2	3K	28	3	0.060	0.046	2.500	0.150	330	
[Load]								2,000		4.30		179.28	10.76	2,739,000	
01/30/89	0.25	7.88	7.37	104	10.9	92.8	3U	4	3	0.020	0.074	2.000	0.140	40 S	
[Load]								86		0.43		43.20	3.02	100,000	
02/13/89	0.14	1.30	7.47	114	13.0	92.9	3U	4	2	0.051	0.138	1.904	0.050	37	
[Load]								48		0.62		23.03	0.60	51,800	
02/27/89	0.47	4.95	7.08	92	12.7	100.2	3U	11	3	0.030	0.045	2.300	0.050	37 S BOF	
[Load]								450		1.22		93.40	2.03	173,900	
03/13/89	1.91	--	6.50	72	11.5	79.3	3K	13	5	0.070	--	4.600	0.070	100 S	
duplicate								14	4	0.040		4.700	0.060	68 S	
[Load]								2,200		11.55		767.36	10.73	1,604,400	
04/10/89	0.24	9.80	6.99	90	--	--	3U	7	3	0.020	0.036	1.400	0.050	21	
[Load]								150		0.41		29.03	1.04	50,400	
05/08/89	--	14.10	7.65	128	10.3	101.8	3U	3	2	0.040	0.452	1.100	0.080	84	
[Load]															
06/06/89	0.04	15.40	6.98	121	9.9	100.8	3U	1 U	2	0.020	0.54	0.980	0.080	230	
[Load]								3		0.07		3.39	0.28	92,000	
07/11/89	0.03	14.40	7.83	127	10.4	103.5	3U	1 U	1	0.010 U	0.174	1.140	0.080	130	
[Load]								3		0.03		2.95	0.21	39,000	
08/08/89	0.03	14.60	7.64	140	9.9	99.0	3U	1 U	1	0.010	0.144	1.210	0.090	140	
[Load]								3		0.03		3.14	0.23	42,000	
09/19/89	0.03	11.00	7.76	153	10.7	98.5	3U	1 U	1	0.010	0.115	1.039	0.082	84	
[Load]										0.03		2.69	0.21	24,360	
10/10/89	0.04	11.30	7.68	138	9.9	91.4	3U	2	1	0.020	0.195	1.020	0.090	450	
[Load]								7		0.07		3.53	0.31	180,000	
11/14/89	0.37	7.80	6.83	112	10.9	92.6	3U	6	2	0.030	0.032	2.070	0.060	160	
[Load]								190		0.96		66.17	1.92	592,000	
Runoff Events															
03/06/89	--	5.40	7.57	84	--	--	3U	--	--	--	--	--	--	92	1
[Load]															
03/22/89	--	7.40	--	83	--	--	3U	--	--	--	--	--	--	110	1
[Load]															
11/07/89	--	8.50	7.22	133	--	--	3U	--	--	--	--	--	--	100	<1.5

"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"S" Spreader
"BOF" Bottle over-filled

Table A5. Water quality monitoring data at station UN2.0 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]
Routine Survey													
12/21/88	0.11	5.69	6.60	105	9.0	72.4	4	2	0.050	0.026	0.970	0.130	520
[Load]							38		0.48		9	1.24	572,000
01/09/89	0.14	5.00	6.24	100	9.5	75.0	7	2	0.050	0.011	1.200	0.150	26
[Load]							85		0.60		15	1.81	36,400
01/30/89	0.06	8.23	6.47	105	8.4	72.1	2	2	0.060	0.029	1.300	0.130	7
[Load]							10		0.31		7	0.67	4,200
02/13/89	0.04	2.00	6.67	103	10.0	72.9	55	14	0.060	0.027	1.295	0.220	28
[Load]							190		0.21		4	0.76	11,200
02/27/89	0.09	5.40	6.07	90	10.0	79.8	1	2	0.060	0.009	1.300	0.050	14
[Load]							8		0.47		10	0.39	12,600
03/13/89	0.17	--	6.80	86	9.8	67.6	3	2	0.040	--	2.100	0.060	14
[Load]							44		0.59		31	0.88	23,800
04/10/89	0.06	11.30	6.57	70	--	--	1 K	2	0.030	0.023	1.000	0.060	33
[Load]							5		0.16		5	0.31	19,800
05/08/89	--	14.30	6.72	78	9.3	92.3	3	4	0.030	0.041	0.830	--	260
[Load]													
06/06/89	0.01	15.20	6.51	105	7.5	76.0	5	5	0.040	0.036	0.640	0.080	260
[Load]							4		0.03		1	0.07	26,000
07/11/89	0.003	17.90	6.96	189	6.7	72.0	5	5	0.020	0.062	0.560	0.090	1,100
[Load]							1.30		0.005		0.15	0.02	33,000
08/08/89	no flow												
[Load]													
09/19/89	no flow												
[Load]													
10/10/89	no flow												
[Load]													
11/14/89	0.14	8.99	6.63	114	7.3	63.7	3	3	0.050	0.037	0.780	0.080	26
[Load]							36		0.60		9.43	0.97	36,400
Runoff Events													
03/06/89	--	6.80	7.24	99	--	--	--	5	--	--	--	--	11
03/22/89	--	6.60	--	95	--	--	--	1 U	--	--	--	--	44
11/07/89	--	10.20	6.91	130	--	--	--	5	--	--	--	--	54

"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

Table A6. Water quality monitoring data at station P5.2 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]
Routine Survey													
12/21/88	0.57	5.47	6.97	171	8.5	68.0	4	3	1.200	1.453	2.000	0.370	250
[Load]							200		59.10		98.50	18.22	1,425,000
01/09/89	0.83	4.86	6.81	157	9.1	71.6	6	3	1.000	0.798	2.200	0.440	240
[Load]							430		71.71		157.77	31.55	1,992,000
01/30/89	0.43	8.70	6.76	172	7.6	66.0	4	2	0.280	0.271	1.800	0.250	84S
[Load]							150		10.40		66.87	9.29	361,200
02/13/89	0.29	4.40	7.20	208	9.6	74.6	23	8	0.648	1.221	10.275	0.280	200
[Load]							580		16.24		257.45	7.02	580,000
02/27/89	0.54	5.90	--	170	9.3	75.2	5	3	0.590	--	1.800	0.270	140
[Load]							230		27.53		83.98	12.60	756,000
03/13/89	1.29	--	6.60	120	9.5	65.5	8	5	0.850	--	2.920	0.420	600S
[Load]							890		94.74		325.45	46.81	7,740,000
04/10/89	0.52	11.90	6.97	173	--	--	11	3	0.490	0.986	1.500	0.160	110
[Load]							490		22.01		67.39	7.19	572,000
05/08/89	0.23	13.60	7.48	230	9.4	91.8	6	2	0.040	0.295	1.100	0.080	410
[Load]							120		0.79		21.86	1.59	943,000
06/06/89	0.22	14.00	7.07	210	8.7	85.8	6	2	0.040	0.119	1.030	0.100	1,500
[Load]							110		0.76		19.58	1.90	3,300,000
07/11/89	0.19	13.80	7.52	230	8.7	85.4	i U	2	0.020	0.164	1.200	0.070	770
[Load]							16		0.33		19.70	1.15	1,463,000
08/08/89	0.13	13.80	7.37	233	8.3	81.5	8	1	0.030	0.175	1.000	0.070	780
[Load]							90		0.73		11.23	0.79	1,014,000
09/19/89	0.12	10.90	7.31	250	8.1	74.4	1 U	1	0.023	0.093	0.975	0.059	380
[Load]							48		0.24		10.11	0.61	471,200
10/10/89	0.11	11.50	7.32	224	7.4	68.7	7	2	0.090	0.392	1.020	0.060	210
duplicate					7.6	52.2	4	2	0.040	0.174	1.020	0.060	210
[Load]							190		0.62		9.69	0.57	231,000
11/14/89	0.28	8.29	6.94	166	7.5	64.1	5	3	0.590	0.836	2.050	0.320	92
[Load]							120		14.27		49.59	7.74	257,600
Runoff Events													
03/06/89	--	5.0	7.24	178	--	--	10	--	--	--	--	--	930
03/22/89	--	7.60	--	155	--	--	2	--	--	--	--	--	420S
11/07/89	--	9.00	7.26	223	--	00	4	--	--	--	--	--	180

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"S" Spreader

Table A7. Water quality monitoring data at station P7.3 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Flow (m^3/s)	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	BOD (mg/L)	TSS (mg/L) [kg/day]	Turb. (NTU)	NH_3-N (mg/L) [kg/day]	Un-ionized Ammonia (ug/L)	NO_3+ NO_2-N (mg/L) [kg/day]	Total P (mg/L) [kg/day]	Fecal Coliform (#/100 mL) [fc/sec]
Routine Survey														
12/21/88	0.15	4.63	7.15	82	12.4	97.0	--	2	3	0.020	0.034	1.800	0.100	66
[Load]								26		0.26		23.33	1.30	99,000
01/09/89	0.28	4.11	6.68	75	12.4	95.7	--	5	3	0.200	0.111	2.200	0.320	210
duplicate										0.020	0.011	2.000	0.120	
[Load]								120		2.66		50.80	5.32	588,000
01/30/89	0.09	7.70	7.12	82	10.9	92.3	--	1	1	0.010 U	0.020	1.700	0.110	930
[Load]								8		0.08		13.22	0.86	837,000
02/13/89	0.04	2.10	7.13	108	13.2	96.5	--	2	1	0.014	0.019	41.760	0.033	3,900
duplicate								1	1	0.022	0.029	13.000	0.096	2,000
[Load]								5		0.06		94.63	0.76	1,120,000
02/27/89	0.14	4.40	--	72	13.3	103.4	--	8	9	0.040	--	1.700	0.050	500
[Load]								97		0.48		20.56	0.60	700,000
03/13/89	0.49	--	6.80	58	12.7	87.6	--	10	4	<0.010	--	3.770	0.040	360
[Load]								420		<0.42		159.61	1.69	1,764,000
04/10/89	0.12	12.20	6.97	75	--	--	3 U	4	1	0.010	0.021	1.200	0.040	440
[Load]								41		0.10		12.44	0.41	528,000
05/08/89	0.02	17.60	8.28	153	11.3	120.7	3 U	1	1	0.010	0.596	0.580	0.030	140
duplicate								1	1	0.020	1.193	0.570	0.040	63
[Load]								2		0.03		0.99	0.06	7,700
06/06/89	0.03	18.40	7.42	125	10.6	115.2	--	1 U	1	0.010	0.092	0.540	0.040	220
[Load]								3		0.03		1.40	0.10	66,000
07/11/89	0.002	18.10	8.76	155	13.2	142.5	3 U	1 U	1	0.010 U	1.658	0.410	0.060	51
[Load]								0.2		0.002		0.07	0.01	1,020
08/08/89	0.002	19.00	8.72	152	14.0	154.1	3 U	5	2	0.010U	1.623	0.240	0.060	96S
[Load]								1		0.002		0.04	0.01	1,920
09/19/89	0.003	13.60	8.50	166	12.9	126.1	3 U	1 U	1	<0.010	0.722	0.469	0.035	40
[Load]								0.3		0.003		0.12	0.009	1,200
10/10/89	0.02	13.30	8.23	540	5.5	53.3	30	56	29	1.080	42.397	1.050	5.920	14,000S
[Load]								97		1.87		1.81	10.23	2,800,000
11/14/89	0.14	7.96	6.81	83	11.2	95.5	3 U	1	1	0.010	0.010	2.220	0.030	88
[Load]								12		0.12		26.85	0.36	123,200
Runoff Events														
03/06/89	--	3.80	7.53	74	--	--	3	--	--	--	--	--	--	300
03/22/89	--	7.20	--	70	--	--	1 U	--	--	--	--	--	--	770
11/07/89	--	8.90	7.42	147	--	--	3	--	--	--	--	--	--	150

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"S" Spreader

Table A8. Water quality monitoring data at station P2.5 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey							
12/21/88	5.51	6.99	186	5.3	42.4	2	220
01/09/89	4.82	6.75	167	6.3	49.5	2	110
01/30/89	8.46	7.00	186	2.1	18.1	2	77
02/13/89	3.20	7.31	190	--	--	18	120
02/27/89	5.70	7.14	170	--	--	1	14
03/13/89	--	6.80	140	--	--	5	970S
04/10/89	10.20	6.94	200	--	--	1	84S
05/08/89	12.60	7.38	210	5.7	54.4	7	750
06/06/89	14.00	6.88	192	5.5	54.2	5	450
07/11/89	12.70	7.34	187	7.1	67.9	1U	330
08/08/89	14.10	7.25	205	6.4	63.3	12	200
09/19/89	10.30	7.31	216	6.6	59.5	1U	77
10/10/89	11.10	7.21	208	5.9	54.3	14	47
11/14/89	8.18	6.84	179	4.0	34.4	3	31S
duplicate				4.0	34.4	8	42
Runoff Events							
03/06/89	5.40	7.19	212	--	--	8	1,200
03/22/89	--	--	180	--	--	6	260S
11/07/89	8.80	6.93	195	--	--	10	420

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

"S" Spreader

Table A9. Water quality monitoring data at station UN5.4 during the sample period, December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey							
12/21/88	5.70	7.06	201	6.1	49.1	2	32
01/09/89	5.33	6.92	207	6.0	47.8	2	200
01/30/89	9.50	--	188	--	--	3	88
02/13/89	2.10	6.81	189	--	--	6	170
02/27/89	6.40	--	150	--	--	2	11
03/13/89	--	6.60	180	--	--	11	420S
04/10/89	10.80	7.08	198	--	--	1K	47
05/08/89	14.60	7.17	190	--	--	1U	370
06/06/89	16.30	6.71	168	2.6	27.0	1U	140
07/11/89	14.30	6.94	175	1.2	11.9	1U	110
08/08/89	16.60	6.94	178	0.7	7.3	1	190
duplicate				0.9	9.4	1	84
09/19/89	11.62	6.76	179	0.9	5.9	1U	11
10/10/89	12.50	6.85	168	1.3	8.7	4	66
11/14/89	8.15	6.74	209	3.0	20.7	4	3
Runoff Events							
03/06/89	6.10	7.23	206	--	--	4	760
duplicate							700
03/22/89	7.70	--	203	--	--	1U	730
11/07/89	8.30	6.93	203	--	--	3	23

"U" or "K" Compound was analyzed for but was not detected. The associated numerical value is the sample quantitation detection limit.

"S" Spreader

Table A10. Water quality monitoring data at station P6.0 during the sample period, December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey							
12/21/88	6.73	7.29	217	8.4	69.4	3	66
01/09/89	6.46	7.20	210	8.8	72.2	3	80
01/30/89	9.50	--	216	--	--	4	120
02/13/89	5.20	7.45	208	--	--	2	92
02/27/89	7.50	--	205	--	--	2	49
03/13/89	--	6.90	190	--	--	1	70
04/10/89	13.00	7.31	220	--	--	2	130 76
05/08/89	15.10	7.60	238	--	--	1U	130
06/06/89	15.90	7.27	181	10.8	111.1	1	140
07/11/89	17.19	7.62	225	11.1	117.5	1U	66
08/08/89	15.70	7.39	229	10.3	105.5	1U	80
09/19/89	12.95	7.67	238	10.5	101.1	1U	54
duplicate				10.7	73.7	1U	69
10/10/89	11.20	7.37	222	8.5	78.5	2	130
duplicate				8.5	78.5	1	280
11/14/89	8.66	7.30	215	8.9	77.5	2	230X
Runoff Events							
03/06/89	7.30	7.44	208	--	--	2	140
03/22/89	8.80	--	210	--	--	1U	83
11/07/89	10.10	7.46	223	--	--	1	11

"U" Compound was analyzed for but was not detected. The associated numerical value is the sample quantitation detection limit.

"X" Many background organisms.

Table A11. Water quality monitoring data at station P8.1 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Turb. (NTU)	NH_3-N (mg/L)	NO_3+ NO_2-N (mg/L)	Total P (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey											
12/21/88	6.76	7.01	154	10.8	89.3	4	--	--	--	--	3
01/09/89	4.11	7.29	63	12.8	98.8	5	--	--	--	--	63
01/30/89	7.30	--	66	--	--	5	--	--	--	--	1,330
02/13/89	2.60	7.04	82	13.0	96.3	1 U	1	0.012	3.325	0.030	8,900
02/27/89	4.20	--	64	13.1	101.3	2	1	0.010	1.700	0.030	730
03/13/89	--	6.50	91	12.8	88.3	15	3	<0.010	3.370	0.050	300
04/10/89	13.00	6.95	68	--	--	1 K	1	0.010	1.200	0.060	560
05/08/89	15.30	7.63	135	9.7	98.5	1 U	1	0.020	0.880	0.060	560
06/06/89	15.10	7.13	105	9.5	96.0	1 U	--	0.020	0.760	0.070	42,000 L,J
07/11/89	16.35	7.70	145	9.1	94.6	1 U	1	0.010U	0.740	0.080	900
08/08/89	16.70	7.55	149	8.9	93.2	1 U	1	0.020	0.710	0.090	2,900
09/19/89	13.30	7.67	238	9.4	91.5	1 U	1	<0.010	0.806	0.097	700
duplicate				9.6	66.1	1 U	1	<0.010	0.805	0.098	1,000
10/10/89	12.10	7.74	--	9.7	91.4	1	1	0.010U	0.970	0.100	52,000L,J
11/14/89	7.70	6.84	68	11.7	99.1	2	1	0.010	1.670	0.030	6,000

"U" or "K" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.
"L" Total plate count greater than 200
"J" Estimated value; not accurate

Table A12. Water quality monitoring data at station F2.5 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey							
12/21/88	4.58	7.00	106	11.9	93.0	9	170
01/09/89	4.21	7.00	99	12.0	92.8	12	120
01/30/89	8.40	--	110	--	--	10	16
02/13/89	1.90	6.81	117	--	--	5	32
02/27/89	4.90	--	97	--	--	15	190
duplicate						8	210
03/13/89	--	6.30	73	--	--	17	100S
04/10/89	10.30	7.07	74	--	--	8	44
05/08/89	14.20	7.81	100	11.0	109.0	6	96
06/06/89	14.70	7.14	125	11.3	113.2	6	470
duplicate		7.20				5	470
07/11/89	15.90	7.80	142	10.8	111.1	1U	210
08/08/89	14.30	7.65	144	10.2	101.3	4	330
09/19/89	11.90	6.94	153	10.7	100.6	1U	140
10/10/89	11.20	7.47	135	9.7	89.7	8	2,500
11/14/89	8.10	6.76	120	10.6	90.6	8	360
Runoff Events							
03/06/89	3.90	6.96	84	--	--	16	49
03/22/89	6.60	--	85	--	--	6	33S
11/07/89	8.50	7.27	139	--	--	4	160
duplicate						3	190

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

"S" Spreader

Table A13. Water quality monitoring data at station F4.3 during the sample period December 21, 1988 - November 14, 1989.

Parameter	Temp. (°C)	pH (S.U.)	Cond. (umhos/cm)	D.O. (mg/L)	D.O. (% Sat.)	TSS (mg/L)	Fecal Coliform (#/100 mL)
Routine Survey							
12/21/88	5.52	7.19	102	11.7	93.7	8	20
01/09/89	4.80	7.20	95	12.2	95.9	9	6
01/30/89	8.29	6.97	103	10.8	92.9	6	22
02/13/89	3.00	7.29	75	--	--	8	14
duplicate						2	3
02/27/89	5.20	--	61	--	--	11	12
03/13/89	--	6.40	56	--	--	44	12
04/10/89	10.00	7.07	101	--	--	9	13
05/08/89	11.80	7.72	110	11.2	104.9	25	96
duplicate						1	140
06/06/89	12.90	7.06	106	10.3	99.0	4	12
07/11/89	13.50	7.69	121	10.2	99.4	1	80
08/08/89	13.30	7.71	129	10.4	100.9	4	63
09/19/89	10.72	7.48	137	10.7	97.7	1U	14
10/10/89	11.00	7.43	122	9.3	85.7	100	770
11/14/89	8.20	7.02	113	10.8	93.0	1	1U
Runoff Events							
03/06/89	4.00	7.57	70	--	--	15	3
03/22/89	6.80	--	68	--	--	4	13
11/07/89	9.00	7.25	122	--	--	1	3U

"U" Compound was analyzed for but was not detected. The associated numerical value is the sample quantitation detection limit.

Appendix B

Runoff-Event Monitoring Data

Table B1. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 20-hour period at station P1.3 on Portage Creek, March 6, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 13:00						
Interval:	1	1.78	6	0.114	1.898	0.064
	2	2.06	15	0.111	2.024	0.085
	3	2.30	23	0.142	2.003	0.094
	4	2.48	40	0.173	1.993	0.108
	5	2.58	40	0.208	2.076	0.127
	6	2.58	30	0.197	1.867	0.114
	7	2.66	19	0.149	29.344	0.101
	8	2.75	15	0.133	2.076	0.089
	9	2.94	14	0.156	2.422	0.095
	**10	3.03	11	0.171	2.412	0.096

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation

TableB2. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station FO.8 on Fish Creek, March 6, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 13:05						
Interval:	1	0.61	32	0.200	2.412	0.089
	2	0.64	60	0.223	2.412	0.116
	3	0.71	74	0.275	2.160	0.155
	4	0.95	54	0.286	2.024	0.159
	5	1.15	42	0.209	1.698	0.114
	6	1.23	27	0.156	1.835	0.096
	7	1.55	28	0.146	1.783	0.078
	8	1.61	18	0.122	1.993	0.150
	9	1.67	19	0.199	2.003	0.169
	10	2.03	18	0.102	1.993	0.139
	11	2.11	13	0.085	262.095	0.134
	**12	2.11	13	0.095	19.925	0.069

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation

Table B3. Results of nutrient and total susspended solids analysis for bi-hourly composited samples over a 24-hour period at station P1.3 on Portage Creek, March 22, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 08:00						
Interval:	1	1.63	14	0.080	4.172	0.091
	2	1.63	12	0.080	2.913	0.098
	3	1.63	14	0.097	2.642	0.093
	4	1.80	1 U	0.085	2.610	0.091
	5	1.84	16	0.106	2.809	0.094
	6	1.96	10	0.107	2.673	0.094
	7	2.01	10	0.123	2.934	0.115
	8	2.11	14	0.137	2.642	0.125
	9	2.22	14	0.163	2.579	0.120
	10	2.38	14	0.265	2.579	0.146
	11	2.53	14	0.370	2.516	0.159
	**12	2.58	4	0.390	2.590	0.145

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation

Table B4. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station P3.7 on Portage Creek, March 22, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 07:15						
Interval:	1	1.99	1 U	0.284	2.412	0.166
	2	1.99	1 U	0.332	2.673	0.178
	3	1.99	1 U	0.326	2.642	0.176
	4	1.99	1 U	0.304	2.516	0.169
	5	1.99	1 U	0.322	2.485	0.172
	6	1.99	1 U	0.418	2.621	0.199
	7	1.99	1 U	0.458	2.725	0.198
	8	1.99	6	0.558	2.621	0.232
	10	1.99	10	0.651	2.537	0.244
	11	1.99	12	0.707	2.516	0.283
	**12	1.99	6	0.718	2.809	0.304

"U" Compound was analyzed for but not detected.
* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation

Table B5. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station F0.8 on Fish Creek, March 22, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 07:40						
Interval:	1	0.44	12	0.060	6.633	0.067
	2	0.44	8	0.057	4.079	0.043
	3	0.55	12	0.094	2.359	0.048
	4	0.59	12	0.081	2.307	0.043
	5	0.59	16	0.118	2.516	0.070
	6	0.67	10	0.083	2.600	0.056
	7	0.67	8	0.076	2.412	0.062
	8	0.59	8	0.064	2.307	0.065
	9	0.62	14	0.076	2.286	0.052
	10	0.78	18	0.095	2.286	0.096
	11	0.98	18	0.116	2.307	0.088
	**12	0.95	12	0.112	3.580	0.078

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation

Table B6. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station P1.3 on Portage Creek, November 7, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 11:20						
Interval:	1	7.05	1	0.081	2.280	0.064
	2	8.26	2	0.043	1.680	0.085
	3	7.83	9	0.034	1.200	0.069
	4	8.81	16	<0.005	0.625	0.044
	5	DATALOGGER	60	<0.005	0.438	0.052
	6	FAILURE	48	0.008	0.309	0.066
	7	•	57	<0.005	0.277	0.073
	8	•	55	0.018	0.277	0.073
	9	•	36	0.015	0.336	0.066
	***10	•	18	0.024/0.028	0.143/0.145	0.057/0.055
	11	•	8	0.036	1.070	0.068
	**12	•	7	0.028	1.190	0.082

* estimate from flow-rating curve (flow information limited due to equipment failure)
**sample chosen for use in monitoring design evaluation
***split samples derived from this time interval

Table B7. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station P3.7 on Portage Creek, November 7, 1989.

PARAMETER		FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 12:07						
Interval:	1	0.70	7	0.025	1.830	0.112
	2	0.70	3	0.020	1.600	0.121
	3	0.70	3	0.026	1.500	0.130
	4	0.70	4	0.025	1.540	0.139
	5	0.70	5	0.032	1.490	0.148
	6	0.70	10	0.077	1.460	0.135
	7	0.70	7	0.146	1.560	0.133
	***8	0.70	7	0.156/0.166	1.540/1.540	0.120/0.123
	9	0.70	5	0.038	2.160	0.120
	10	0.70	4	0.033	1.620	0.124
	11	0.70	6	0.038	1.670	0.123
	**12	0.70	7	0.036	1.680	0.126

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation
***split samples derived from this time interval

Table B8. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station P7.1 on Portage Creek, November 7, 1989.

PARAMETER	FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 13:49					
Interval: 1	0.59	5	0.066	2.400	0.126
2	1.02	3	0.056	2.190	0.116
3	1.34	2	0.075	2.160	0.122
4	1.49	4	0.096	2.150	0.126
5	1.87	5	0.123	1.720	0.129
***6	1.60	4	0.131/0.130	1.990/1.940	0.119/0.119
7	1.29	4	0.116	2.410	0.116
8	1.01	5	0.096	2.140	0.107
9	0.97	1	0.091	2.270	0.105
10	1.06	1	0.084	2.100	0.105
11	1.06	2	0.073	2.020	0.098
**12	0.97	2	0.063	2.170	0.096

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation
***split samples derived from this time interval

Table B9. Results of nutrient and total suspended solids analysis for bi-hourly composited samples over a 24-hour period at station F0.8 on Fish Creek, November 7, 1989.

PARAMETER	FLOW* (m^3/S)	TSS (mg/L)	NH_3-N (mg/L)	NO_3+NO_2-N (mg/L)	TOTAL P (mg/L)
Start Time 12:48					
Interval: 1	0.08	4	0.046	1.530	0.076
2	0.09	1	0.044	1.410	0.055
3	0.10	4	0.046	1.300	0.048
***4	0.12	3	0.060/0.066	1.660	0.041/0.041
***5	0.13	5	0.059	1.300/1.300	0.051
6	0.13	3	0.053	1.460	0.048
7	0.13	4	0.049	1.280	0.044
8	0.13	4	0.055	1.240	0.039
9	0.12	2	0.048	1.280	0.036
10	0.11	2	0.061	1.220	0.033
11	0.11	3	0.046	1.250	0.035
**12	0.10	2	0.074/0.071	1.150/1.150	0.034

* estimate from flow-rating curve
**sample chosen for use in monitoring design evaluation
***split samples derived from these time intervals

Appendix C

Sediment Analysis

Table C1. Physical attributes of the sediment analysis at select stations on Portage Creek, August 8, 1989.

	P1.3	P3.7	P7.1	F0.8
Grain Size				
% Gravel (2000-4000 um)	16.40	0.28	25.80	34.10
% Very Coarse Sand (1000-2000 um)	1.55	0.00	29.70	10.77
% Coarse Sand (500-1000 um)	4.83	0.84	9.78	23.20
% Medium Sand (250-500 um)	8.45	6.69	20.70	21.10
% Fine Sand (125-250 um)	22.30	14.80	6.62	10.20
% Very Fine Sand (63-125 um)	12.80	23.90	3.57	1.37
% Silt/Clay (<63 um)	33.80	53.40	3.84	-0.62
% Total Solids	19.65	19.40	62.50	78.20
Total Organic Carbon (mg/g)	27.00	47.30	6.69	2.58

Table C2. Results of BNA pollutant scan of sediment samples from three Portage Creek stations and one Fish Creek station, August 8, 1989.

	Station	P1.3	P3.7	P7.1	F0.8
	Lab Log #	348050	348051	348052	348053
	Contract #	3524A	3524B	3524C	3524D
	BNA Compounds				
ppb	Phenol	200 U	430 U	140 U	150 U
ppb	Bis(2-Chloroethyl)Ether	100 U	210 U	71 U	75 U
ppb	2-Chlorophenol	100 U	210 U	71 U	75 U
ppb	1,3-Dichlorobenzene	100 U	210 U	71 U	75 U
ppb	1,4-Dichlorobenzene	100 U	210 U	71 U	75 U
non	Benzyl Alcohol	510 U	1100 U	360 U	370 U
ppb	1,2-Dichlorobenzene	100 U	210 U	71 U	75 U
non	2-Methylphenol	100 U	210 U	71 U	75 U
ppb	Bis(2-chloroisopropyl)ether	100 U	210 U	71 U	75 U
non	4-Methylphenol	100 U	210 U	71 U	75 U
ppb	N-Nitroso-Di-n-Propylamine	100 U	210 U	71 U	75 U
ppb	Hexachloroethane	200 U	430 U	140 U	150 U
ppb	Nitrobenzene	100 U	210 U	71 U	75 U
ppb	Isophorone	100 U	210 U	71 U	75 U
ppb	2-Nitrophenol	510 U	1100 U	360 U	370 U
ppb	2,4-Dimethylphenol	200 U	430 U	140 U	150 U
non	Benzoic Acid	1010 U	2100 U	710 U	750 U
ppb	Bis(2-Chloroethoxy)Methane	100 U	210 U	71 U	75 U
ppb	2,4-Dichlorophenol	300 U	640 U	210 U	220 U
ppb	1,2,4-Trichlorobenzene	100 U	210 U	71 U	75 U
ppb	Naphthalene	100 U	210 U	71 U	75 U
non	4-Chloroaniline	300 U	640 U	210 U	220 U
ppb	Hexachlorobutadiene	200 U	430 U	140 U	150 U
ppb	4-Chloro-3-Methylphenol	200 U	430 U	140 U	150 U
non	2-Methylnaphthalene	100 U	210 U	71 U	75 U
ppb	Hexachlorocyclopentadiene	510 U	1100 U	360 U	370 U
ppb	2,4,6-Trichlorophenol	510 U	1100 U	360 U	370 U
non	2,4,5-Trichlorophenol	510 U	1100 U	360 U	370 U
ppb	2-Chloronaphthalene	100 U	210 U	71 U	75 U
non	2-Nitroaniline	510 U	1100 U	360 U	370 U
ppb	Dimethyl Phthalate	100 U	210 U	71 U	75 U
ppb	Acenaphthylene	100 U	210 U	71 U	75 U
non	3-Nitroaniline	510 U	1100 U	360 U	370 U
ppb	Acenaphthene	100 U	210 U	71 U	75 U
ppb	2,4-Dinitrophenol	1010 U	2100 U	710 U	750 U
ppb	4-Nitrophenol	510 U	1100 U	360 U	370 U
non	Dibenzofuran	100 U	210 U	71 U	75 U
ppb	2,4-Dinitrotoluene	510 U	1100 U	360 U	370 U
ppb	2,6-Dinitrotoluene	510 U	1100 U	360 U	370 U
ppb	Diethyl Phthalate	100 U	210 U	71 U	75 U
ppb	4-Chlorophenyl-Phenylether	100 U	210 U	71 U	75 U
ppb	Fluorene	100 U	210 U	71 U	75 U
non	4-Nitroaniline	510 U	1100 U	360 U	370 U
ppb	4,6-Dinitro-2-Methylphenol	1010 U	2100 U	710 U	750 U
ppb	N-Nitrosodiphenylamine	100 U	210 U	71 U	75 U
ppb	4-Bromophenyl-Phenylether	100 U	210 U	71 U	75 U
ppb	Hexachlorobenzene	100 U	210 U	71 U	75 U
ppb	Pentachlorophenol	510 U	1100 U	360 U	370 U
ppb	Phenanthrene	100 U	210 U	71 U	75 U
ppb	Anthracene	100 U	210 U	71 U	75 U
ppb	Di-n-Butyl Phthalate	100 U	210 U	71 U	75 U
ppb	Fluoranthene	100 U	210 U	71 U	75 U
ppb	Pyrene	100 U	210 U	71 U	75 U
ppb	Butylbenxylphthalate	100 U	210 U	71 U	75 U
ppb	3,3'-Dichlorobenzidine	510 U	1100 U	360 U	370 U
ppb	Benzo(a)Anthracene	100 U	210 U	71 U	75 U
ppb	Chrysene	100 U	210 U	71 U	75 U
ppb	Bis(2-Ethylhexyl)phthalate	100 U	210 U	71 U	75 U
ppb	Di-n-Octyl Phthalate	100 U	210 U	71 U	75 U
ppb	Benzo(b)Fluoranthene	100 U	210 U	71 U	75 U
ppb	Benzo(k)Fluoranthene	100 U	210 U	71 U	75 U

Table C2 (Continued). Results of BNA pollutant scan of sediment samples from three Portage Creek stations and one Fish Creek station, August 8, 1989.

	Station	P1.3	P3.7	P7.1	F0.8
	Lab Log #	348050	348051	348052	348053
	Contract #	3524A	3524B	3524C	3524D
ppb	Benzo(a)Pyrene	100 U	210 U	71 U	75 U
ppb	Indeno(1,2,3-cd)Pyrene	100 U	210 U	71 U	75 U
ppb	Dibenzo(a,h)Anthracene	100 U	210 U	71 U	75 U
ppb	Benzo(g,h,i)Perylene	100 U	210 U	71 U	75 U

Data Qualifiers:

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

"ppb" concentration in parts per billion (ug/kg)

"non" non-priority pollutant

Table C3. Results of Pesticide/Herbicide pollutant scan of sediment samples from three Portage Creek stations and one Fish Creek station, August 8, 1989.

	Station	P1.3	P3.7	P7.1	F0.8
	Lab Log #	348050	348051	348052	348053
	Contract #	3524A	3524B	3524C	3524D
	Pesticide/PCB Compounds				
ppb	gamma-BHC (Lindane)	3 U	7 U	3 U	2 U
ppb	Aldrin	3 U	7 U	3 U	2 U
ppb	alpha-BHC	3 U	7 U	3 U	2 U
ppb	beta-BHC	3 U	7 U	3 U	2 U
ppb	delta-BHC	3 U	7 U	3 U	2 U
ppb	Heptachlor Epoxide	3 U	7 U	3 U	2 U
ppb	alpha-Endosulfan	3 U	7 U	3 U	2 U
ppb	Dieldrin	3 U	7 U	3 U	2 U
ppb	4,4'-DDD	3 U	7 U	3 U	2 U
ppb	4,4'-DDE	3 U	7 U	3 U	2 U
ppb	Heptachlor	3 U	7 U	3 U	2 U
ppb	Endrin	3 U	7 U	3 U	2 U
ppb	beta-Endosulfan	3 U	7 U	3 U	2 U
ppb	Endosulfan Sulfate	3 U	7 U	3 U	2 U
ppb	4,4'-DDT	3 U	7 U	3 U	2 U
ppb	Methoxychlor	10 U	20 U	10 U	5 U
ppb	Chlordane	3 U	7 U	3 U	2 U
ppb	Toxaphene	90 U	210 U	90 U	60 U
ppb	Aroclor-1016	30 U	70 U	30 U	20 U
ppb	Aroclor-1221	30 U	70 U	30 U	20 U
ppb	Aroclor-1232	30 U	70 U	30 U	20 U
ppb	Aroclor-1242	30 U	70 U	30 U	20 U
ppb	Aroclor-1248	30 U	70 U	30 U	20 U
ppb	Aroclor-1254	30 U	70 U	30 U	20 U
ppb	Aroclor-1260	30 U	70 U	30 U	20 U
ppb	Endrin Aldehyde	3 U	7 U	3 U	2 U
	Herbicide Compounds				
ppb	Pentachlorophenol	40 U	40 U	20 U	15 U
ppb	Dinoseb	100 U	160 U	50 U	50 U
ppb	MCPP	1000 U	1600 U	1000 U	1000 U
ppb	2,4,5-TP(Silvex)	50 U	80 U	25 U	25 U
ppb	2,4,5-T	50 U	80 U	25 U	25 U
ppb	2,4,5-TB	100 U	320 U	100 U	100 U
ppb	MCPA	1000 U	1600 U	1000 U	1000 U
ppb	2,4-D	70 U	160 U	50 U	50 U
ppb	MCPB	1000 U	1600 U	1000 U	1000 U
ppb	2,4-DB	140 U	320 U	100 U	100 U
ppb	Ioxynil	100 U	160 U	50 U	50 U
ppb	Bromoxynil	100 U	160 U	50 U	50 U
ppb	Dicamba	50 U	80 U	25 U	25 U
ppb	Picloram	100 U	160 U	50 U	50 U
ppb	2,3,4,5-Tetrachlorophe+	40 U	40 U	20 U	15 U

Data Qualifiers:

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

"ppb" concentration in parts per billion (ug/kg)

"non" non-priority pollutant

Table C4. Results of a priority pollutant metal scan of sediment samples from three Portage Creek stations and one Fish Creek station, August 8, 1989.

	Station	P1.3	P3.7	P7.1	F0.8
	Lab Log #	348050	348051	348052	348053
	Contract #	3524A	3524B	3524C	3524D
	Priority pollutant metals				
ppm	Antimony	0.20 U	0.46 U	0.18 U	0.11 U
ppm	Arsenic	11.60	24.00	11.00	5.00
ppm	Beryllium	0.27	0.47	0.31	0.12
ppm	Cadmium	0.39 U	1.12	0.36 U	0.22 U
ppm	Chromium	72.40	122.00	40.90	50.80
ppm	Copper	25.30	34.20	16.90	4.30
ppm	Lead	9.10	23.30	10.70	4.00
ppm	Mercury	0.08	0.19 U	0.06 U	0.07 U
ppm	Nickel	74.00	91.40	54.90	24.00
ppm	Selenium	1.00 U	2.30 U	0.90 U	0.50 U
ppm	Silver	0.59 U	1.40 U	0.54 U	0.32 U
ppm	Thallium	0.20 U	0.47 U	0.18 U	0.11 U
ppm	Zinc	67.50	109.00	69.80	39.60

Priority pollutants not on the list:
Asbestos
Cyanide
2-Chloroethylvinylether
Dimethylnitrosamine
Acrylonitrile
Acrolein
TCDD (or Dioxin)

Data Qualifiers:

"U" Compound was analyzed for but not detected. The associated numerical value is the sample quantitation detection limit.

"ppm" concentration in parts per million (mg/kg)

Appendix D

Macroinvertebrate Abundance Tables

Table D1. Abundance of benthic macroinvertebrates in replicate samples at station P1.3 on Portage Creek using the modified Chandler Biotic Scores, 6 July 1989.

Taxon ID	Rep 1	Rep 2	Rep 3	Trophic Status
Megaloptera				
Sialidae				
Sialis sp.	P	--	--	Predator
Coleoptera				
Dytiscidae (larvae)	P	P	P	Predator
Elmidae				
Optioservus sp.	P	F	P	Collector-Gatherer Scraper
Ampumixis sp. (Adult)	P	--	--	Collector-Gatherer Scraper
Ephemeroptera				
Leptophlebiidae				
Leptophlebia sp.	V	C	F	Collector-Gatherer
Baetidae				
Baetis sp.	C	F	C	Collector-Gatherer
Trichoptera				
Brachycentridae				
Amiocentrus sp.	--	P	--	Collector-Gatherer
Plecoptera				
Chloroperlidae				
Paraperla sp.	P	--	--	Collector-Gatherer Scraper
Nemouridae				
Amphinemura sp.	F	P	P	Collector-Gatherer Shredder
Oligochaeta				
Naididae	V	V	V	Collector-Filterer
Lumbriculidae	P	F	--	Collector-Filterer
Diptera				
Chironomidae (Larvae)	V	V	V	Collector-Gatherer
Chironomidae (Pupae)	P	P	P	
Simuliidae				
Simulium venustum	F	P	A	Collector-Filterer
Tipulidae				
Dicranota sp.	--	--	P	Predator
Hirudinea	P	P	P	Predator
Amphipoda				
Talitridae				
Hyallela azteca	F	C	F	Collector-Gatherer
Chandler Biotic Score		770		

Abundance Rating:

P=present (1-5 organisms)
F=few (6-10 organisms)
C=common (11-25 organisms)
A=abundant (26-50 organisms)
V=very abundant (>50 organisms)

Table D2. Abundance of benthic macroinvertebrates in replicate samples at station P3.7 on Portage Creek using the modified Chandler Biotic Scores, 6 July 1989.

Taxon ID	Rep 1	Rep 2	Rep 3	Trophic Status
Diptera				
Chironomidae (Larvae)	P	P	P	Collector-Gatherer
Gastropoda				
Planorbidae				
Gyraulus sp.	P	--	--	Scraper
Pelecypoda				
Sphaeriidae				
Pisidium sp.	P	P	--	Collector-Filterer
Chandler Biotic Score		81		

note: Hyallela azteca was observed on benthos at this sample site, but was not successfully collected by the Eckman Grab.

Abundance Rating:

P=present (1-5 organisms)
F=few (6-10 organisms)
C=common (11-25 organisms)
A=abundant (26-50 organisms)
V=very abundant (>50 organisms)

Table D3. Abundance of benthic macroinvertebrates in replicate samples at station P7.1 on Portage Creek using the modified Chandler Biotic Scores, 6 July 1989.

Taxon ID	Rep 1	Rep 2	Rep 3	Trophic Status
Coleoptera				
Dytiscidae (larvae)	--	--	P	Predator
Elmidae				
Optioservus sp.	C	C	A	Collector-Gatherer Scraper
Ampumixis sp. (Adult)	P	P	--	Collector-Gatherer
Ephemeroptera				
Leptophlebiidae				
Leptophlebia sp.	P	F	F	Collector-Gatherer
Baetidae				
Baetis sp.	C	C	C	Collector-Gatherer
Trichoptera				
Brachycentridae				
Amiocentrus sp.	P	--	--	Collector-Gatherer
Micrasema sp.	P	--	P	Shredder
Hydroptilidae				
Ochrotrichia sp.	P	P	--	Collector-Gatherer
Limnephilidae				
Neophylax sp.	P	P	--	Scraper
Glossosomatidae				
Glossosoma sp.	--	P	--	Scraper
Polycentropodidae				
Polycentropus sp.	--	P	--	Predator
Rhyacophilidae				
Rhyacophila sp.	--	--	P	Predator
Plecoptera				
Perlodidae				
Cascadoperla sp.	C	P	--	Predator
Skwala sp.	--	F	F	Predator
Nemouridae				
Amphinemura sp.	P	F	--	Collector-Gatherer Scraper
Oligochaeta				
Naididae	A	C	C	Collector-Filterer
Lumbriculidae	F	A	P	Collector-Filterer
Diptera				
Chironomidae (Larvae)	V	C	C	Collector Gatherer
Chironomidae (Pupae)	P	P	--	
Tipulidae				
Dicranota sp.	P	P	P	Predator
Hirudinea	P	--	--	Predator
Amphipoda				
Talitridae Hyallela azteca	F	F	F	Collector-Gatherer

Table D3 (Cont.). Abundance of benthic macroinvertebrates in replicate samples at station P7.1 on Portage Creek using the modified Chandler Biotic Scores, 6 July 1989.

Taxon ID	Rep 1	Rep 2	Rep 3	Trophic Status
Gastropoda				
Planorbidae				
Gyraulus sp.	A	A	F	Scraper
Odonata				
Zygoptera	--	--	P	Predator
Decapoda				
Astacidae				
Pacifasticus sp.	--	--	P	Predator
Ostracoda	--	--	P	Collector-Filterer
Chandler Biotic Score		1268		

Abundance Rating:

P=present (1-5 organisms)
F=few (6-10 organisms)
C=common (11-25 organisms)
A=abundant (26-50 organisms)
V=very abundant (>50 organisms)

Table D4. Abundance of benthic macroinvertebrates in replicate samples at station F0.8 on Portage Creek using the modified Chandler Biotic Scores, 6 July 1989.

Taxon ID	Rep 1	Rep 2	Rep 3	Trophic Status
Coleoptera				
Elmidae				
Optioservus sp.	P	F	P	Collector-Gatherer Scraper
Ampumixis sp. (Larvae)	P	--	--	Collector-Gatherer Scraper
Ampumixis sp. (Adult)	P	--	--	Collector-Gatherer Scraper
Ephemeroptera				
Ephemerellidae				
Serratella sp.	C	C	C	Collector-Gatherer
Baetidae				
Baetis sp.	C	A	V	Collector-Gatherer
Trichoptera				
Glossosomatidae				
Glossosoma sp.	F	C	C	Scraper
Glossosoma (Pupae)	--	P	P	
Hydropsychidae				
Hydropsyche betteni	F	C	C	Collector-Filterer
Rhyacophilidae				
Rhyacophila sp.	P	P	P	Predator
Plecoptera				
Perlodidae				
Cascadoperla sp.	F	F	F	Predator
Nemouridae				
Amphinemura sp.	P	--	--	Collector-Gatherer Shredder
Oligochaeta				
Naididae	P	P	P	Collector-Filterer
Lumbriculidae	P	P	--	Collector-Filterer
Diptera				
Chironomidae (Larvae)	F	P	C	Collector-Gatherer
Simuliidae				
Simulium venustum	P	P	C	Collector-Filterer
Pelecypoda				
Margaratiferidae				
Margaratifera falcata	--	P	--	Collector-Filterer
Chandler Biotic Score		742		

Abundance Rating:

P=present (1-5 organisms)
F=few (6-10 organisms)
C=common (11-25 organisms)
A=abundant (26-50 organisms)
V=very abundant (>50 organisms)