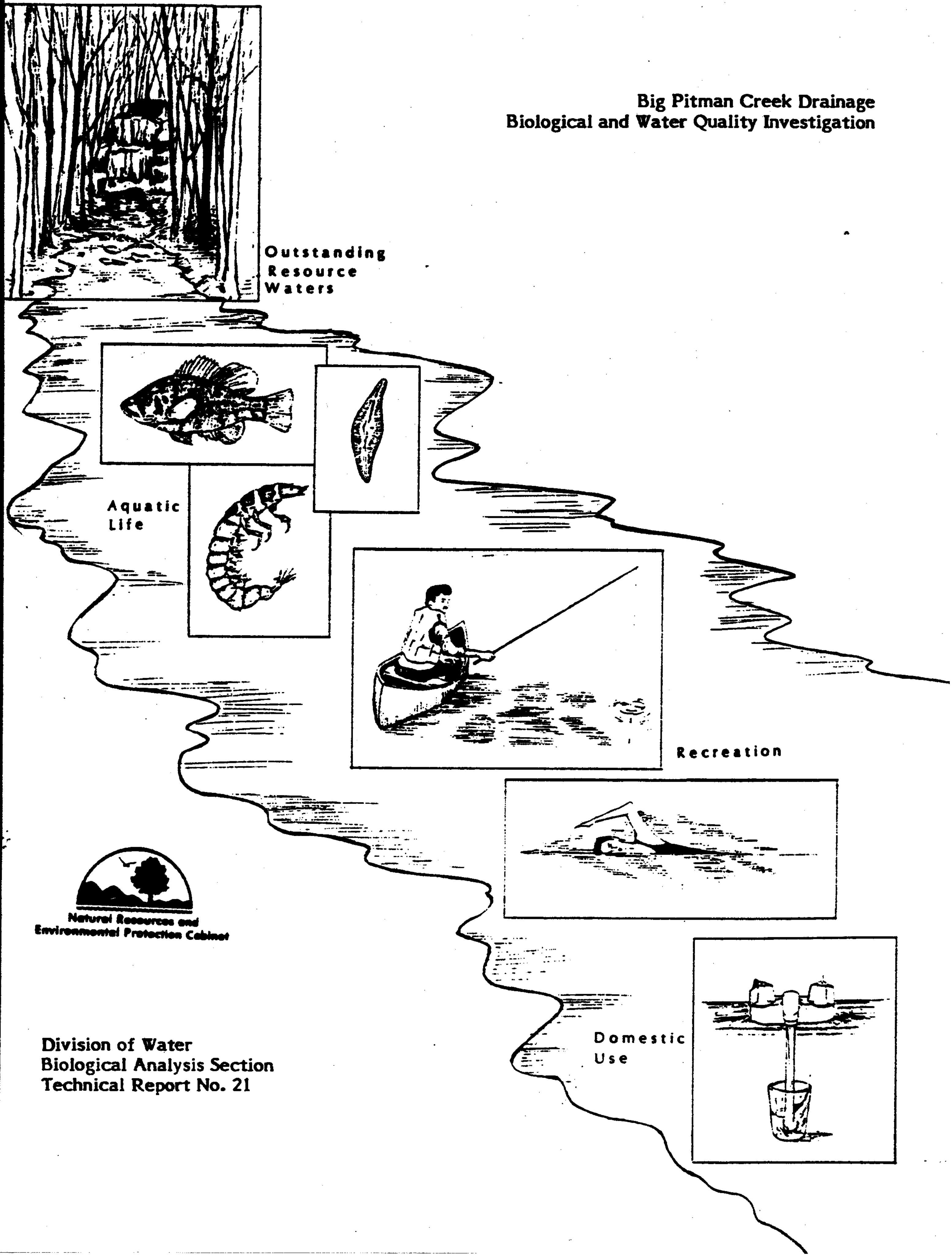
Big Pitman Creek Drainage
Biological and Water Quality Investigation



Natural Resources and Environmental Protection Cabinet

Division of Water
Biological Analysis Section
Technical Report No. 21

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Biological and Water Quality Investigation

Kentucky Department for Environmental Protection
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Frankfort, Kentucky

This report has been approved for release:

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Abstract

A biological and physicochemical survey of the Big Pitman Creek subbasin was conducted during 1984 to determine the existing water quality and the impacts of the Campbellsville Wastewater Treatment Plant discharge on Little Pitman Creek. It was determined that the color in the effluent was adversely impacting the biological communities and the recreational potential of Little Pitman Creek in the reach (10 mi) below the WWTP.

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Recommendations

1. The amount of chlorination utilized by the Campbellsville Wastewater Treatment Plant (WWTP) should be restricted to that amount which ensures disinfection and compliance with permit requirements only. Alternative means of disinfection might also be evaluated.

2. Color discharged to Little Pitman Creek should not allow ambient color levels to be exceeded. Color in excess of these levels may adversely impact the aquatic biota or impair primary and secondary contact recreational uses.

3. Measures (i.e. additional treatment or source reduction) should be employed to reduce the concentrations of color, conductivity, total dissolved solids, chloride and sodium discharged to Little Pitman Creek.

4. Based on the diversity of the aquatic biota and habitat, it is recommended that the Big Pitman Creek subbasin (segment 03024) be designated for Aquatic Life/Warmwater Aquatic Habitat per 401 KAR 5:031, Section 5 (1) and that the criteria of that section be applied throughout the segment without modification.

5. Based on the fecal coliform and pH data, it is further recommended that the segment be designated for Primary and Secondary Contact Recreation per 401 KAR 5:031, Section 7 and that the criteria of that section be applied throughout the segment without modification.

6. It is recommended that the Campbellsville Reservoir be designated for Domestic Water Supply per 401 KAR 5:031, Section 6 at the point of supply and that the criteria of that section be applied in addition to the above criteria without modification.

7. It is also recommended that chronic toxicity testing be conducted on the Campbellsville WWTP effluent.

Summary

1. During the February, early July and September sampling periods, Little Pitman Creek was impacted by dyes emanating from the Union Underwear indirect discharge to the Campbellsville Wastewater Treatment Plant (WWTP). This discharge caused the creek to turn various colors from maroon to black.
2. There was at least a three-fold increase in color concentration at the impacted sites in Little Pitman below the WWTP when compared to the upstream control station during the February, early July and September sampling period. During the mid-July sampling period, when the Union Underwear indirect discharge was absent from Little Pitman Creek, the color levels at all sites were similar.
3. True color of natural waters is derived from substances in solution and/or colloidal suspension. In addition, suspended colloidal inorganic substances may account for certain colors; the dyes originating from the Union Underwear industrial discharges fall into this latter category. The stream colors observed below the WWTP were not colors which naturally occur in the aquatic environment.
4. The high color concentrations observed in Little Pitman Creek appears to have a direct negative effect on benthic algae, due to reduced light penetration and/or toxicity, and an indirect, and possibly direct toxic effect, on the macroinvertebrate and fish faunas. Ten miles of Little Pitman Creek and at least 2.6 miles of Big Pitman Creek below the confluence with Little Pitman have been adversely impacted by the high color concentrations present in these streams.
5. The color present in Little Pitman Creek poses a recreational hazard because of limited visibility into the water; for example, the depth of the stream cannot be determined and snags, submerged logs, and boulders may go

unnoticed. The color, therefore, limits the ability of users to estimate depth and see subsurface hazards easily and clearly.

6. The color present in Little and Big Pitman creeks, coming from the Campbellsville WWTP, is a violation of Kentucky Surface Water Standard 401 KAR 5:031, Section 3 (3).

7. Parameter values for conductivity, total dissolved solids, chloride, chemical oxygen demand, total organic carbon and sodium were elevated in Little Pitman Creek below the WWTP during the February, early July and September sampling periods, but were similar to unimpacted areas during the mid-July sampling period when the Union Underwear indirect discharge was absent from the creek.

8. In an attempt to decolor and disinfect the effluent, operators of the Campbellsville WWTP were employing the use of excessive chlorination from February through mid June. This severely impacted the aquatic flora and fauna in Little Pitman Creek below the WWTP. After cessation of this chlorination practice on June 20, 1984, a limited aquatic flora and fauna recolonized previously impacted areas of Little Pitman Creek, but not to levels seen in control sampling locations.

9. Nutrient values for nitrite + nitrate - nitrogen and total phosphorous were elevated, during some sampling periods, in Little Pitman Creek below the Campbellsville WWTP.

10. Kentucky Surface Water Standards, 401 KAR 5:031, Section 5 (h) (3) for free cyanide, undissociated hydrogen sulfide and phenols were occasionally exceeded.

11. United States Environmental Protection Agency (U. S. EPA) water quality criteria for copper, mercury and zinc were occasionally exceeded.

12. Sediment analysis revealed the presence of two organic pollutants (pentachlorophenol and 2,4,4,5 tetrachlorophenol). Metals analyses indicate

that sediments are moderately polluted with arsenic (As), manganese (Mn) and chromium (Cr) at one or more sites and heavily polluted with Mn at several sites.

13. Bacteriological data indicate that the Campbellsville WWTP meets its NPDES permit requirements for fecal coliform. Kentucky Surface Water Standards for fecal coliform bacteria were exceeded at one or more stations during all sampling periods in Little Pitman Creek. The source of fecal pollution is most likely due to non-point sources. In addition, Big Pitman and Middle Pitman creeks are capable of meeting KSWS primary and secondary contact recreation requirements.

14. Algae data collected in February indicated that excessive chlorination practices employed by the Campbellsville WWTP severely reduced periphyton abundance in Little Pitman Creek. Data collected during July, when the Union Underwear plant was closed for vacation, revealed abundant periphyton growth in Little Pitman Creek due to high nutrient concentrations attributable to the WWTP effluent. Periphyton values in September, when the Union Underwear plant was in operation, were significantly lower than observed in July, suggesting toxic effects. The color observed in Little Pitman Creek below the WWTP dramatically reduced benthic algal production.

15. The macroinvertebrate fauna of Little Pitman Creek was impacted by the effluent of the Campbellsville WWTP. Data from the February sample indicated that excessive chlorination practices severely impacted the macroinvertebrate fauna of Little Pitman Creek. The elimination of excessive chlorination allowed for some reestablishment of the macroinvertebrate community in Little Pitman Creek. The color from the Union Underwear indirect discharge inhibited light penetration, resulting in reduced benthic algae growth, which resulted in the virtual elimination of the scraper-grazer functional feeding group of macroinvertebrates. Under natural conditions, this

group is a major component of most stream macroinvertebrate communities. The macroinvertebrate species diversity and equitability values in Little Pitman Creek below the WWTP were indicative of impacted streams, while the remainder of the Big Pitman Creek drainage exhibited values characteristic of unimpacted streams.

16. The Big Pitman Creek drainage supports a speciose and viable fish fauna, except for Little Pitman Creek below the WWTP. This area showed the classical effects of stream pollution from wastewater. In addition, this portion of Little Pitman Creek had an obvious reduction in the numbers of darters and intolerant species. The reduction was attributed to both reduction of food organisms and possible toxic effects.

17. Toxic screening tests of the Campbellsville WWTP effluent in February showed that the effluent was acutely toxic to fathead minnows and water fleas. This was attributed to excessive chlorination. Tests conducted in July on the WWTP effluent indicated that no acute toxicity occurred to fathead minnows in 24 hours at any level of concentration. The chronic effects of the effluent on aquatic life were not tested and are therefore unknown.

Acknowledgements

The Biological Analysis Section would like to extend our appreciation to Bill Eddins and Hugh Glasscock (DOW) for aiding in sample collection and the Organic and Inorganic Branches of the Division of Environmental Services for analyzing the physicochemical and sediment samples. We would also like to extend our appreciation to Sam Garrison and other members of the Campbellsville Wastewater Treatment Plant for their cooperation during this study.

INTRODUCTION

Instream impacts on water quality can be difficult to assess, particularly when dealing with complex effluents such as industrial discharges to Municipal Wastewater Treatment Plants (WWTP). These impacts can manifest themselves in various degrees and may be obvious or subtle. Obvious impacts, such as fish kills or the absence of benthic aquatic life, may be more easily explained by the magnitude of a pollution problem, which can be measured in pounds of BOD, dissolved oxygen concentrations or parts per billion of priority pollutants. In general, subtle impacts, such as alterations in species composition, trophic feeding groups or benthic periphyton communities, are not easily explained and require sophisticated measurement techniques, but they may be just as important as the obvious impacts to the aquatic community.

In a study such as this, it is easy to become involved in the technical expertise required to determine the impacts and to resolve the problem. However, general criteria, such as color and aesthetic appearance of streams, are a focal point of the public and are a major concern to those members of the public who wish to use the water body. Aesthetics is classically defined as the branch of philosophy that provides a theory of the beautiful (CWQC 1972). Aesthetically pleasing waters are those that people enjoy using, and are only pleasing if they are virtually free from materials that cause color, odors, turbidity, floating scums or oils, and objectional deposits. Of these aesthetically displeasing impacts, color is often considered most important in the public eye. The aesthetic appearance of a stream will have a direct bearing on its uses. For instance, it is doubtful that anyone would want to catch fish, swim, canoe, irrigate, water livestock, etc. from a stream which is maroon in color.

Because of the impacts, including aesthetic degradation, occurring to the Big Pitman Creek system, a biological and physicochemical water quality survey was undertaken by the Department for Environmental Protection, Division of Water (DOW), Biological Analysis Section from February through September 1984. The purposes of the study were as follows:

1. To determine existing water quality of the Big Pitman Creek system.
2. To determine the impact that the Campbellsville wastewater treatment plant (WWTP) is having on physical, chemical and biological characteristics of Little Pitman Creek system.
3. To determine the impacts of color on the biological communities of Little Pitman Creek.

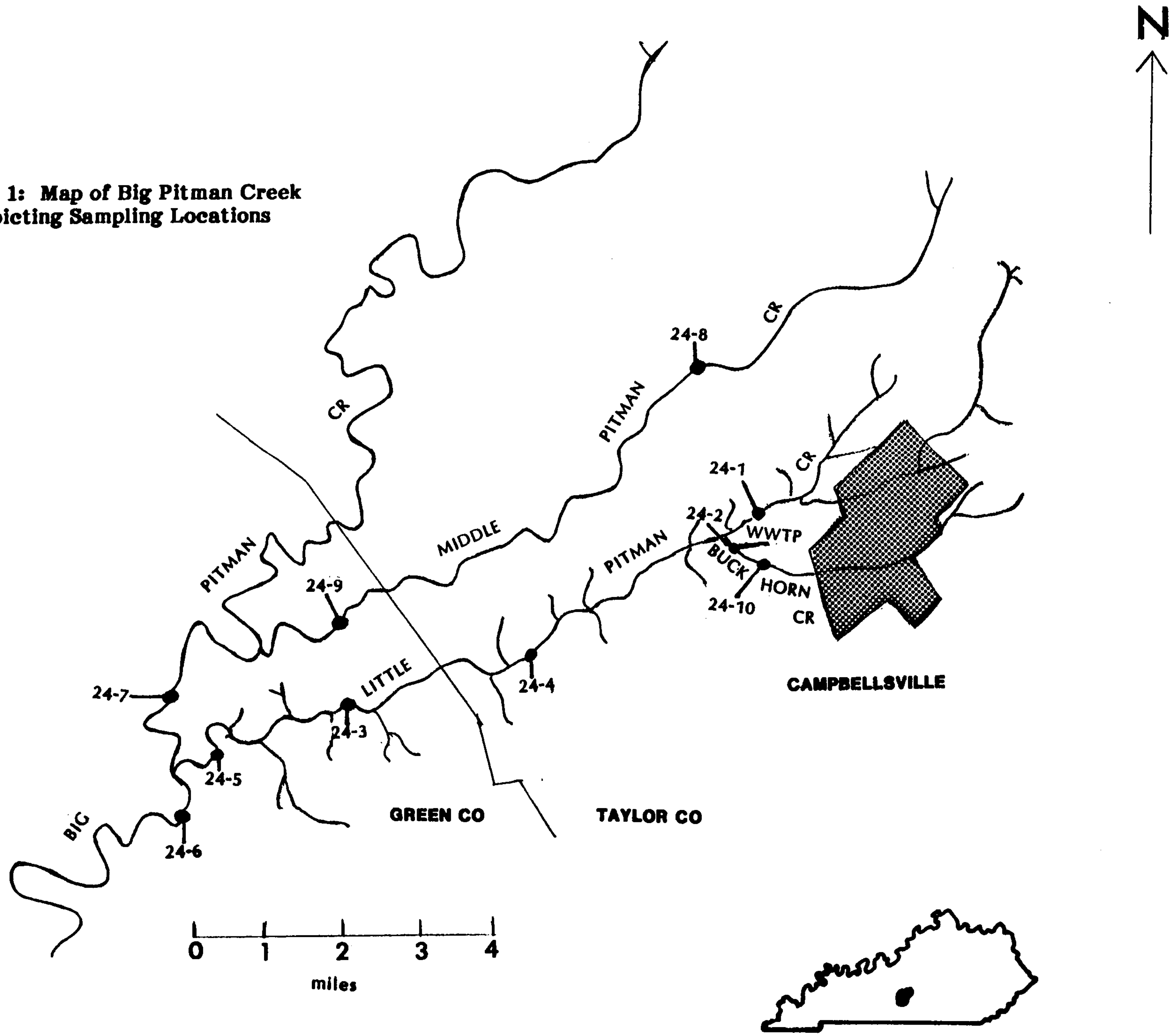
Big Pitman Creek rises in Taylor County north of Campbellsville, Kentucky and flows in a southwesterly direction to join the Green River in west-central Green County. Major tributaries include Middle Pitman and Little Pitman Creeks. The Big Pitman Creek basin lies within 303e segment 03 (Green River) 024.

Ten sampling stations were established in the Pitman Creek basin (Figure 1). Station 24-2 was located at the outfall of the Campbellsville WWTP at mile point (MP) 0.01 on Buck Horn Creek. Two sampling stations were located on Big Pitman, two on Middle Pitman, while the remaining five were located in the Little Pitman system.

Literature Review

A limited amount of published material exists on the Big Pitman Creek drainage. Studies of the ground and surface waters polluted by oil well brines were conducted by Krieger and Hendrickson (1960), Hopkins (1963) and Charles (1964). Fish data is reported by Woolman (1892), Charles (1964), Axon (1981) and Division of Environmental Services (DES) (1984). Published aquatic macroinvertebrate data is presented by Charles (1964) and DES (1984). The effects of the Campbellsville Wastewater Treatment Plant (WWTP) on the flora (algae) and fauna (fish and macroinvertebrates) of Little Pitman Creek were studied by DES (1984). DOW (1984) assessed the trophic status of the Campbellsville city lake.

Figure 1: Map of Big Pitman Creek Depicting Sampling Locations



Basin Impacts

The Big Pitman Creek subbasin is impacted primarily by domestic wastewater and agricultural nonpoint runoff. Table 1 lists permitted discharges to the subbasin. The Campbellsville WWTP is the major discharger of domestic wastewater in the drainage. The city of Campbellsville (pop 8,663) completed construction and began operation of the 4.2 million gallons per day (MGD) design flow WWTP (carrousel type facility) in June 1979 (DES 1984). A lesser impact in the drainage is nonpoint urban and agricultural runoff.

Table 1: Permitted Discharges to the Big Pitman Creek Subbasin

Facility #	Facility Name	Design Flow GD	Receiving Stream
03024005	Campbellsville, city of -WWTP	4,200,000	Buck Horn Creek
03024271	Summerville Elem. School	5,000	U.T. Big Pitman
03024273	Arrowhead Mobile Manor -WWTP	10,000	U.T. Little Pitman
03024274	Medco Corp -WWTP	12,000	Buck Horn Creek
03024279	Tennessee Gas Pipeline Co. Station #96	-	

During the late 1950's and early 1960's, the Greensburg oil field was developed in the headwaters of the Big Pitman Creek drainage. During this time, brine discharges severely impacted the stream system, as well as the Green River below the confluence with Big Pitman. Kentucky water regulations established during this time period required injection of brine material to a depth of 175 feet or more (Hopkins 1963). This eventually resulted in the recovery of the Big Pitman stream system. Oil well operations are still occurring in the drainage, but the pollution to surface waters resulting from these operations is apparently minimal.

A Division of Water executive summary from the Kentucky Pollution Discharge Elimination System (KPDES) files indicates past operational problems with the Campbellsville WWTP plant. In addition, KPDES files for Campbellsville from 1940 to present show this to be a historical problem.

Stream Uses

The city of Campbellsville withdraws water from an impounded (Campbellsville City Lake) portion of Trace Fork, a tributary to Little Pitman Creek, at mile point 1.1. No other permitted water withdrawals occur in the basin.

According to Axon (1981), fishing is limited in the Big Pitman Creek system to bass, catfish and suckers. He further states that the stream is used as a source of minnows for bait fishing.

In the past, swimming occurred in the impacted portions of the Pitman Creek drainage. Now, however, local individuals (personal communication) express fear of and aversion to swimming in the colored water.

Hunting for waterfowl, small mammals and deer occurs throughout the watershed in rural areas. Those game animals, as well as non-game species, utilize the various streams and adjacent buffer zones for breeding, rearing young and feeding, as well as a water supply for drinking. Trapping, principally for small mammals, such as muskrats, mink, etc., may also occur in rural sections of the drainage.

METHODS

Water and sediment samples were collected and analyzed in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater (APHA 1981) and United States Environmental Protection Agency's (U. S. EPA) Methods for Chemical Analysis of Water and Waste (U. S. EPA 1979). Field turbidity measurements were taken with an HF Instruments Model DRT-15 turbidimeter. Field conductivity was determined with a Yellow Springs Instrument Company (YSI) Model 33 S-C-T meter. Field measurements for dissolved oxygen (DO) and water temperature were conducted with a YSI Model 54A oxygen meter. An Analytical Measurements Model 707B pH meter was used for field pH. Chlorine was measured with a Hach Model DR-100 colorimeter. Illumination was measured with a Protomatic Photometer at the surface and a depth of one meter.

Biological samples were collected utilizing a variety of techniques. Periphytometers (artificial substrates) were used to determine attached algal standing crop (chlorophyll **a**), biomass (ash-free dry weight (AFDW)), and diatom community structure. Floating Design Alliance periphytometers, containing eight glass microscope slides held in a vertical position, were used to obtain surface data. Benthic values were obtained by attaching six glass slides to a construction brick in a horizontal position at a depth of 0.8 m. Substrates were exposed for two weeks from July 2 - July 17, 1984 (Union Underwear plant closed for vacation) and September 11 - September 25, 1984 (plant in operation). Triplicate surface periphytometers and one benthic periphytometer were placed at eight stream sites in July and four sites in September. Three replicate slides from each periphytometer recovered were analyzed for chlorophyll **a** by the fluorometric method, corrected for phaeophytin pigments (Strickland & Parsons 1968, Weber 1973). Three additional replicate slides were analyzed for AFDW by standard methods (APHA 1981, Weber 1973). Data were compared using Student's t-distribution (Sokal and Rohlf 1969).

Attached algae were removed from two surface periphytometer slides collected from each of four Little Pitman Creek sites in September. The samples were cleaned by incineration and mounted in HYRAX for diatom enumeration. A minimum of 500 diatom valves were identified from each sample. Diversity ($\bar{d}$) and equitability (e) were calculated in accordance with Weber (1973).

Macroinvertebrate qualitative samples were taken by selectively picking various substrate types and by collecting in different habitats with a triangular kick net. Quantitative samples were collected using a modified Hornig and Pollard (1978) travel-kick method. Three replicates were collected with a 0.045 m^2 triangular kick net by the travel-kick method over a 10 foot area for 60 seconds. All invertebrate samples were preserved in the field in 70% alcohol solution and transported to the DOW biological laboratory for enumeration and identification. The trophic relationships follow those outlined by Merritt and Cummins (1978) and Hawkins and Sedall (1981). Aquatic macroinvertebrates were placed into one of three pollution categories (i.e. tolerant, facultative and intolerant), generally based on information presented by Weber (1973) and Hart and Fuller (1974). These categories are defined by Beck (1955) and Weber (1973) as follows: tolerant organisms are associated with gross organic contamination and generally are capable of thriving under anaerobic circumstances; facultative organisms are capable of tolerating a wide range of environmental conditions, including moderate levels of organic enrichment, but cannot exist under anaerobic conditions; intolerant organisms are sensitive to even moderate levels of organic enrichment and generally are unable to withstand even moderate reductions of dissolved oxygen.

Fish were collected using a 3.4 m by 1.2 m, 0.3 cm mesh, common sense minnow seine and Coffelt backpack electrofishing unit. Both pool and riffle areas and all recognizable habitat types were sampled. The fish samples were preserved in 10% formalin solution and transported to the DOW biological laboratory for enumeration and identification. Fish community structure was analyzed using the Index of Biotic Integrity (Karr 1981, Karr et al. 1984, Fausch et al. 1984).

Bacteriological samples were collected from directly below the water's surface in 250 ml, wide mouth, sterile nalgene jars, placed on wet ice and returned for analysis to the biological laboratory within six hours. Analyses for fecal coliform and fecal streptococcus bacteria were performed using the membrane filter techniques outlined by Bordner et al. (1978).

Toxic screening tests were done in accordance with methods developed by Peltier (1978). Control and dilution water for the toxic screening consisted of chlorinated tap water run through a series of two carbon-filters and aerated overnight. Test concentrations were obtained by dilution of whole effluent until the desired percentage was reached. Tests were started by placing fathead minnows in glass jars and *Daphnia pulex* in 250 ml flasks, each vessel containing the appropriate test concentration. Dissolved oxygen (DO), pH, total alkalinity, total hardness, temperature, conductivity and total and free chlorine were measured at the beginning and end of the tests. An Orion Research Model 601A digital ionalyzer was used for measuring pH. Total alkalinity and total hardness were analyzed in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater (APHA 1981). The remainder of the parameters were measured as previously stated in this section.

Quality Assurance

Coordination of the stream study was outlined by the principal investigator preceeding and during all on-site work. A reconnaissance trip was made to all sites before the study, and details such as sampling sites, transfer of samples, sampling dates, measurements and parameter coverage were delineated. Chain of Custody records were maintained for all samples.

All instruments were calibrated by methods provided by manufacturers. Physicochemical and biological sampling and toxicity testing procedures and methods in referenced published reports were followed. Where identical measurements were made in the field and laboratory, field values were reported. In addition, replicate samples were obtained and reference standards were used where applicable.

Little Pitman Creek was studied for impacts of pollutants on water quality and biotic integrity. In addition to comparing sites upstream and downstream of the Campbellsville WWTP, a reference or control stream of similar physical dimensions (i.e. length, drainage and discharge and physical characteristics) was selected for comparison. The stream used in this study was Middle Pitman, an adjacent stream, similar to Little Pitman with the exception of point discharges and nonpoint urban impacts. Middle Pitman Creek is not a pristine or undisturbed control, but is the best stream in the immediate area for control purposes. The control stream provides a basis for determining typical and potential stream conditions of similar watersheds.

PHYSICAL EVALUATION

Little Pitman Creek is a third order tributary to Big Pitman Creek (RMI 13.7). It flows 21.7 km (13.5 mi) in a southwesterly direction and drains 75.9 km^2 (29.3 mi^2). Middle Pitman Creek is a fourth order tributary to Big Pitman Creek (RMI 17.5). It flows 22.4 km (13.9 mi) in a southwesterly direction and drains 64.4 km^2 (24.9 mi^2). Big Pitman Creek, a fifth order stream in the Green River basin, drains pastures, row crops and an urban center, i.e. Campbellsville. The stream originates in northcentral Taylor County near Spurlington, Kentucky. It flows 67.6 km (42 mi) in a southwesterly direction, joining the Green River (RMI 265.8) in west-central Green County. Total drainage area for Big Pitman Creek is 350 km^2 (135 mi^2) (Bower and Jackson 1981).

The Pitman Creek drainage lies in the Greensburg subsection of the Highland Rim, a physiographic region within the Interior Low Plateaus Province (Quarterman and Powell 1978). The topography is typically a rolling upland dissected by several streams. The underlying rock strata in upstream areas are Mississippian aged silty dolomite and clastic limestone (McDowell et al. 1981). Further downstream, Big Pitman Creek cuts through limestone bodies of Lower Mississippian age (McDowell et al. 1981). The two major soil groups and their characteristics are given in Table 2. Elevations range from 311 m (1020 ft) above mean sea level (msl) in the headwaters to 176.8 m (580 ft) above msl at the mouth. Average stream gradient for Little Pitman is 4.2 m/km (22.2 ft/mi), for Middle Pitman is 4.5 m/km (23.7 ft/mi) and for Big Pitman is 2.3 m/km (11.9 ft/mi).

Flow measurements were made at nine stations in the Big Pitman Creek drainage (Table 3). Maximum flow, recorded on Big Pitman Creek at RMI 11.1 on July 17, 1984, was 53.9 ft^3/s. Minimum flow, recorded on Little Pitman Creek at RMI 10.5 on July 2, 1984, was 0.3 ft^3/s. On July 3 and 17, 1984, Little Pitman comprised 25% and 26%, respectively, of the flow in Big Pitman. According to Sullavan (1980), the seven day, ten-year low flow (7Q10) for Big Pitman Creek near Gabe, Kentucky is 0.3 ft^3/s.

Table 2: Soils of the Big Pitman Creek System

Soil[1] Association	Slope[1,2] %	Drainage[2] Class	Potential[1] Sediment Runoff	Infiltration[1]	Septic Tank[1] Absorbtion Rating
Frederick	2-20	———	Medium	Moderate	Slight
Crider	3-12	Well-drained	Medium	Moderate	Slight
Mountview	3-12	Well-drained	Medium	Moderate	Slight
Frederick	2-20	———	Medium	Moderate	Slight
Mountview	3-12	Well-drained	Medium	Moderate	Slight
Bedford	1-10	Moderately Well-drained	Low	Slow	Severe

(1) R. F. Weston, Inc. (1975)
(2) Bailey and Winsor (1964)

Table 3: Flow Data for the Big Pitman Creek System

Station	Stream	RMI	Flow (ft^3/s)	Date
03024001	Little Pitman	10.5	0.3	7-2-84
03024003	Little Pitman	3.6	2.9	7-2-84
03024004	Little Pitman	7.2	2.7	7-2-84
03024005	Little Pitman	1.5	1.9	7-3-84
03024006	Big Pitman	11.1	7.5	7-3-84
03024007	Big Pitman	15.7	5.0	7-3-84
03024008	Middle Pitman	9.4	2.2	7-10-84
03024009	Middle Pitman	0.2	6.4	7-10-84
03024010	Buck Horn Creek	0.11	0.5	7-2-84
03024002 (WWTP)	Buck Horn Creek	0.1	2.25 MGD	7-2-84
03024003	Little Pitman	3.6	13.3	7-17-84
03024004	Little Pitman	7.2	13.0	7-17-84
03024005	Little Pitman	1.5	14.3	7-17-84
03024006	Big Pitman	11.1	53.9	7-17-84
03024007	Big Pitman	15.7	9.2	7-23-84
03024008	Middle Pitman	9.4	0.6	7-23-84
03024009	Middle Pitman	0.2	2.7	7-23-84
03024010	Buck Horn Creek	0.11	3.0	7-17-84

A diversity of stream habitats included pools, riffles, undercut banks, rock ledges, submerged roots and logs, gravel bars and various substrates. Riparian buffer zones were commonly narrow (under 30 m) with much of the watershed modified to agricultural use. Pastures and row crops frequently extended to within a few feet of the water's edge.

A total of 78 plant taxa (Appendix B) were noted from nine sampling stations. Boxelder (*Acer negundo*), silver maple (*Acer saccharinum*), sycamore (*Platanus occidentalis*) and green ash (*Fraxinus pennsylvanica*) were common canopy species. False nettle (*Boehmeria cylindrica*), morning-glory (*Ipomea* sp.), smartweed (*Polygonum* sp.) and dock (*Rumex* sp.) were common groundcover species. Bank failure was a common problem in areas where the woody vegetation had been cleared to the water's edge. Riparian vegetation can help stabilize stream banks and improve water quality (Karr and Schlosser 1978). A well developed plant cover will minimize erosion as well as collect sediments and nutrients in surface runoff (Peterjohn and Correll 1984). The impacts of runoff from agricultural areas to benthic macroinvertebrates can be severe (Lenat 1984). Buffer zones also provide food and cover for invertebrates, fish and wildlife (Nelson et al. 1978, Johnson and McCormick 1978).

The following is a brief description of the sampling stations (Figure 1). More detailed information is given in Appendix A.

Little Pitman Creek

03024001 (24-1)

This site was located approximately 0.8 km (0.5 mi) upstream of the mouth of Buck Horn Creek. Sampling was conducted 0.5 km upstream of the bridge on KY 210 (RMI 10.5) in Taylor County. Little Pitman Creek at this location is a third order stream with moderate gradient. Adjacent land use was grass and hay fields. Stream banks were only fairly stable, with a 0 to 3 m buffer zone. Stream substrate was primarily bedrock in the pools and gravel/pebble in the riffles. On July 2, 1984, the water was clear with low flow; on July 17, the water was clear; on September 11, the water was clear; and on September 25, the water was clear.

Campbellsville WWTP effluent

03024002 (24-2)

Samples were collected from the Campbellsville WWTP effluent pipe, before entering Buck Horn Creek.

Little Pitman Creek

03024003 (24-3)

This station was located approximately 10.3 km (6.4 mi) downstream of the mouth of Buck Horn Creek. Sampling was conducted downstream of the KY 793 (formerly KY 1516) bridge (RMI 3.6) in Green County. Little Pitman Creek at this location is a third order stream with moderate gradient. Adjacent land use was farm pastures. Bank stability was considered fair, with a 0 to 6 m buffer zone. Stream substrates were primarily cobble/pebble in riffles and pools. A small (less than 100 ft) area of gravel dredging was noted at the downstream edge of the site. On July 2, 1984, the water was maroon colored with low flow; on July 17, the water was clear; on September 11, the water was maroon colored; and on September 25, the water was black.

Little Pitman Creek

03024004 (24-4)

This site was located approximately 4.5 km (2.8 mi) downstream of the mouth of Buck Horn Creek. Sampling was conducted at the bridge on Summersville Road (RMI 7.2) in Taylor County. Little Pitman Creek at this location is a third order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures and row crops. Bank stability was considered good with a 6 to 12 m buffer zone. Stream substrates varied from fines to boulders. On July 2, 1984, the water was maroon colored with low flow; on July 17, the water was maroon colored; on September 11, the water was maroon colored; and on September 25, the water was black.

Little Pitman Creek

03024005 (24-5)

This station was located approximately 13.7 km (8.5 mi) downstream of the mouth of Buck Horn Creek. Sampling was conducted at the KY 793 bridge (RMI 1.5) in Green County. Little Pitman Creek at this location is a third order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures, hay fields and row crops. Bank stability was considered fair, with a 0 to 3 m buffer zone. Stream substrates were primarily cobble/pebble. On July 3, 1984, the stream was maroon colored with low flow; on July 17, the water was clear; on September 11, the water was maroon colored; and on September 25, the water was black.

Big Pitman Creek

03024006 (24-6)

This site was located approximately 4.2 km (2.6 mi) downstream of the mouth of Little Pitman Creek. Sampling was conducted at the KY 61 bridge (RMI 11.1) in Green County. Big Pitman Creek at this location is a fifth order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures and hay fields. Bank stability was considered fair, with a 0 to 6 m buffer zone. Stream substrates were primarily boulders, cobble and pebbles. On July 3, 1984, the water was maroon colored with low flow; and on July 17, the water was clear.

Big Pitman Creek

03024007 (24-7)

This station was located approximately 3.2 km (2 mi) upstream of the mouth of Little Pitman Creek. Sampling was conducted at the Ray Chadion Road bridge (RMI 15.7) in Taylor County. Big Pitman Creek at this location is a fourth order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures, hay fields and row crops. Bank stability was considered fair with a 0 to 5 m buffer zone. Stream substrates were primarily cobble/pebble. On July 3, 1984, the water was clear to slightly turbid with low flow; and on July 23, the water was clear.

Middle Pitman Creek

03024008 (24-8)

This station was located at the bridge on Salem Road (RMI 9.4) in Taylor County. The site was chosen to provide background water quality from a watershed very similar to Little Pitman Creek (difference in drainage area is less than five square miles). Middle Pitman Creek at this location is a third order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures, hay fields and row crops. Bank stability was considered good with a 0 to 30 m buffer zone. Stream substrates were primarily silt covered bedrock in the pools and cobble/pebble in the riffles. On July 10 and 23, 1984, the water was clear with low flow.

Middle Pitman Creek

03024009 (24-9)

This station was located just upstream of the confluence with Big Pitman Creek (RMI 0.2) in Green County. The site was also chosen to provide background water quality because of its similarities to the Little Pitman Creek watershed. Middle Pitman Creek at this location is a fourth order stream with alternating pools and riffles and a moderate gradient. Adjacent land use was pastures, hay fields and row crops. Bank stability was considered excellent with a 0 to 3 m buffer zone. Stream substrates were primarily cobble/pebble/gravel. On July 10 and 23, 1984, the water was clear to slightly turbid with low flow.

Buck Horn Creek

03024010 (24-10)

This station was located just upstream of the Campbellsville WWTP outfall (RMI .11) in Taylor County. Buck Horn Creek at this location is a first order stream with alternating pools and riffles and a moderate to high gradient. Adjacent land use was hay fields and pastures. This station also receives urban runoff from Campbellsville. Wooded hillsides extended beyond one bank. Bank stability was considered fair with a 0 to 30^+ m buffer zone. Stream substrates were primarily exposed bedrock in the pools and scattered boulders on bedrock in the riffles. On July 2 and 17, 1984, the water was clear with low flow.

PHYSICOCHEMICAL EVALUATION

A total of 50 physicochemical parameters were analyzed from surface grab samples of the Campbellsville WWTP effluent and nine additional locations in the Big Pitman Creek system. The physicochemical data are presented in Table 4. Thirty-eight parameters were analyzed from sediments collected from selected stations. Physicochemical samples were taken during four time periods in 1984, once in February, twice in July and once in September (Table 4).

The physicochemical parameter values (with the exception of the nutrients) observed during this study at the control stations (24-1, 24-7, 24-8, and 24-9) were probably close to seasonal background levels for small streams draining limestone lithology in that portion of Kentucky. In general, conductivity, chloride, sulfate, color, total dissolved solids, total organic carbon, chemical oxygen demand and some metal values (Table 4) observed at the downstream impacted stations on Little Pitman (24-3, 24-4, 24-5) were elevated above those observed at the control stations (24-1, 24-7, 24-8, 24-9). Big Pitman Creek, below the confluence with Little Pitman Creek (Station 24-6), had essentially the same elevated physicochemical values as the impacted Little Pitman sites. The effluent (24-2) typically had the highest parameter values observed in this study. This is understandable, since the Campbellsville WWTP treats a variety of industrial and domestic wastes. The effluent values are provided here (Table 4) for comparative purposes and generally will not be discussed.

The color data presented in Table 5 and Figure 2 indicate the impacted sites (24-3, 24-4, 24-5 and to a lesser extent 24-6) had considerably higher color values during the February, early July and September sampling periods than did the control sites. There was at least a three-fold increase in color values from the control to the impacted stations during these three sampling periods. During the July 17 sampling period, all color values at all sites except the effluent (24-2) were similar (Table 5, Figure 2). The Union Underwear Company had ceased discharging approximately two weeks (June 29-

Table 4: Physicochemical Data for the Big Pitman Creek System

Parameter	24-01				24-02				24-03	
Date	02/10/84	07/02/84	07/17/84	09/11/84	02/10/84	07/3/84	07/17/84	09/11/84	02/10/84	07/02/84
Conductivity (umhos/cm @ 25 C)	262	398	313	360	1876	1980	1224	1960	611	1950
pH	8.0	7.4	7.8	7.1	7.2	7.7	7.6	7.5	7.6	8.2
Air temperature (C)	7.0	ND	29.0	24.0	11.0	23.0	32.0	21.	13.0	ND
Water temperature (C)	5.0	24.0	26.0	22.0	15.0	25.5	24.0	26.5	8.0	25.0
Turbidity (NTU)	3.2	10.0	10.0	8.0	7.0	11.0	12.0	22.0	6.0	3.2
DO (mg/l)	13.0	6.3	9.0	5.6	8.6	8.4	8.4	7.6	11.0	7.6
Photometer - surface	300	550	64	ND	ND	ND	ND	ND	300	170
Photometer - 1 meter	180	400	20	ND	ND	ND	ND	ND	60	7
Chlorine Residual - free mg/l	0.05	0.1	0.05	0.05	2.0	0.28	0.24	0.25	0.1	0.18
Chlorine Residual - total mg/l	0.07	0.1	0.05	0.05	3.5	0.4	0.24	0.50	0.3	0.20
Acidity (mg/l)	0.9	0.98	0.2	2.0	1.8	2.5	3.8	6.5	1.7	K0.1
Alkalinity (mg/l)	88.0	133.0	125.0	164.0	212.0	171.0	177.0	249.0	146.0	225.0
BOD5 (mg/l)	1.0	0.5	0.2	1.3	17.4	2.5	7.0	NA	3.6	K0.1
Chloride (mg/l)	14.7	21.0	11.9	22.2	470.0	517.0	328.0	492.0	142.0	414.0
COD (mg/l)	2.7	6.8	4.4	NA	191.0	96.5	42.8	97.5	42.9	57.4
CN (free) (mg/l)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	NA	K0.01	K0.01
Total Dissolved Solids (mg/l)	159.0	262.0	230.0	286.0	1190.0	1290.0	952.0	1310.0	478.0	1080.0
Fluoride (mg/l)	0.06	0.08	0.08	0.11	ND	1.20	1.47	1.52	1.0	0.89
Total Hardness (mg/l)	126.0	172.0	156.0	206.0	123.0	106.0	122.0	104.0	155.0	150.0
Sulfide (mg/l)	ND	0.4	K0.1	K0.1	ND	0.1	K0.1	K0.1	ND	K0.1
MBAS	0.02	ND	ND	ND	0.42	ND	ND	ND	0.12	ND
Phenols (mg/l)	K0.01	K0.01	0.017	12.0	K0.01	K0.01	0.010	NA	K0.01	K0.01
Sulfate (mg/l)	22.5	38.8	23.0	38.5	69.7	71.4	56.1	65.9	31.6	64.0
TOC (mg/l)	ND	3.6	1.2	2.4	ND	25.2	10.7	25.0	ND	23.3
Suspended Solids (mg/l)	4.0	14.0	10.0	7.0	35.0	18.0	15.0	22.0	23.0	15.0
NH3-N (mg/l)	K0.05	K0.05	K0.05	0.050	0.250	0.060	0.091	0.124	0.542	0.058
NO2 + NO3 - N (mg/l)	2.53	0.345	1.82	0.140	0.07	15.0	5.95	6.30	2.10	0.450
TKN (mg/l)	0.355	0.255	0.333	0.340	3.53	11.6	2.10	3.71	0.399	1.66
Phosphorous (total) (mg/l)	0.021	0.018	0.022	0.100	5.28	6.20	5.15	9.10	2.11	3.00
Phosphorous (dissolved) Ortho (mg/l)	0.05	K0.05	0.014	NA	4.80	7.50	5.05	7.0	1.58	2.7
Al (total) (ug/l)	92.0	110.0	85.0	112.0	1090.0	644.0	351.0	601.0	1010.0	99.0
As (total) (ug/l)	K1.0	1.0	1.0	1.0	7.0	4.0	3.0	6.0	6.0	7.0
Ba (total) (ug/l)	250	156.0	46.0	76.0	32.0	47.0	781.0	NA	30.0	102.0
Be (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Cd (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	3.0	2.0	1.0	NA	3.0	4.0
Ca (total) (mg/l)	32.0	47.1	36.1	66.7	5.6	32.3	31.1	NA	34.5	48.3
Cr (total) (ug/l)	3.0	1.0	4.0	2.0	14.0	6.0	5.0	13.0	11.0	2.0
Cu (total) (ug/l)	3.0	3.0	3.0	1.0	133.0	149.0	18.0	171.0	123.0	76.0
Fe (total) (ug/l)	30.0	60.0	40.0	160.0	140.0	130.0	130.0	NA	130.0	60.0
Pb (total) (ug/l)	K1.0	24.0	K1.0	K1.0	1.0	K1.0	1240.0	K1.0	1.0	K1.0
Mg (total) (mg/l)	7.77	11.1	7.78	13.2	7.64	6.24	5.19	NA	7.02	8.11
Mn (total) (ug/l)	10.0	30.0	40.0	100.0	510.0	30.0	60.0	NA	460.0	30.0
Hg (total) (ug/l)	0.2	2.0	0.02	0.2	0.4	0.3	0.2	0.1	0.2	0.2
Ni (total) (ug/l)	10.0	K1.0	1.0	K1.0	40.0	K3.0	13.0	8.0	200	11.0
K (total) (mg/l)	1.49	2.0	2.08	3.14	29.5	21.5	20.3	NA	26.2	19.3
Se (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Ag (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	1.0	K1.0
Na (total) (mg/l)	6.5	10.5	5.8	14.0	351.0	362.0	248.0	NA	324.0	302.0
Zn (total) (ug/l)	5.0	9.0	12.0	2.0	444.0	196.0	183.0	NA	406.0	107.0

K - below detection limit; ND - not determined; NA - not available at time of report preparation

Table 4: Physicochemical Data for the Big Pitman Creek System

Parameter	24-03		24-04			24-05			24-06	
Date	07/17/84	09/11/84	07/02/84	07/17/84	09/11/84	07/03/84	07/17/84	09/11/84	07/03/84	07/17/84
Conductivity (umhos/cm @ 25 C)	431	1716	1650	500	1590	1717	337	1313	918	265
pH	7.8	8.0	8.1	7.8	7.6	8.0	7.4	7.9	7.8	7.6
Air temperature (C)	27.0	24.0	29.0	30.0	24.0	23.0	26.0	24.5	29.0	24.0
Water temperature (C)	25.0	23.0	25.0	25.0	22.0	21.0	24.0	24.5	24.0	24.0
Turbidity (NTU)	14.0	6.0	2.5	8.4	ND	5.4	40.0	9.0	12.0	172.0
DO (mg/l)	9.5	7.8	9.4	10.0	6.0	7.2	8.2	83	7.2	7.0
Photometer - surface	220	ND	100	70	ND	4	320	ND	80	82
Photometer - 1 meter	110	ND	7	ND	ND	1	130	ND	10	0.7
Chlorine Residual - free mg/l	0.20	0.10	0.08	0.08	0.08	0.08	0.10	0.15	0.05	0.10
Chlorine Residual - total mg/l	0.20	0.10	0.12	0.15	0.08	0.08	0.10	0.20	0.10	0.10
Acidity (mg/l)	1.2	K0.1	K0.1	K0.1	1.5	0.1	0.2	K0.1	0.1	1.4
Alkalinity (mg/l)	115.0	243	222.0	130.0	215.0	225.0	111.0	232.0	172.0	99.0
BOD5 (mg/l)	0.7	1.3	K0.1	0.3	1.70	K0.1	0.4	1.5	K0.1	0.1
Chloride (mg/l)	30.9	409.0	386.0	57.0	350.0	422.0	19.1	372.0	188.0	16.1
COD (mg/l)	8.2	43.9	58.6	11.7	45.0	85.2	26.5	35.2	18.4	19.2
CN (free) (mg/l)	K0.01	K0.1	K0.01	K0.01	7.5	K0.01	K0.01	K0.01	K0.01	K0.01
Total Dissolved Solids (mg/l)	266.0	1060	1030.0	350.0	962.0	1070.0	224.0	978.0	560.0	194.0
Fluoride (mg/l)	0.24	0.95	1.03	0.32	109.0	0.84	0.18	0.81	0.33	11.0
Total Hardness (mg/l)	NA	162	133.0	160.0	139.0	158.0	138.0	164.0	173.0	120.0
Sulfide (mg/l)	K0.1	K0.1	0.3	K0.1	K0.1	0.1	K0.1	K0.1	0.2	K0.1
MBAS	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenols (mg/l)	0.017	5.0	K0.01	K0.01	10.0	K0.01	K0.01	K0.005	K0.01	0.029
Sulfate (mg/l)	28.2	58.8	65.7	34.7	61.5	61.9	24.3	57.2	34.2	15.3
TOC (mg/l)	1.4	11.1	18.8	3.2	11.3	20.6	2.9	8.7	8.3	4.0
Suspended Solids (mg/l)	9.0	5.0	8.0	9.0	1.0	8.0	33.0	3.0	10.0	148.0
NH3-N (mg/l)	K0.05	0.062	0.094	K0.05	0.073	0.114	0.067	0.062	0.114	0.083
NO2 + NO3 - N (mg/l)	10.6	0.505	0.615	6.52	5.20	0.300	4.03	0.665	0.230	1.99
TKN (mg/l)	0.697	1.40	2.02	0.998	1.64	1.77	1.30	1.21	0.738	1.18
Phosphorous (total) (mg/l)	0.899	4.88	3.25	1.30	5.88	2.90	0.620	3.60	0.950	0.304
Phosphorous (dissolved) Ortho (mg/l)	ND	2.9	2.3	1.16	4.4	2.70	0.440	3.6	0.5	0.129
Al (total) (ug/l)	122.0	86.0	98.0	131.0	50.0	144.0	231.0	84.0	155.0	758.0
As (total) (ug/l)	2.0	6.0	5.0	3.0	3.0	7.0	2.0	4.0	4.0	K1.0
Ba (total) (ug/l)	81.0	48.0	67.0	62.0	51.0	71.0	1210.0	53.0	51.0	100.0
Be (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Cd (total) (ug/l)	K1.0	3.0	3.0	1.0	2.0	3.0	K1.0	3.0	2.0	K1.0
Ca (total) (mg/l)	41.7	49.3	41.0	43.0	52.4	51.9	37.1	55.5	66.6	32.1
Cr (total) (ug/l)	2.0	2.0	5.0	1.0	4.0	1.0	K1.0	5.0	1.0	K1.0
Cu (total) (ug/l)	8.0	59.0	69.0	20.0	72.0	65.0	6.0	53.0	24.0	3.0
Fe (total) (ug/l)	80.0	70.0	70.0	80.0	50.0	100.0	220.0	110.0	130.0	850.0
Pb (total) (ug/l)	K1.0	K1.0	K1.0	1.0	K1.0	K1.0	K1.0	K1.0	K1.0	1.0
Mg (total) (mg/l)	5.96	8.68	6.28	6.75	7.34	7.50	5.72	8.29	8.74	5.04
Mn (total) (ug/l)	40.0	40.0	40.0	40.0	30.0	80.0	60.0	40.0	70.0	160.0
Hg (total) (ug/l)	0.02	0.2	0.07	0.02	0.2	0.02	0.02	0.2	0.2	0.04
Ni (total) (ug/l)	K1.0	1.0	7	4.0	K1.0	8.0	K1.0	16.0	4.0	K1.0
K (total) (mg/l)	4.34	24.4	18.1	6.68	24.3	17.4	4.24	20.4	8.17	3.55
Se (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Ag (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Na (total) (mg/l)	21.1	323.0	268.0	48.8	298.0	277.0	14.8	280.0	127.0	9.4
Zn (total) (ug/l)	K1.0	88.0	117.0	31.0	96.0	78.0	14.0	60.0	29.0	13.0

K - below detection limit; ND - not determined; NA - not available at time of report preparation

Table 4: Physicochemical Data for the Big Pitman Creek System

Parameter	24-07		24-08		24-09		24-10		
Date	07/03-84	07/23/84	07/10/84	07/23/84	07/10/84	07/23/84	07/02/84	07/17/84	09/11/84
Conductivity (umhos/cm @ 25 C)	389	398	191	284	300	306	1060	431	477
pH	7.7	7.9	7.5	7.8	7.4	ND	7.4	7.8	7.4
Air temperature (C)	27.0	29.0	27.0	31.0	28.0	33.0	27.0	32.0	21.5
Water temperature (C)	21.0	21.0	22.0	26.0	25.0	24.0	22.0	26.0	22.0
Turbidity (NTU)	6.6	ND	9.0	ND	10.0	ND	2.2	9.0	3.0
DO (mg/l)	7.8	8.1	7.7	9.0	7.6	9.9	9.4	10.0	5.4
Photometer - surface	275	33.0	270	2500	300	2900	ND	19	ND
Photometer - 1 meter	80	150	100	700	100	900	ND	10	ND
Chlorine *Residual - free mg/l*	0.05	0.05	0.05	0.05	0.04	0.08	0.05	0.08	0.03
Chlorine Residual - total mg/l	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.11	0.08
Acidity (mg/l)	0.98	1.8	0.98	0.8	0.98	0.7	0.1	K1.0	1.0
Alkalinity (mg/l)	142.0	285.0	283.0	227.0	121.0	261.0	168.0	158.0	176.0
BOD5 (mg/l)	K0.1	0.7	0.5	0.8	0.2	0.4	K0.1	0.1	0.6
Chloride (mg/l)	54.0	37.6	9.8	10.6	8.9	9.7	254.0	18.2	38.3
COD (mg/l)	5.1	4.6	5.4	5.0	4.5	4.5	10.0	7.0	10.1
CN (free) (mg/l)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Total Dissolved Solids (mg/l)	266.0	246.0	194.0	186.0	200.0	152.0	678.0	286	338
Fluoride (mg/l)	0.08	0.09	0.06	0.06	0.06	0.06	0.14	0.12	0.16
Total Hardness (mg/l)	168.0	179.0	141.0	139.0	147.0	156.0	243.0	214.0	224.0
Sulfide (mg/l)	0.2	K0.1	0.3	K0.1	0.1	K0.1	0.20	K0.1	K0.1
MBAS	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenols (mg/l)	0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	7.0
Sulfate (mg/l)	16.9	19.0	16.7	15.3	16.3	15.3	42.1	36.6	41.9
TOC (mg/l)	2.3	1.0	1.7	1.1	1.5	0.9	6.2	1.1	2.9
Suspended Solids (mg/l)	7.0	11.0	22.0	6.0	12.0	10.0	4.0	7.0	2.0
NH3-N (mg/l)	K0.05	K0.50	0.112	K0.05	0.158	K0.05	0.052	0.027	K0.05
NO2 + NO3 - N (mg/l)	0.160	0.720	2.50	1.05	2.25	0.970	0.440	3.83	0.490
TKN (mg/l)	0.154	0.245	0.621	0.177	0.515	0.177	0.497	0.474	0.401
Phosphorous (total) (mg/l)	0.015	0.022	0.046	0.022	0.036	0.025	0.075	0.079	0.071
Phosphorous (dissolved) Ortho (mg/l)	K0.5	0.003	K0.05	0.004	K0.05	0.008	K0.05	0.079	K0.1
Al (total) (ug/l)	70.0	134.0	163.0	100.0	119.0	117.0	25.0	98.0	28.0
As (total) (ug/l)	2.0	2.0	1.0	K1.0	1.0	2.0	2.0	2.0	1.0
Ba (total) (ug/l)	78.0	68.0	89	49	47.0	48.0	61.0	70.0	70.0
Be (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Cd (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	1.0	K1.0	K1.0
Ca (total) (mg/l)	57.9	45.0	42.2	58.7	47.8	52.7	74.7	59.7	74.3
Cr (total) (ug/l)	7.0	K1.0	1.0	K1.0	8.0	K1.0	2.0	K1.0	3.0
Cu (total) (ug/l)	2.0	1.0	1.0	1.0	1.0	1.0	5.0	4.0	3.0
Fe (total) (ug/l)	70.0	140.0	60.0	70.0	110.0	70.0	50.0	450.0	40.0
Pb (total) (ug/l)	9.0	K1.0	2.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Mg (total) (mg/l)	8.20	8.81	6.87	8.18	7.17	7.74	11.4	8.09	10.7
Mn (total) (ug/l)	50.0	60.0	40.0	50.0	50.0	50.0	20.0	30.0	30.0
Hg (total) (ug/l)	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.1
Ni (total) (ug/l)	4	37.0	1.0	13.0	K1.0	6.0	2.0	K1.0	1.0
K (total) (mg/l)	1.98	2.38	3.2	2.72	3.03	2.70	4.2	3.42	3.78
Se (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Ag (total) (ug/l)	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0	K1.0
Na (total) (mg/l)	22.8	16.8	4.2	3.8	4.1	3.2	135.0	11.4	27.2
Zn (total) (ug/l)	11.0	1.0	12.0	K1.0	12.0	K1.0	14.0	10.0	3.0

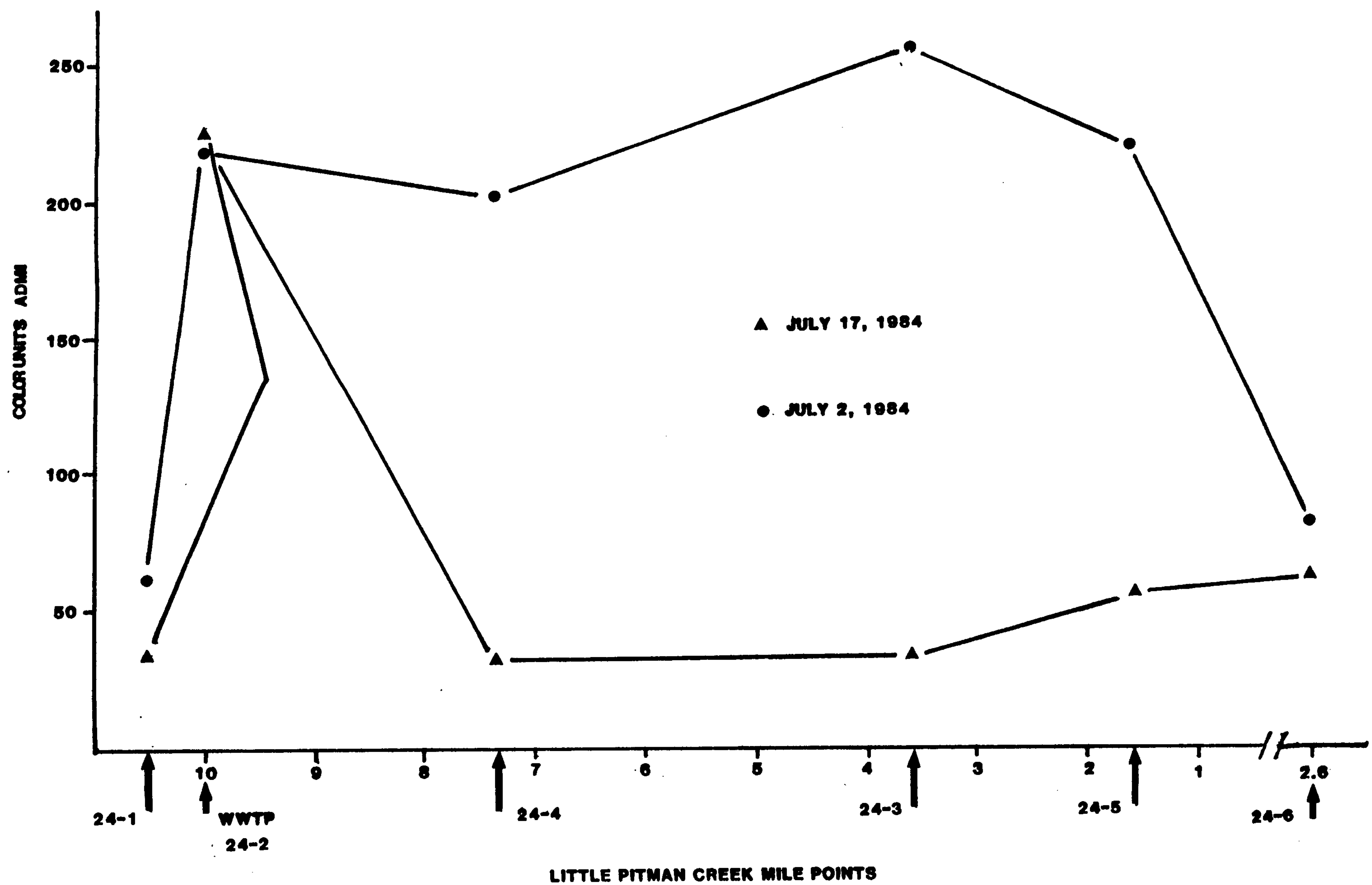
K - below detection limit; ND - not determined; NA - not available at time of report preparation

Table 5: Color Values (in ADMI) for the Big Pitman Creek System

	Color-unfiltered					Color-filtered				
Station	**10-Feb**	**2-Jul**	**17-Jul**	**23-Jul**	**11-Sept**	**10-Feb**	**2-Jul**	**17-Jul**	**23-Jul**	**11-Sept**
24-1	15.0	58.8	50.6	ND	62.8	ND	61.3	36.3	ND	48.3
24-2	85.0	306	231	ND	474	ND	219	225	ND	270
24-3	58.0	268	48.8	ND	140	ND	256	42.5	ND	150
24-4	ND	236	50.6	ND	156	ND	201	42.5	ND	145
24-5	ND	220	53.8	ND	227	ND	220	58.8	ND	202
24-6	ND	107	60.0	ND	ND	ND	83.8	63.8	ND	ND
24-7	ND	43.8	ND	92.5	ND	ND	75.5	ND	53.1	ND
24-8	ND	ND	ND	73.8	ND	ND	ND	ND	46.9	ND
24-9	ND	ND	ND	93.8	ND	ND	ND	ND	58.8	ND
24-10	ND	51.3	46.3	ND	48.3	ND	44.4	41.4	ND	48.3

ND - Not Determined

Figure 2: Color Data for Little Pitman Creek at Stations 24-1, 24-2 24-3, 24-4 and 24-5 and Big Pitman Creek at 24-6 on July 2 and 17, 1984



July 16) prior to this sampling date, resulting in the elimination of dyes from the creek system (Figure 2). However, just prior to July 17, Union Underwear resumed operation which accounts for the elevated color value in the effluent. Apparently, insufficient time had elapsed to allow the dyes to reach the first sampling site (24-4) (Figure 1) downstream. The high color concentrations observed appear to have a direct negative effect on the algae and an indirect negative effect on the macroinvertebrate and fish faunas (refer to Biological Evaluation for additional discussion). The color in Little Pitman Creek is a violation of 401 KAR 5:031, Section 3 (3).

Color and turbidity determine light transmission in natural waters and consequently "regulate" biological processes in a body of water (Reid 1961, Reid and Wood 1976). Color and turbidity are similar in determining the hue and optical qualities of water. Color in water principally results from degradation processes in the natural environment (U. S. EPA 1976), and all dissolved substances and particulate organic matter contribute to the color and turbidity of natural waters (Reid 1961). In the aquatic environment, "true color" of natural water is derived from substances in solution or colloidal suspension. Another term used in color determination is "apparent color" which is the result of light interaction with suspended material and including such factors as stream bottom and sky reflection. In addition to the above, suspended colloidal inorganic substances may account for certain colors. In general, the dyes originating from the Union Underwear industrial discharge fall into this latter category. Non-natural colors, such as dyes, should not be present in concentrations perceptible to the human eye (U. S. EPA 1976). Color can be perceived at 10 or 15 color units in natural waters (Hach and Gibbs 1974).

Turbidity is defined as the degree of opaqueness produced in water by suspended particulate matter. The nature of the material is mainly responsible for the color quality, while the concentration of the material determines the transparency by limiting the degree of light penetration in the water column. Turbidity reduces light penetration resulting in decreased algal production (Reid and Wood 1976).

It might appear that color and turbidity act together to exert relative effects on light penetration. Such may not always be the case. Studies in Atwood Lake, a reservoir in Ohio, have indicated that color and turbidity are very probably independent variables exhibiting no interaction with respect to transparency (Reid and Wood 1976). It was further found that color may be the major factor affecting light penetration, except during periods of heavy rainfall when large amounts of silt are introduced (Reid and Wood 1976). Stream color may be affected by a variety of conditions. Typically, upper reaches of streams are characterized by clear waters during non-flood conditions.

The effect of water color on aquatic life is principally through the reduction of light penetration, resulting in reduced photosynthesis by phytoplankton and restriction of the zone of vascular plant growth (U. S. EPA 1976). The light supply necessary to support plant life is dependent, at least in part, on intensity and effective wave lengths (Welch 1952). In general, the rate of photosynthesis increases with an increase in intensity of incident light (U. S. EPA 1976). Photosynthetic rates are most affected in the red region and least affected in the blue-violet region of incident light (Welch 1952). As much as 10% of incident light may be required for plankton to photosynthetically produce sufficient oxygen to balance their respiration rates (NTAC 1968). The color in Little Pitman, caused by the dyes from Union Underwear, effectively reduced light penetration, thereby degrading the stream (see Biological Evaluation for supporting information).

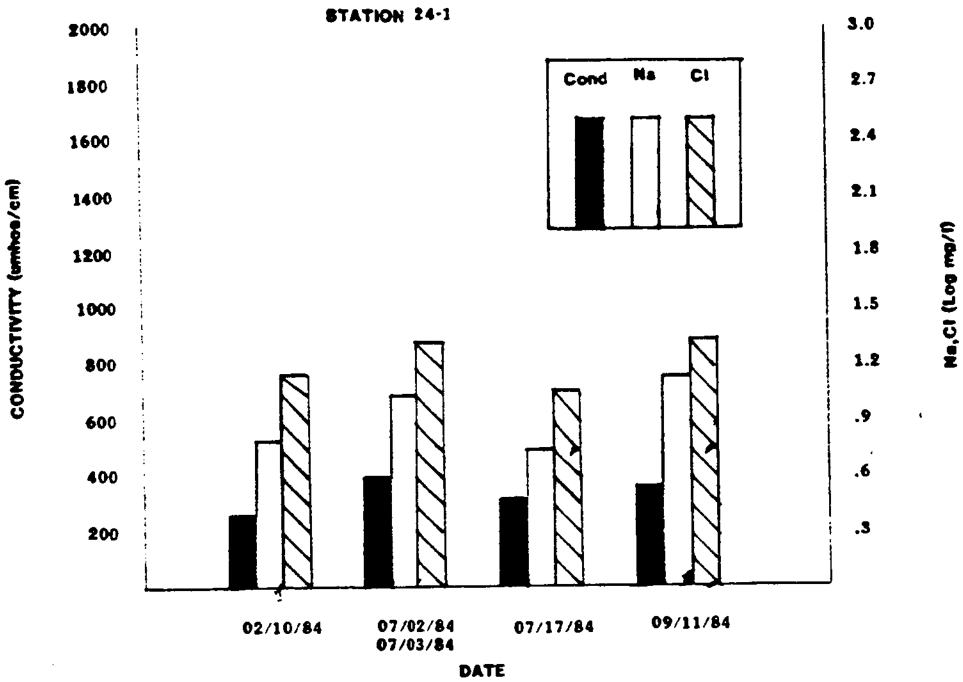
During the study period, dissolved oxygen (DO) and pH did not violate Kentucky Surface Water Standards (KSWS) for warmwater aquatic habitat at any sampling location. In addition, the values observed (Table 4) for these parameters were not considered limiting to aquatic life.

Values for conductivity and total dissolved solids (TDS) were elevated at the impacted stations (24-3, 24-4, 24-5, 24-6), when compared to stations 24-1, 24-8, and 24-9 during the February, early July and September sampling periods. They also exceeded STORET (1979-1982) mean values. During the mid-July sample, all the impacted sites exhibited their lowest conductivity and TDS values (Table 4, Figures 3, 4, and 5). This was due to the fact that the WWTP was not receiving industrial discharges from Union Underwear. The principal difference between the mid-July and other sampling dates was the presence of the Union Underwear indirect discharge. Elevated conductivity values may cause impacts to the fish community of a stream. Ellis (1937) reported that conductivities of streams supporting well developed fish faunas were between 150 and 500 umhos/cm. The control sites all fell within this range, while the impacted sites all exceeded this range.

In general, the alkalinity, hardness and acidity values were similar at all sites. The values for alkalinity and hardness seen in this study are what would be expected from streams draining limestone lithologies.

Chloride (Cl^-) and sulfate ($SO_4^=$) values were elevated at the impacted stations (24-3, 24-4, 25-5, 24-6) when compared to stations 24-1, 24-8 and 24-9. In addition, the Cl^- values at these stations were considerably higher than the STORET (1979-1982) mean value of 21.5 mg/l. A perusal of the chloride data (Table 4) indicated the discharges from the Union Underwear plant to the Campbellsville WWTP were responsible for the excessive chloride concentrations at the impacted stations. During the mid-July sampling period, the chloride values at the impacted stations had dropped to that approaching the upstream site (24-1) on Little Pitman (Figures 3, 4, and 5). At this time, the Union Underwear discharge had not reached station 24-4 on the Little Pitman creek. Union Underwear apparently utilizes chloride solutions in their industrial process, which are eventually discharged to the WWTP. Chloride is

Figure 3: Conductivity, Sodium (Na) and Chloride (Cl) Values on Little Pitman Creek at Stations 24-1 and 24-2



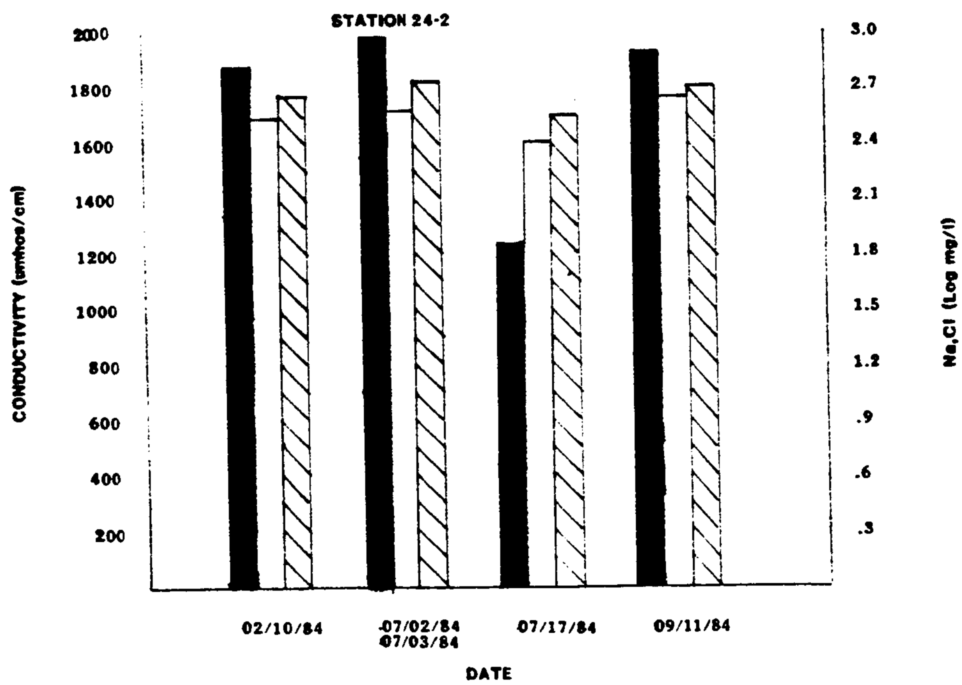
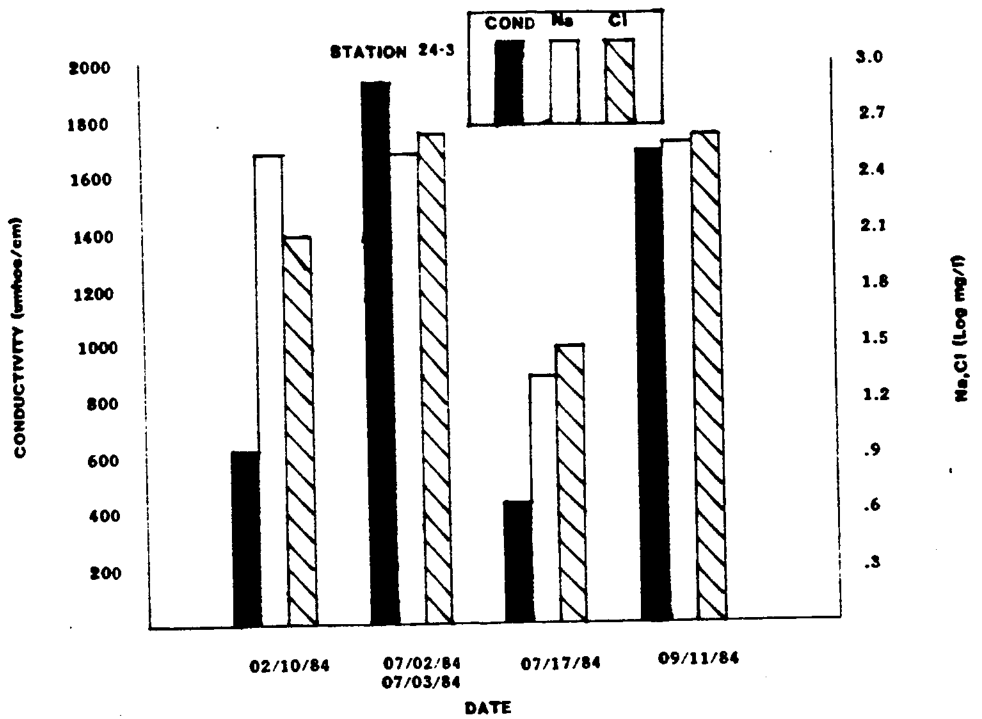


Figure 4: Conductivity, Sodium (Na) and Chloride (Cl) Values on Little Pitman Creek at Stations 24-3 and 24-4



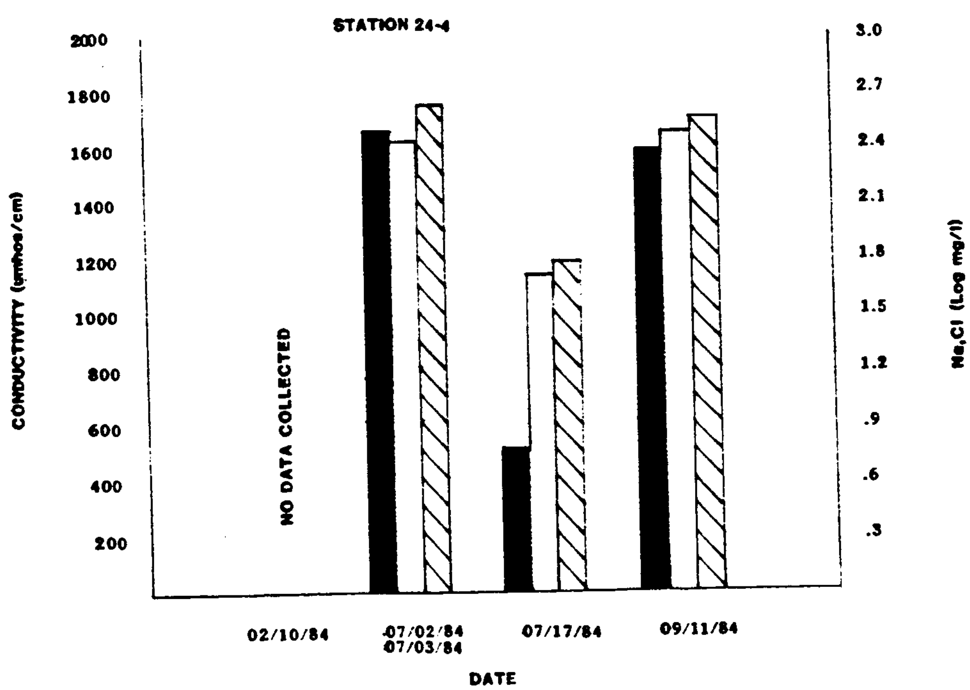
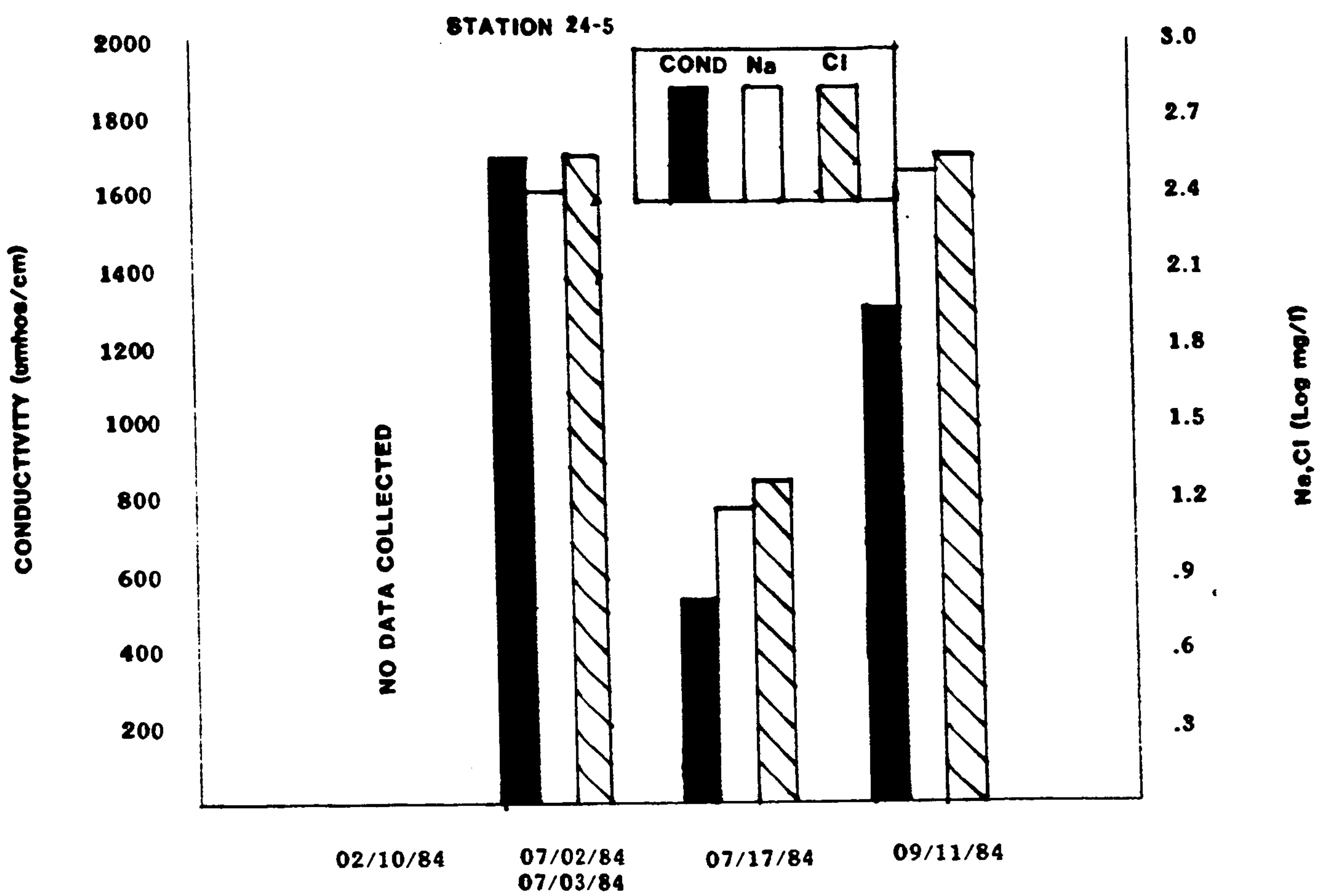


Figure 5: Conductivity, Sodium (Na) and Chloride (Cl) Values on Little Pitman Creek at Station 24-5



a universal constituent of sewage (Hynes 1974), primarily because of the dietary use of salt, which causes increased concentrations of chloride in domestic sewage over that normally found in freshwater (Dierberg and Brezonik 1983). However, the values seen in this study are extremely high (compared to other WWTP studies) and cannot be attributed solely to domestic wastes.

Total residual chlorine (TRC) was considerably higher at station 24-3 (below the WWTP) than at the station 24-1 (above the WWTP) during the February and early July sampling periods (Table 4). The February value observed at 24-3 is 30 times in excess of KSWS for warmwater aquatic habitat and exceeds U. S. EPA (1983) proposed criterion by more than 21 times. Since chlorine is extremely toxic to aquatic flora and fauna, the high levels of TRC observed at 24-3 may be responsible for the elimination and/or reduction of algae, macroinvertebrates and fish. By the mid-July sampling period, the Campbellsville WWTP had changed its chlorination practices and the TRC was comparable to other instream sampling locations.

The biochemical oxygen demand (BOD_5) generally remained low at all sampling locations, while the chemical oxygen demand (COD) was higher at the impacted stations (24-3, 24-4, 24-5, and 24-6). The BOD_5 value exceeded the STORET (1979-1982) mean value (1.31 mg/l) at station 24-3 during the February sampling period but was not considered high enough to adversely impact aquatic life. The BOD_5 values at all the remaining impacted sampling sites were considerably below the STORET (1979-1982) mean during all sampling periods. The low BOD_5 values for the impacted sites (24-3, 24-4, 24-5 and to a lesser extent 24-6) is unusual, since streams receiving municipal waste generally have BOD_5 values that exceed the STORET (1979-1982) mean value. The low values may be the result of a toxic condition caused by a constituent of the effluent, such as chloride or a metal(s).

The COD values were considerably elevated above the STORET (1979-1982) mean value of 13.42 mg/l at the impacted sites, except during the mid-July sampling period. Again, this seems to indicate the high values are the result of the Union Underwear industrial discharges.

Total Organic Carbon (TOC) displays the same pattern as COD. As with COD, the lower TOC values in mid-July seem to indicate that the aforementioned industrial effluent is the principal contributor.

Of the nutrients tested (ammonia-nitrogen (NH_3-N), nitrite+nitrate-nitrogen (NO_2 + NO_3 - N), total Kjeldahl nitrogen (TKN), total phosphorous (TP), and dissolved ortho phosphorous (P-ortho)), NH_3-N showed the least fluctuation. Ammonia-nitrogen remained consistently low, well below toxic levels, at all sampling locations. In fact, NH_3-N exceeded the STORET (1979-1982) mean value of 0.023 mg/l only in the February sample at station 24-3 (Table 4). Nitrite+nitrate-nitrogen underwent dramatic fluctuations at the impacted sites (Table 4). At least once during the sampling period, each impacted location (24-3, 24-4, 24-5, and 24-6) exceeded the STORET (1979-1982) mean value of 0.23 mg/l. In addition, at each impacted site, the NO_2 + NO_3 - N approached or exceeded the 2.0 mg/l value Patrick (1950) used to categorize healthy streams in the eastern United States. The total Kjeldahl nitrogen (TKN) concentration exceeded the STORET (1979-1982) mean value of 0.64 mg/l at the impacted locations (24-3, 24-4, 24-5, and 24-6). Total Kjeldahl nitrogen, a measure of organic nitrogen and ammonia (APHA 1981), is typically low in streams unless they are impacted by some type of organic waste. The total phosphorus concentrations at the impacted stations (24-3, 24-4, 24-5, and 24-6) also exhibited large fluctuations among sampling times. At those stations, the TP levels dramatically exceeded the STORET (1979-1982) mean value of 0.156 mg/l. These occasional excessive TP values, combined with the previously discussed high NO_2 + NO_3 - N values, have the potential to create severe eutrophication problems in the stream. Total phosphorus in flowing waters is generally below 0.1 mg/l (NTAC 1968, Keup 1968), except in streams receiving agricultural waste (Omernik 1977) or discharges from WWTP's (Wetzel 1975).

Free cyanide, undissociated hydrogen sulfide and phenols ocassionally exceeded Kentucky Surface Water Standards (KSWS) in the Big Pitman Creek system (Table 4). Those violations were generally found at the impacted sites (24-3, 24-4, 24-5, and 24-6).

In general, most total metals and minerals values were higher at the impacted locations (24-3, 24-4, 24-5, and 24-6) than at the control sites. Values for aluminum (Al), arsenic (As), barium (Ba), chromium (Cr), copper (Cu), manganese (Mn), potassium (K), sodium (Na) and zinc (Zn) were generally elevated at the impacted stations during one or more of the sampling periods (Table 4). STORET (1979-1982) mean values were exceeded for As, Ba, Cu, Mn and Zn. United States Environmental Protection (U. S. EPA) water quality criteria were exceeded at station 24-3 for Cu (U. S. EPA 1980a), Hg (U. S. EPA 1980b), Zn (U. S. EPA 1980c) and Cr (U. S. EPA 1980a). In addition, U. S. EPA (1980b) criteria for Hg was also exceeded at station 24-1 and cadmium (Cd) approached, but did not exceed, the U. S. EPA (1980d) criteria at station 24-3.

Sediment samples were taken above (24-1) and below (24-3) the Campbellsville WWTP during the February sampling period and from all sites except 24-10 during the early July sampling period (Table 6). All organic priority pollutants tested (Table 6) were below detection levels at all stations, except pentachlorophenol (24-1, 24-7) and 2,3,4,5 tetrachlorophenol (24-3, 24-4, 24-5, 24-6, 24-7, 24-8, and 24-9) (Table 6). During the February sampling period, the remaining parameters (metals, TOC, COD, nutrients and oil and grease) were generally higher at the downstream location (24-3). These parameters were compared with U. S. EPA (1977) sediment guidelines. With the exception of Al and TOC, for which there are no guidelines, all metals, nutrients and oil and grease fell within the unpolluted category, except for As and Mn during the February sampling period. Arsenic at station 24-3 was classified as moderately polluted, as was Mn at 24-1 during February.

Table 6: Sediment Data for the Big Pitman Creek Drainage

Stations	24-1		24-3		24-4	24-5	24-6	24-7	24-8	24-9
Parameter (mg/l)	2/10/84	7/2/84	2/10/84	7/2/84	7/2/84	7/3/84	7/3/84	7/3/84	7/10/84	7/10/84
PCB's	K0.01	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1
Aldrin	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Dieldrin	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
DDT	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
O,P'DDE	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
P,P'DDE	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
O,P'DDD	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
P,P'DDD	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
O,P'DDT	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
PP'DDT	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Chlordane	K0.03	ND	K0.03	ND	ND	ND	ND	ND	ND	ND
Cis Isomer (chlordane)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Trans Isomer (chlordane)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Oxychlordane	K0.01	ND	K0.01	ND	ND	ND	ND	ND	ND	ND
Trans Isomer (nonachlor)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Endrin	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Endrin Ketone	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Endrin Aldehyde	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Endosulfan I	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.0 1
Endosulfan II	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Endosulfan Sulfate	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Methoxychlor	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Hexachlorobenzene	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Pentachlorophenol	K0.01	0.028	K0.01	K0.01	K0.01	K0.01	K0.01	0.023	K0.01	K0.01
2,3,4,5-Tetrachlorophenol	K0.01	K0.01	K0.01	0.018	0.34	0.15	0.13	0.44	0.041	0.019
2,3,4,6-Tetrachlorophenol	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Hexachlorocyclohexane										
alpha BHC	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Delta BHC	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Beta BHC	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
gamma BMC (Lindane)	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Toxaphene	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1	K0.1
Mirex	ND	K0.01	ND	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01	K0.01
Cn	ND	K0.49	ND	K0.49	K0.50	K0.50	K0.48	K0.49	K0.50	K0.50
As	1.51	0.202	3.98	0.133	0.090	0.124	0.189	0.112	0.226	0.078
Cd	0.085	0.016	0.269	0.048	0.057	0.35	0.009	0.009	0.029	0.028
Cr	3.38	0.976	16.6	25.9	21.9	21.0	7.89	2.84	6.40	14.3
Cu	8.61	6.35	13.0	4.88	16.9	2.26	6.34	3.14	1.66	4.99
Hg	0.027	0.027	0.130	0.027	0.047	0.026	0.029	0.018	0.043	0.028
Pb	14.4	15.3	20.8	19.0	23.8	13.2	16.0	11.8	20.7	28.8
Zn	26.4	16.4	47.1	69.9	79.3	58.4	19.3	11.5	31.7	21.8
Al	4090.0	4320.0	6820.0	2280.0	2210.0	2390.0	2630.0	1120.0	4290.0	2810.0
Fe	6530.0	4080.0	10700.0	6910.0	5990.0	7080.0	5390.0	2450.0	5450.0	4920.0
Mn	483.0	296.0	1370.0	686.0	381.0	619.0	534.0	161.0	649.0	669.0
Ni	7.69	4.82	11.8	4.96	3.90	0.027	4.69	2.46	2.40	3.92
NH_3-N	1.56	14.5	2.12	51.5	26.1	38.7	23.2	9.40	29.7	17.4
Oil and Grease	23.0	190.0	12.0	460.0	340.0	520.0	110.0	10.0	480.0	220.0
Total Kjeldahl Nitrogen	47.9	524.0	46.3	589.0	506.0	699.0	561.0	215.0	1980.0	1020.0
Total Organic Carbon	1.2	0.40	2.2	0.27	0.27	0.27	0.28	0.131	ND	ND
Volatile Solids	4.9	4.5	4.75	2.6	10.1	3.9	3.8	1.8	ND	ND
Chemical Oxygen Demand	ND	24,900	ND	19,500	34,200	19,100	17,800	11,200	ND	ND

K - below detection levels
ND - not determined

During early July, sediment samples were taken from all sampling locations except 24-10. Cadmium, Cr, Zn, Fe and oil and grease were generally higher at the Little Pitman Creek sites downstream of the WWTP (24-3, 24-4, 24-5) than at other sampling sites. The TKN values observed during the early July sampling period were highest at the Middle Pitman sites (24-8, 24-9). Comparing the parameter values from the early July sampling period with U. S. EPA (1977) criteria, Cr at 24-3 was moderately polluted and Mn was moderately polluted at 24-4 and heavily polluted at 24-3, 24-5, 24-6, 24-8 and 24-9.

BIOLOGICAL EVALUATION

Biological data were collected during every sampling period. Bacteria collections were made during June, twice in July and September. Algae collections were made in February, July and September, and fish and macroinvertebrate collections were made in February and July.

The bacteria data indicated the Campbellsville WWTP meets its NPDES fecal coliform permit requirements. Also, the Middle Pitman and Big Pitman sites did not violate the KSWS fecal coliform (FC) bacteria standard for primary contact recreation during low flow periods; however, KSWS FC standards were exceeded in Little Pitman Creek at one or more stations during all sampling periods.

Algal data indicated the excessive chlorination practices previously employed by the Campbellsville WWTP in February severely impacted the periphyton community in Little Pitman Creek. Effluent chlorination was reduced in June, 1984. Abundant periphyton growth occurred in Little Pitman when the Union Underwear plant was closed for vacation during early July, due to the high nutrient concentrations originating from the WWTP effluent. Periphyton growth was significantly lower in September after the plant resumed operation. The color observed in Little Pitman below the WWTP appears to restrict benthic algal growth.

During February, the macroinvertebrate community was depauperate in Little Pitman Creek below the Campbellsville WWTP, a result of the excessive chlorination practices. After cessation of excessive chlorination, a portion of the macroinvertebrate community was reestablished in Little Pitman Creek; however, the scraper-grazer functional group remained severely reduced. This functional group requires attached periphyton as a food source. The inhibition of attached periphyton resulting from the high color levels is associated with the reduction in or elimination of the scraper-grazer functional group. The macroinvertebrate species diversity ($\bar{d}$) and equitability (e) values for Little Pitman below the WWTP were characteristic of impacted streams; the remainder of the Big Pitman system generally had higher $\bar{d}$ and e values (Appendix D).

The Big Pitman Creek system supports a speciose fish fauna. However, Little Pitman Creek below the WWTP exhibited classical effects of stream pollution from wastewater. There was a reduction of darters and intolerant species in Little Pitman below the WWTP when compared to control areas.

Stations 24-8 and 24-9 on Middle Pitman Creek were compared to stations 24-1 and 24-5 on Little Pitman Creek respectively. Stations 24-1 and 24-8 and stations 24-5 and 24-9 were similar in gradient, discharge, stream order, and drainage area. The algal, macroinvertebrate and fish communities were similar at 24-1 and 24-8, but 24-5 differed substantially from 24-9. This is attributed to the discharge of the Campbellsville WWTP effluent to Little Pitman Creek.

Toxic screening tests conducted on the Campbellsville WWTP effluent in February by DES (1984) and U. S. EPA showed the effluent to be toxic. Again, this was probably the result of excessive chlorination. The DOW toxicity tests conducted on the WWTP effluent in July indicated no toxicity at any concentration to fathead minnows.

The biological data indicate that the entire reach of Little Pitman Creek (10 mi) below the Campbellsville WWTP is impaired. This impairment extends downstream in Big Pitman Creek for at least 2.6 miles below the confluence with Little Pitman Creek.

Bacteria

The fecal coliform (FC) standard for primary contact recreation (KAR 5:031, section 7 (1)) was violated in 62% of 34 samples, with 11 of 16 samples taken from Little Pitman Creek being in violation (Table 7). The FC standard for secondary

Table 7: Big Pitman Creek System
Bacteriological Results

Station	Source		20 June 84	10 July 84	17 July 84	11 Sept 84
24-10	Buck Horn Creek	FC	1100	1200/1200*	1800	40
		FS	ND	340/300*	110	54
		FC/FS	ND	3.5/4.0	16.36	0.74
24-2	Campbellsville WWTP	FC	<2	14	80	10
		FS	ND	60	200	10
		FC/FS	ND	0.23	0.4	1.0
	Total chlorine residual (mg/l)		5.7	0.5	0.2	0.5
	Lbs Per Day Chlorine		800	75	25	75
24-1	Little Pitman Creek	FC	2	1600	2000/1500*	400
		FS	ND	400	1000/1200*	1500
		FC/FS	ND	4.0	2.0/1.25*	0.27
24-4	Little Pitman Creek	FC	>800	1000	1400	400
		FS	ND	260	460	1900
		FC/FS	ND	3.85	3.04	0.21
24-3	Little Pitman Creek	FC	ND	1600	1200	280
		FS	ND	400	310	1200
		FC/FS	ND	4.0	3.87	0.23
24-5	Little Pitman Creek	FC	210	1400	1400	520
		FS	ND	360	370	1200
		FC/FS	ND	3.89	3.78	0.45
24-8	Middle Pitman Creek	FC	ND	1800	ND	ND
		FS	ND	1700	ND	ND
		FC/FS	ND	1.06	ND	ND
24-9	Middle Pitman Creek	FC	ND	1000	ND	30
		FS		580	ND	1300
		FC/FS	ND	1.72	ND	0.02
24-11	Big Pitman Creek	FC	ND	ND	ND	260
		FS	ND	ND	ND	520
		FC/FS	ND	ND	ND	0.5
24-7	Big Pitman Creek	FC	270	660	ND	410
		FS	ND	290	ND	340
		FC/FS	ND	2.28	ND	1.21
24-6	Big Pitman Creek	FC	ND	1100	5600	160/140*
		FS	ND	350	1800	290/240*
		FC/FS	ND	3.14	3.11	0.55/0.58*

FC - Fecal Coliforms per 100 ml
FC/FS - Fecal Coliforms/Fecal Streptococci Ratio
*Duplicate Sample Analysis

FS - Fecal Streptococci per 100 ml
ND = Not Determined

contact recreation (KAR 5:031, Section 7 (2) (a) (Table 4)) was not violated at any station. There were no violations of the standard for pH.

Results of fecal coliform and fecal streptococcal (FS) analyses indicated Little Pitman Creek receives fecal pollution from both man and animal. The FC/FS ratios, which indicate the origin of fecal pollution being man or animal, generally indicated both sources were contributing fecal pollution to Little Pitman Creek (Table 7). The source of the fecal pollution is most likely due to nonpoint sources (i.e. septic tank infiltration into surface waters and agricultural runoff). The largest discharger in the drainage, the Campbellsville WWTP, is one of the lesser contributers of fecal pollution with FC counts less than all the other stations during the sampling periods (Table 7).

During normal operation of the Campbellsville WWTP, to remove color received from the Union Underwear discharge, approximately 800 lbs per day of chlorine was used from February through June. Comparing chlorine use per day versus permit compliance for FC bacteria, approximately ten to thirty times the required chlorine dosage necessary for disinfection was used. This level of chlorination (800 lbs per day) is capable of causing instream disinfection and a higher level of chlorinated by-products such as trihalomethanes and chloramines. Even with the excessive chlorination, extreme color persisted.

Both the excessive chlorination to remove the color and the color itself have pronounced effects on the aesthetic quality of recreational waters. Color has an effect on the aesthetic appearance of the water. It is important that swimming areas be clear enough for users to estimate depth and see subsurface hazards easily (EPA, 1982 draft). During sample collection in February, early July and September on Little Pitman Creek, the stream bottom was not visible through a large portion of the stream reach due to the color discharged by the Campbellsville WWTP when Union Underwear was in operation.

Secondary contact recreation (i.e. boating, fishing) is adversely affected by the color caused by the Union Underwear discharge. Boating and fishing requires aesthetically pleasing water for its full enjoyment (CWQC 1973).

Algae

Surface and benthic periphytometers (artificial substrates) were utilized in this study to assess the effects of nutrient enrichment, turbidity and color, and toxicity on actively growing attached algal communities (2 week exposure period). Nutrient enrichment increases algal standing crop (chlorophyll a) and biomass (AFDW). In the absence of water column turbidity and/or color, benthic values are generally elevated (sometimes exceeding surface values) due to sedimentation of nutrient rich particles in pool (depositional) areas. In turbid or highly colored waters, benthic algal growth is limited by reduced light availability, while surface periphytometer values are relatively unaffected. Under conditions of toxicity, both surface and benthic values are negatively affected (DES 1983, 1984).

In an earlier study (DES 1984), it was found that excessive chlorination to remove color from the Campbellsville WWTP treated effluent was toxic to attached algal communities at a downstream site (24-3), while water quality at the upstream control site (24-1) allowed the development of typical periphyton communities.

Data collected in July 1984, when the Union Underwear plant was closed for vacation, show a pattern of longitudinal variation in algal biomass and standing crop (Figures 8 and 9) typical of streams affected by WWTP discharges. Maximum surface and benthic values were observed at station 24-3, located 6.5 miles downstream from the WWTP. Values remained elevated, with respect to the control station (24-1), at the downstream station, 24-5. Nutrient values were high at all Little Pitman Creek sites below the WWTP.

Comparison of parallel sites on Middle and Little Pitman creeks (Figure 1) showed that, while headwater sites (24-1, 24-8) were not significantly different, chlorophyll a was significantly higher in Little Pitman Creek (24-5) than Middle Pitman Creek (24-9) (Table 8). This was attributable to nutrient enrichment from the Campbellsville WWTP.

Data collected in September 1984, when the Union Underwear plant was in operation, show the effects of turbidity and color as well as toxicity. While values at the control station (24-1) were higher than in July due to seasonal factors, values downstream were consistently lower (Figures 6 and 7). Significantly lower surface values, particularly at stations 24-4 and 24-5, suggest toxic effects, while the persistently low values of benthic chlorophyll a downstream from the WWTP show the negative effect of turbidity and color and/or toxicity on benthic algal communities. The elevated benthic AFDW values at 24-5 (Figure 7) are attributable to the sedimentation of cotton fiber particles from the Union Underwear plant.

Analysis of algal communities that had colonized the glass periphytometer slides during the two week exposure period in September revealed only small differences in diatom diversity ($\bar{d}$), equitability (e), and community structure (Appendix C) among the sites. Stations located downstream from the WWTP contained larger abundances of halophilic species, which parallels physicochemical data for chlorides and conductivity. Nitrogen heterotrophic species were dominant at all Little Pitman Creek stations. These diatoms are able to reduce nitrogenous compounds to provide energy for metabolism in lieu of sunlight. Large populations of heterotrophs are generally found downstream of WWTP discharges.

Little Pitman Creek

Station 24-1

Located 0.5 miles upstream from the WWTP discharge, this site served as a control station in the study. Mean values for chlorophyll a and AFDW in July were not significantly different from those observed in Middle Pitman Creek, station 24-8.

Figure 6: Surface and Benthic Chlorophyll a Data for the Big Pitman Creek System

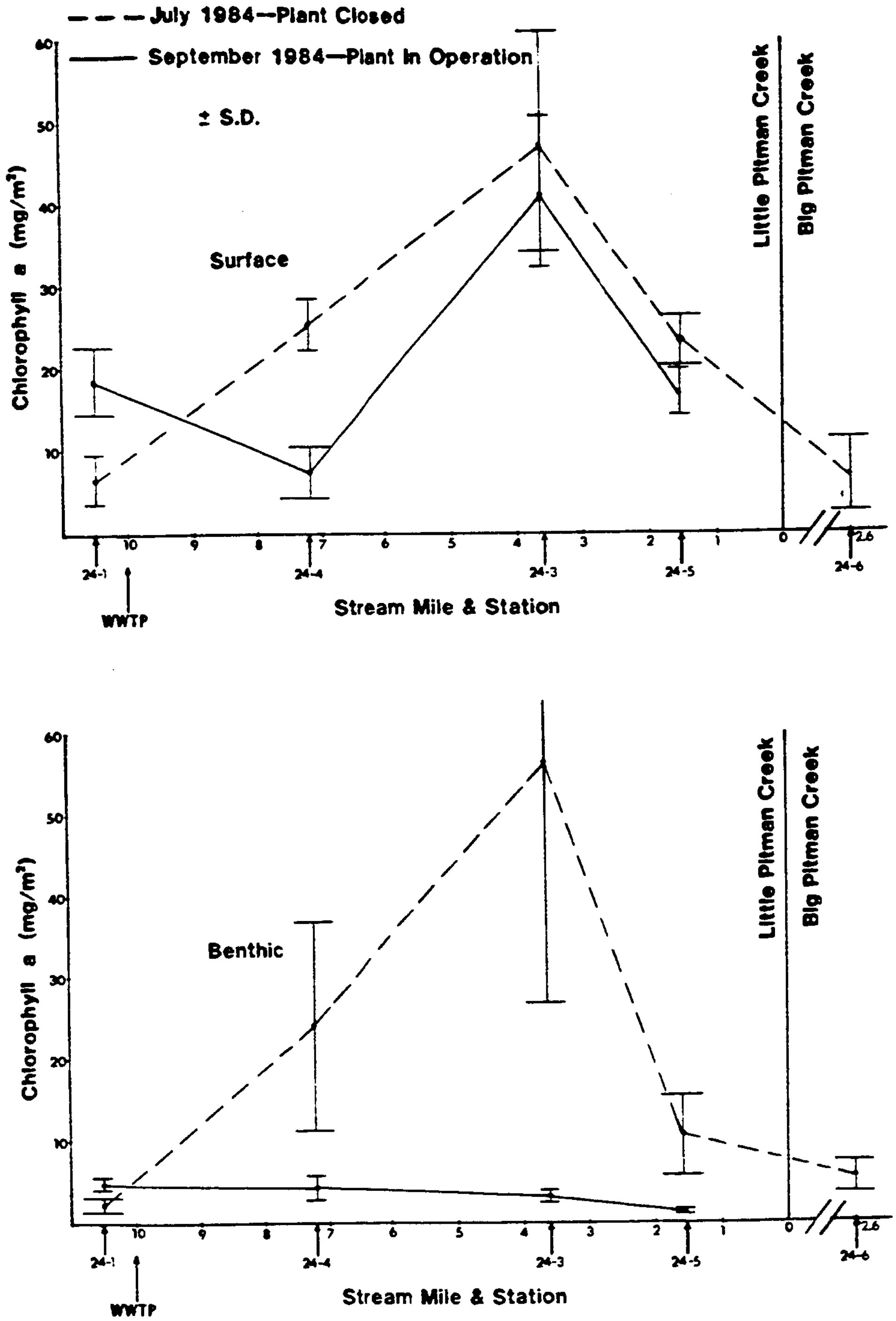
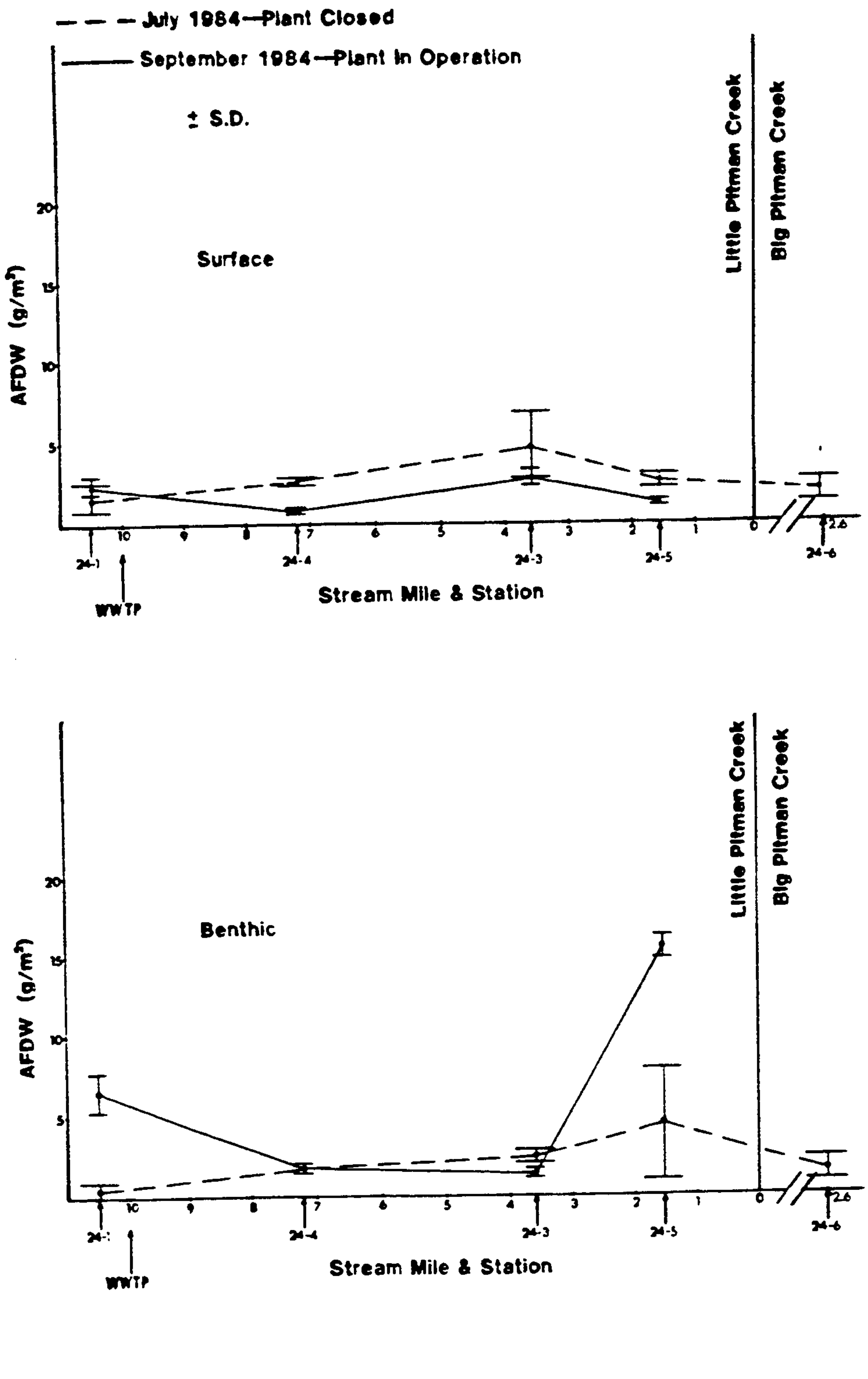


Figure 7: Surface and Benthic Ash Free Dry Weight (AFDW) for the Big Pitman Creek System



Surface and benthic chlorophyll a values in July were significantly lower than other sites downstream in Little Pitman Creek. Biomass (AFDW) values were significantly lower than those observed at 24-3 but not significantly different from station 24-5.

Chlorophyll a and AFDW values were higher in September than July. This was probably attributable to normal seasonal variation. In contrast, these values were lower in September than July at other sites downstream (Figure 6 and 7). Benthic AFDW values were significantly higher ($\alpha = .005$) than observed at 24-3 and 24-4 in September.

The periphyton community (Appendix C), exclusive of diatoms, consisted largely of planktonic forms, notably the green algal order Chlorococcales. Immature filaments of *Oedogonium* and *Stigeoclonium* were observed on the two week exposure glass slides. The diatom community consisted of a diverse ($\bar{d} = 4.353$, e = 0.558) assemblage of tolerant species (Appendix C). Nitrogen heterotrophic species (*Nitzschia frustulum*, *N. palea*, and *N. amphibia*) (Lowe 1974) dominated (28.6% relative abundance) the community. However, the abundance of *Achnanthes linearis* (16.9%) suggests slightly better water quality here than at the downstream sites. Cholnoky (1968) indicated that this species thrives under conditions of high dissolved oxygen.

Little Pitman Creek

Station 24-3

In contrast to samples collected earlier this year (refer to DES 1984), values for chlorophyll a and AFDW were more typical of nutrient enriched streams. Surface and benthic chlorophyll values were the highest observed during the study. Surface values were significantly higher than at other stations on Little Pitman Creek during both July and August (Figure 6) and exceeded the average periphyton chlorophyll value (17.90 mg/m^2) for streams in Kentucky (DOW unpublished data). Benthic values exceeded surface values in July (Table 8). This phenomonen has been previously observed in streams affected by point source nutrient enrichment (DES 1983). In contrast, benthic values in September were significantly lower (α = .025) (Figure 6), suggesting reduced light penetration due to color and/or toxicity limited algal production.

While surface chlorophyll a values observed in July and September were not significantly different, both surface and benthic AFDW values were significantly lower (α = .005) in September. The reduction of benthic AFDW with respect to the control station (24-1) during September was highly significant. The darkly colored water at this site apparently limits benthic algal production, due to light inhibition and possible toxicity. Surface AFDW, as well as benthic chlorophyll and AFDW, were significantly lower in September when the Union Underwear plant was in operation. Nutrient values, notably phosphorous, were high in September, sufficient to support considerably greater algal biomass and standing crop than was evident in the September periphyton data.

The periphyton community was dominated by tolerant diatoms. Non-diatom algae were limited to sparse amounts of planktonic *Scenedesmus* species (Appendix C). Diversity (4.059) and equitability (0.530) were similar to other sites in Little Pitman Creek. Nitrogen heterotrophic species (Schoeman 1973, Lowe 1974) accounted for over 60% of the diatom community. Species associated with elevated conductivity (Patrick and Reimer 1966, Cholnoky 1968) were prominent in the community.

Little Pitman Creek

Station 24-4

Surface chlorophyll a and AFDW were significantly lower (α = .005) in September than July. While benthic AFDW values were the same in both months, benthic chlorophyll a followed the same pattern as surface values (Figure 6). Surface chlorophyll a and benthic chlorophyll and AFDW were significantly higher than the control station (24-1) in July due to nutrient enrichment from the WWTP, notably phosphorous (Table 3). However, despite similar or higher nutrient concentrations in

Table 8: Mean Chlorophyll a and AFDW Values for Big Pitman Creek Drainage

	Chlorophyll a (mg/m^2)		Ash-free Dry Weight (g/m^2)	
Station	July Surface (Benthic)	September Surface (Benthic)	July Surface (Benthic)	September Surface (Benthic)
24-1	6.01 (2.52)	18.19 (4.95)	1.76 (0.44)	2.39 (6.61)
24-3	47.67 (57.03)	41.57 (3.42)	4.80 (2.50)	2.79 (1.50)
24-4	25.72 (24.76)	7.20 (4.50)	2.86 (1.90)	0.93 (1.90)
24-5	23.29 (10.26)	16.71 (1.41)	2.54 (4.89)	1.30 (15.82)
24-6	6.94 (5.21)	N.S.	2.00 (1.76)	N.S.
24-7	28.11 (35.87)	N.S.	6.01 (7.76)	N.S.
24-8	14.17 (6.67)	N.S.	1.85 (N.S.)	N.S.
24-9	3.56 (0.91)	N.S.	N.S.	N.S.

N.S. - not sampled or sampler not recovered

September, surface chlorophyll and AFDW values (as well as benthic AFDW) were significantly lower (α = .005) than the control station, located 3.3 miles upstream (Figures 6 and 7). This suggests that algal communities were being limited by color as well as toxicity during the September sampling period.

The periphyton community, exclusive of diatoms, was limited to three tolerant taxa. The diatom community was dominated (over 60% relative abundance) by nitrogen heterotrophic species (Appendix C). Diversity (4.353) and equitability (0.558) were similar to other stations in Little Pitman Creek. Species associated with elevated conductivity were prominent in the community.

Little Pitman Creek

Station 24-5

Surface chlorophyll **a** and AFDW, as well as benthic chlorophyll **a** were significantly lower in September than July (Figures 6 and 7). While chlorophyll **a** was significantly higher than the control station (24-1) in July, benthic values were significantly less (α = .005) than the control station in September.

In contrast, benthic AFDW values were higher than the control station in September. Values for benthic AFDW were significantly higher (α = .005) in September than July and represented the highest values observed in the study (Figure 9). Since benthic chlorophyll values were among the lowest observed in the study (Table 8), these high benthic AFDW values are not attributable to attached algae. A large amount of very fine white particles were resuspended in the water column when sediments were disturbed at this station. Earlier analysis of this material (DES 1984) indicated that it was composed largely (93%) of cotton fibers. This phenomenon was also noticed at 24-3 and 24-4, but not to the extent noted here. The likely source of these fine particles is the Campbellsville WWTP and/or the Union Underwear property. It is felt that the sedimentation of these particles in pool areas at this site accounts for the high AFDW values observed here in September. The accumulation of cotton fibers, which are organic material, on benthic slides is reflected as ash-free dry weight. As mentioned previously, the high AFDW values observed here do not represent algal biomass.

In comparison with Middle Pitman Creek, station 24-9, surface chlorophyll **a** was significantly higher at 24-5. Values for nutrients, notably phosphorous, were considerably higher here than at 24-9. The higher nutrient values here are attributable to the Campbellsville WWTP.

The periphyton community, exclusive of diatoms, was limited to one species, *Schizothrix calcicola*, which tolerates a wide range of water quality conditions (Drouet 1968). The diatom community was dominated by tolerant heterotrophic and halophilic species (Appendix C). Diversity (4.059) and equitability (0.530) were similar to other sites in Little Pitman Creek. Species associated with elevated conductivity were very prominent in the community (over 30% relative abundance).

Big Pitman Creek

Stations 24-6 and 24-7

Despite greater nutrient availability at 24-6 (2.6 miles below confluence of Little Pitman Creek) compared with 24-7, algal standing crop and biomass were significantly higher (α = .005) at the upstream site (24-7). While surface chlorophyll **a** was significantly higher than Little Pitman Creek (Figure 6), AFDW and benthic chlorophyll **a** were not significantly different than station 24-5. Sources of nutrients in the Big and Middle Pitman watersheds are probably limited to agricultural activities. The reduction in algal production between stations 24-7 and 24-6 (4.6 miles) (refer to Figure 1) is apparently related to the influence of Little Pitman Creek. According to flow data taken in July, 25% of the flow at 24-6 (Table 3) is attributable to Little Pitman Creek.

Benthic chlorophyll **a** and AFDW values exceeded surface values at station 24-7 (Table 8). This was possibly due to sedimentation of nutrient rich soil particles in pool areas at this site. Agricultural activities are extensive in the Middle and Big Pitman

Creek watersheds. Big Pitman Creek appeared to be carrying a greater silt load in July than either Little or Middle Pitman Creek. Chlorophyll **a** and AFDW values at 24-7 exceeded the average periphyton values (17.90 mg/m^2 and 3.47 g/m^2, respectively) for streams in Kentucky (DOW unpublished data).

Middle Pitman Creek

Stations 24-8 and 24-9

Middle Pitman Creek roughly parallels Little Pitman Creek (Figure 1), with impacts limited to agricultural activities. Station 24-9 was located at the same relative position on Middle Pitman Creek as 24-5 was on Little Pitman Creek, while station 24-8 corresponded with station 24-1, Little Pitman Creek. The relationship between these station pairs has been previously discussed. Surface chlorophyll **a** values were significantly higher (α = .005) at 24-8. The apparent reduction in chlorophyll **a** at 24-9 may be due to a more dense tree canopy at 24-9 and/or upstream utilization of nutrients by algae (as well as adsorption by sediments). No known sources of toxicity are present in the Middle Pitman Creek watershed.

Macroinvertebrates

The invertebrate collections (Appendix D) from Little Pitman Creek reflected obvious differences in species composition and functional groups that are related to a long term degradation of water quality. Those differences are best illustrated when compared to the collections from Middle Pitman (24-8, 24-9), a parallel tributary in the drainage that is considered to be free of obvious impacts and very similar in stream conditions to comparable sites on Little Pitman (24-1 and 24-5).

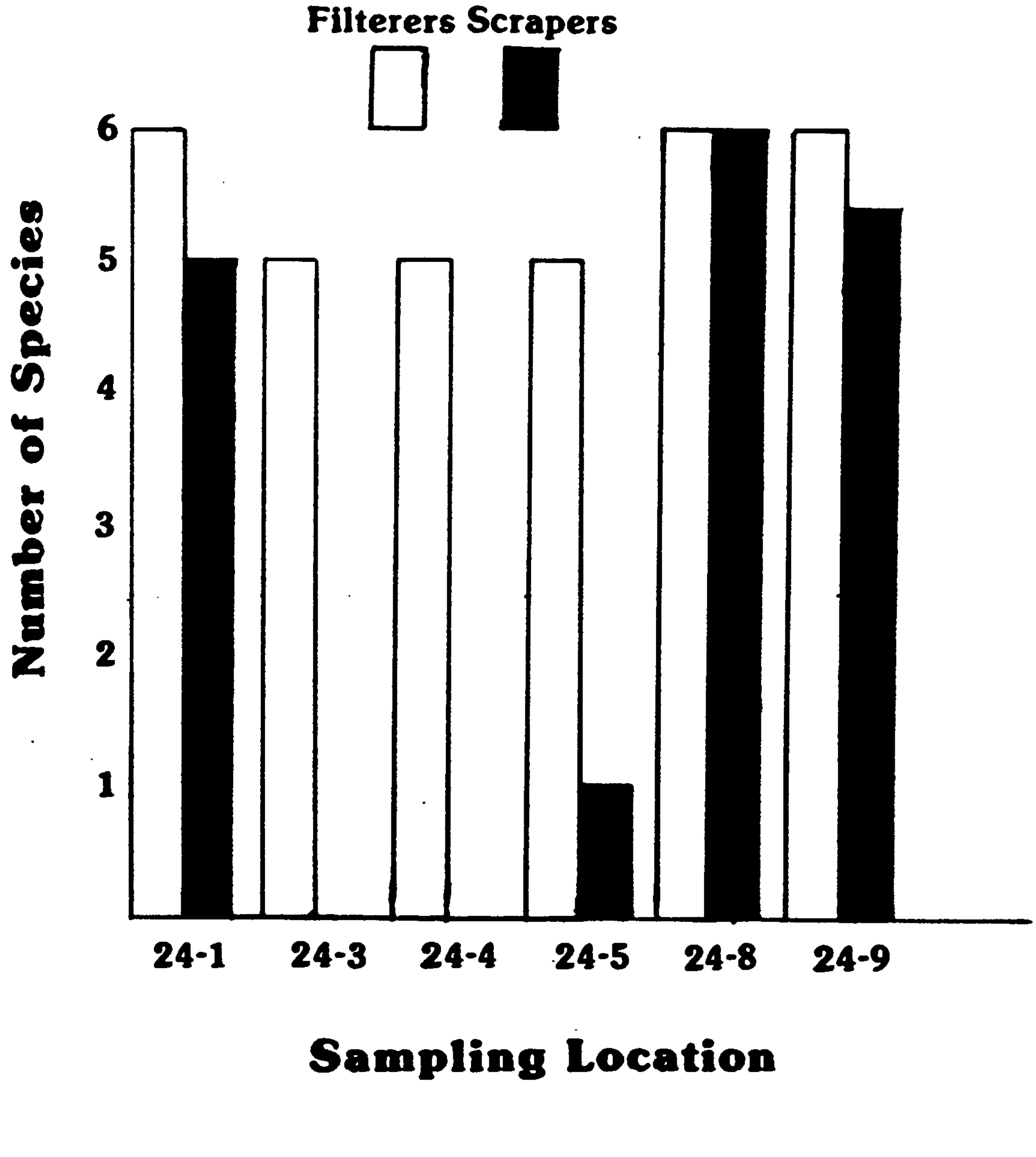
The biological collections taken in early July (after the cessation of excessive chlorination) indicated a portion of the benthic community had become re-established in Little Pitman Creek. In the quantitative collections, $\bar{d}$ and e values were lower in Little Pitman below the WWTP when compared to Middle Pitman or the upstream station (24-1) (Appendix D). The values for $\bar{d}$ and e observed in Little Pitman Creek at 24-3, 24-4 and 24-5 are indicative of impacted streams (refer to Weber 1973). Also, the invertebrate community structure indicated color was indirectly affecting certain members of the community by inhibiting light penetration to a stream substrate, resulting in a reduction of attached periphyton, the only food source for a large group of organisms in the scraper-grazer functional group. This diverse group is an integral and often a dominant component of invertebrate communities in lotic (running) waters. In Little Pitman Creek downstream of the WWTP, scraper-grazer organisms were absent. To illustrate this, the filterers and scraper-grazers functional feeding groups were plotted by number of species at each station on Little and Middle Pitman Creeks (Figure 8). The deleterious effects of color upon attached periphyton and subsequently upon the invertebrate scraper-grazer group are readily obvious. It should be noticed that station 24-5 on Little Pitman contained a single scraper organism in four separate samples. If color continues at the levels observed during this study, the large scraper-grazer functional group will also continue to be absent or severely reduced in the entire length of Little Pitman Creek.

Fishes

A total of 35 species of fish were collected from the Big Pitman Creek drainage (Appendix E), 26 of which were taken at stations on Little Pitman Creek. Number of species per site ranged from three (Little Pitman 24-4) to 19 (Middle Pitman 24-8).

The fish communities of Little Pitman Creek exhibit classical effects of stream degradation by, and recovery from, wastewater. The fish community at the site immediately upstream of Buck Horn Creek (24-1) contained 18 species in July and was well balanced, with an IBI (Index of Biotic Integrity) (Karr 1981, Karr et al. 1984) of 48 which is considered good. Samples taken in February contained 12 species and had an IBI of 44 (fair).

Figure 8: Filter versus Scraper–Grazer Functional Feeding Groups at Selected Stations in the Big Pitman Creek System



However, the Little Pitman station immediately downstream of Buck Horn Creek (24-4) yielded only three tolerant species and had an IBI of 26 (very poor). Progressing downstream, station 24-3 yielded 11 species and an IBI of 38 (fair) (seven species and IBI of 34 in February) and station 24-5 contained 13 species and an IBI of 42 (fair).

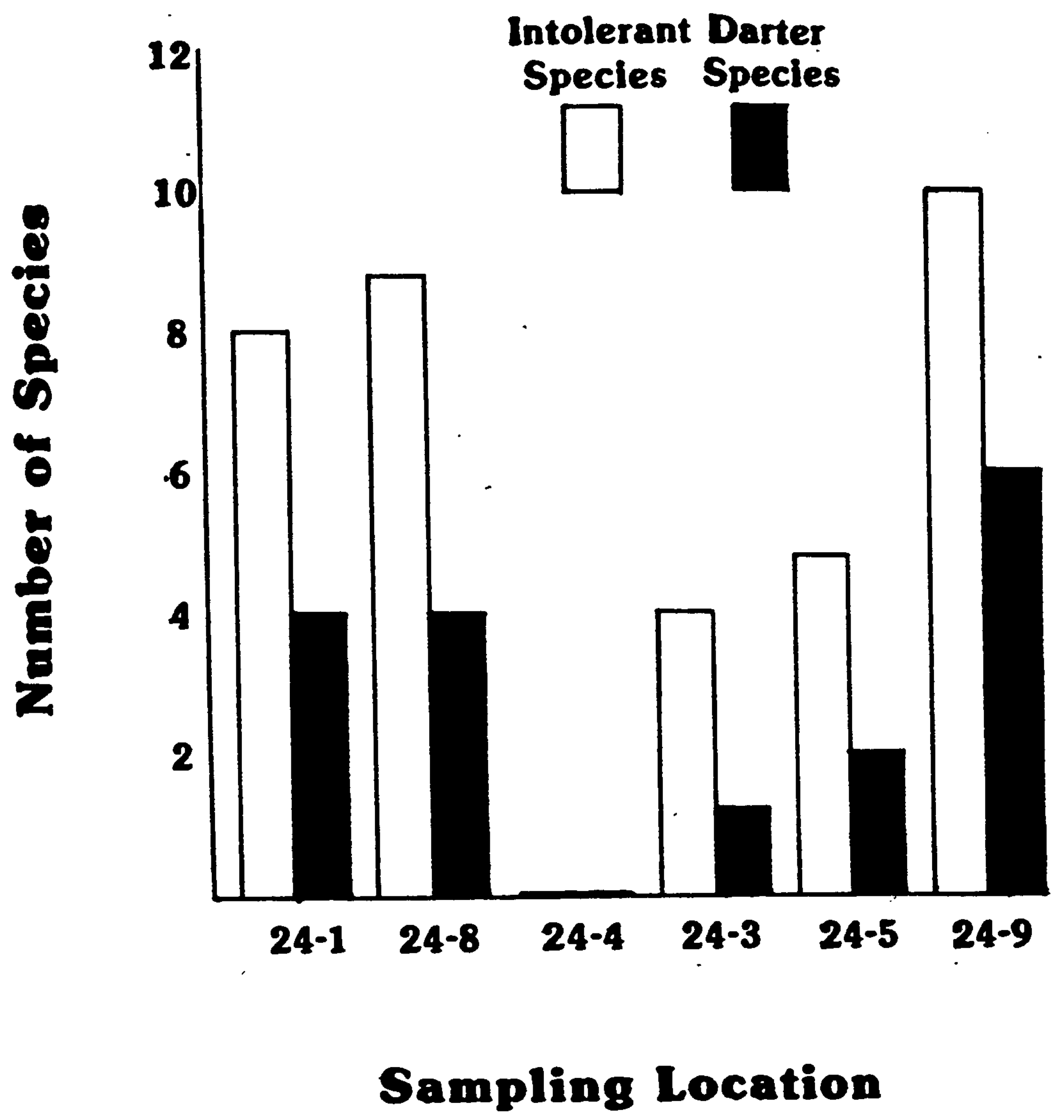
By contrast, two stations (24-8 and 24-9) on Middle Pitman Creek yielded 19 (IBI = 52 good) and 17 species (IBI = 46 good), respectively. Middle Pitman Creek is an adjacent, relatively unimpacted stream of similar size and habitats. Little Pitman, if unimpacted by WWTP effluents, would be expected to contain fish communities similar to Middle Pitman. The communities at upstream stations (24-1, 24-8) of both streams were very similar in structure and number of intolerant and darter species (Figure 9). However, the numbers of darters and of intolerant species were reduced at 24-5 (Little Pitman) compared to 24-9 (Middle Pitman). Therefore, it appears that the Campbellsville WWTP effluent is having an adverse effect on the fish fauna of Little Pitman Creek for the entire reach below Buck Horn Creek (10 mi). The effects are probably both direct (i.e. toxicity) and indirect (reduction of food organisms).

The fish data collected from Big Pitman Creek (14 species at 24-6 and 15 species at 24-7) is probably not indicative of the fish community present. Although water quality was considered good, the large size of the stream made it difficult to properly sample all habitats.

Toxic Screening Evaluation

Both the 24-hour static screening test (DES, Feb. 10) and the 24-hour static toxicity test (EPA) show that at the times sampled, the effluent from the Campbellsville WWTP was acutely toxic to aquatic life. However, results from the July and September tests showed no mortality in the effluent. The toxicity noted in the

Figure 9: Intolerant and Darter Species Present at Selected Stations in the Big Pitman Creek System



February sample was apparently due to excessive chlorination employed at that time by the Campbellsville WWTP. This chlorination practice had ceased by the July sampling period. These screening tests indicate that the WWTP effluent was not acutely toxic in 24 hours; however, the potential for chronic toxicity of the WWTP effluent may exist.

On February 10, July 11 and September 12, 24-hour static screening tests were conducted on grab samples of the effluent from the Campbellsville WWTP. In addition, on September 12, screening tests were run on the influent to the Campbellsville WWTP and on the effluent from Union Underwear. Organisms used in the studies included the fathead minnow (*Pimpehales promelas*) and the water flea (*Daphnia pulex*).

Results of the February 10 test on the Campbellsville WWTP effluent are given in Table 9. Both the fathead minnows and *Daphnia pulex* showed 100% mortality after 30 minutes exposure in 100% effluent and after 15 to 20 hours exposure in 50% and 25% effluent dilutions. Mortality in the remaining dilutions was recorded after 24 hours. A 100% mortality for fathead minnows and water fleas was observed after 24 hours in the 6.25% effluent. No mortality occurred in the 1.5% dilution or the control. Dissolved oxygen, pH and ammonia levels were not considered limiting factors in this test. The acute toxicity to the test organisms was attributed to the excessive chlorination which was employed by the Campbellsville WWTP during this sampling time.

Table 9: Toxicity to Fathead Minnows and Waterfleas by the Campbellsville WWTP Effluent at Various Concentrations on February 10, 1984

% Effluent	Fathead Minnows 0 Hr	Fathead Minnows 24 Hr	Waterfleas 0 Hr	Waterfleas 24 Hr
0	10	10	10	10
1.50	10	10	10	10
3.12	10	7	10	2
6.25	10	0	10	0
12.5	10	0	10	0
25	10	0	10	0
50	10	0	10	0
100	10	0	10	0

Results of the July 11 test on the Campbellsville WWTP effluent are given in Table 10. Only fathead minnows were used in the test. No mortality was reported in any concentration of effluent. Dissolved oxygen, pH and ammonia levels were not considered limiting factors. Excessive chlorination by the Campbellsville WWTP had ceased prior to this sampling period.

Table 10: Toxicity to Fathead Minnows by the Campbellsville WWTP Effluent at Various Concentrations on July 11, 1984

% Effluent	Fathead Minnows 0 Hr	Fathead Minnows 24 Hr
0	6	6
1	6	6
10	6	6
50	6	6
100	6	6

Results of the September 12 toxicity tests on the Campbellsville WWTP effluent are given in Table 11. Again, only fathead minnows were used. Dissolved oxygen, pH and ammonia levels were not considered limiting factors.

Table 11: Toxicity to Fathead Minnows by the Campbellsville WWTP Effluent at Various Concentrations on September 12, 1984

% Effluent	Fathead Minnows 0 Hr	Fathead Minnows 24 Hr
0	6	6
1	6	6
10	6	6
50	6	6
100	6	6

EPA Region IV conducted a 24-hour static toxicity test on the Campbellsville WWTP effluent, during a Compliance Sampling Inspection (CSI) inspection on June 21, 1983. They reported an effluent LC50 of 16% for fathead minnows. A similar toxicity test performed on a sample taken 250 feet upstream of the Campbellsville effluent discharge resulted in no mortality, while a sample taken 250 feet downstream had a LC50 of 16.5%.

Appendix A

Site Information

Site No:	03024001
Stream:	Little Pitman Creek
County:	Taylor
Location:	.3 mi upstream of KY 210 bridge
Latitude:	37° 21' 06"
Longitude:	85° 22' 31"
Stream Order:	III
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	10.5
Sampling Dates:	July 2, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	3 to 12 m
Pool Depth:	.15 to .61 m
Pool Substrate:	Primarily bedrock with occasional boulders to fines
Riffle Width:	.3 to 1 m
Riffle Depth:	.12 to .15
Riffle Substrate:	Primarily gravel/pebble
Bank Height:	.6 to 1.5 m
Bank Slope:	60+%
Riparian Vegetation - %	
Trees:	40
Shrubs:	10
Herbs:	30
Root Mats:	10

Site Information

Exposed:	10
Width:	0 to 3 m
Canopy over Stream - %	50 to 75
Bank Stability:	Fair
Erosion:	Bank failure in areas of no trees
Sedimentation:	Slight
Imbeddedness:	1/4
Periphyton Abundance:	Moderate
Stream Habitat:	Riffle, pool, run, undercut banks, submerged roots, large rocks, gravel bars, various substrates
Hydraulic Structures:	Gravel bars
Physical Impacts:	None
Nonpoint Sources:	Pastures, KY 210, scattered dwellings

ND - Not Determined

Site Information

Site No:	03024002
Stream:	Effluent
County:	Taylor
Location:	Campbellsville WWTP
Latitude:	37° 20' 52"
Longitude:	85° 22' 45"
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	0.1 (Buck Horn Creek)
Sampling Dates:	July 3, 1984
Type Sampling:	Physicochemical

Site Information

Site No:	03024003
Stream:	Little Pitman Creek
County:	Green
Location:	Downstream of the KY 1516 bridge
Latitude:	37° 19' 22"
Longitude:	85° 28' 10"
Stream Order:	III
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	3.6
Sampling Dates:	July 2, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	4.6 to 12.2 m
Pool Depth:	.15 to .9 m
Pool Substrate:	Primarily cobble/pebble
Riffle Width:	.9 to 3 m
Riffle Depth:	.12 to .15 m
Riffle Substrate:	Primarily cobble/pebble
Bank Height:	1.5 to 4.6 m
Bank Slope:	60+%
Riparian Vegetation - %	
Trees:	20
Shrubs:	10
Herbs:	60
Root Mats:	5

Site Information

Exposed:	5
Width:	0 to 6.1 m
Canopy over Stream - %	0 to 25
Bank Stability:	Fair
Erosion:	Some bank failure where no trees
Sedimentation:	Slight
Imbeddedness:	1/4
Periphyton Abundance:	Moderate to dense
Stream Habitat:	Riffle, pool, undercut banks, rock ledges, submerged tree roots, submerged logs or stumps, large rocks, gravel bars, various substrates
Hydraulic Structures:	Gravel bars, ford
Physical Impacts:	Small, in-stream gravel dredge
Nonpoint Sources:	Pastures, KY 1516, gravel road

ND - Not Determined

Site Information

Site No:	03024004
Stream:	Little Pitman Creek
County:	Taylor
Location:	Downstream of bridge on Summersville Rd.
Latitude:	37° 20' 03"
Longitude:	85° 25' 10"
Stream Order:	III
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	7.2
Sampling Dates:	July 2, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	6.1 to 12.2 m
Pool Depth:	.15 to .9 m
Pool Substrate:	Primarily cobble/pebble with some boulders to fines
Riffle Width:	3 to 6 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Boulder to gravel sizes common
Bank Height:	.9 to 1.5 m
Bank Slope:	30 to 40%
Riparian Vegetation - %	
Trees:	50
Shrubs:	10
Herbs:	20
Root Mats:	10

Site Information

Exposed:	10
Width:	6.1 to 12.2 m
Canopy over Stream - %	50 to 75
Bank Stability:	Good
Erosion:	Some areas of bank failure downstream
Sedimentation:	Slight
Imbeddedness:	1/4
Periphyton Abundance:	Moderate to dense
Stream Habitat:	Pool, riffle, undercut banks, submerged roots and logs, large boulders, gravel bars, various substrates
Hydraulic Structures:	Gravel bars
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pasture and row crops), Summersville Rd.

ND - Not Determined

Site Information

Site No:	03024005
Stream:	Little Pitman Creek
County:	Green
Location:	KY 793 bridge
Latitude:	37° 19' 14"
Longitude:	85° 30' 10"
Stream Order:	III
USGS Topo Quad:	Summersville, KY
DOW Map No.:	7-36
RMI:	1.5
Sampling Dates:	July 3, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	4.6 to 15.2 m
Pool Depth:	.15 to .9 m
Pool Substrate:	Primarily cobble/pebble
Riffle Width:	1.5 to 3 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Primarily pebble/cobble
Bank Height:	1.5 to 3 m
Bank Slope:	60+%
Riparian Vegetation - %	
Trees:	40
Shrubs:	10
Herbs:	20
Root Mats:	10

Site Information

Exposed:	20
Width:	0 to 3 m
Canopy over Stream - %	50 to 75
Bank Stability:	Fair
Erosion:	Frequent bank failure in 0 buffer areas
Sedimentation:	Slight
Imbeddedness:	3/4
Periphyton Abundance:	Moderate to dense
Stream Habitat:	Pool, riffle, undercut banks, rock ledges, submerged roots and logs, man-made objects, gravel bars, various substrates
Hydraulic Structures:	Gravel bars, bridge abutments
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pastures and row crops), KY 793

ND - Not Determined

Site Information

Site No:	03024006
Stream:	Big Pitman Creek
County:	Green
Location:	KY 61 bridge
Latitude:	37° 18' 18"
Longitude:	85° 31' 40"
Stream Order:	V
USGS Topo Quad:	Summersville, KY
DOW Map No.:	7-36
RMI:	11.1
Sampling Dates:	July 3, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	6.1 to 15.2 m
Pool Depth:	.15 to .9 m
Pool Substrate:	Primarily cobble/pebble/boulder
Riffle Width:	3 to 6 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Primarily boulder/cobble/pebble
Bank Height:	1.5 to 3 m
Bank Slope:	60+%

Riparian Vegetation - %

Trees:	40
Shrubs:	15
Herbs:	20
Root Mats:	10

Site Information

Exposed:	15
Width:	0 to 6 m
Canopy over Stream - %	50 to 75
Bank Stability:	Fair
Erosion:	Bank failure in areas of 0 buffer
Sedimentation:	Slight
Imbeddedness:	1/2
Periphyton Abundance:	Moderate
Stream Habitat:	Pool, riffle, undercut banks, rock ledges, submerged roots and logs, large boulders, gravel bars, various substrates
Hydraulic Structures:	Gravel bars, bridge abutments
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pastures and row crops), KY 61

ND - Not Determined

Site Information

Site No:	03024007
Stream:	Big Pitman Creek
County:	Taylor
Location:	Ray Chadion Rd.
Latitude:	37° 19' 58"
Longitude:	85° 30' 25"
Stream Order:	IV
USGS Topo Quad:	Summersville, KY
DOW Map No.:	7-36
RMI:	15.7
Sampling Dates:	July 3, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	6.1 to 15.2 m
Pool Depth:	.15 to .9 m
Pool Substrate:	Primarily cobble/pebble/gravel
Riffle Width:	1.5 to 4.6 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	ND
Bank Height:	3 to 4.6 m
Bank Slope:	60 + %

<u>Riparian Vegetation - %</u>

Trees:	60
Shrubs:	10
Herbs:	20
Root Mats:	5

Site Information

Exposed:	5
Width:	0 to 5 m
Canopy over Stream - %	25 to 50
Bank Stability:	Fair
Erosion:	Bank failure in areas of 0 buffer
Sedimentation:	Slight
Imbeddedness:	1/2
Periphyton Abundance:	
Stream Habitat:	Pool, riffle, undercut banks, submerged roots and logs, large boulders, gravel bars, Justicia beds, various substrates
Hydraulic Structures:	Gravel bars, low water concrete bridge
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pastures and row crops), Ray Chadion Rd.

ND - Not Determined

Site Information

Site No:	03024008
Stream:	Middle Pitman Creek
County:	Taylor
Location:	Salem Road bridge
Latitude:	37° 22' 56"
Longitude:	85° 22' 52"
Stream Order:	III
USGS Topo Quad:	Saloma, KY
DOW Map No.:	8-37
RMI:	9.4
Sampling Dates:	July 10, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	3 to 9 m
Pool Depth:	.15 to .8 m
Pool Substrate:	Primarily gravel/fines/exposed bedrock
Riffle Width:	.9 to 3 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Boulder/cobble/pebble/gravel
Bank Height:	.9 to 3 m
Bank Slope:	30 to 60%

<u>Riparian Vegetation - %</u>

Trees:	50
Shrubs:	15
Herbs:	20
Root Mats:	10

Site Information

Exposed:	5
Width:	0 to 30 m
Canopy over Stream - %	25 to 100
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Slight
Imbeddedness:	1/2
Periphyton Abundance:	Sparse
Stream Habitat:	Pool, riffle, undercut banks, submerged roots and logs, large boulders, gravel bars, various substrates
Hydraulic Structures:	Gravel bars, low water concrete bridge
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pastures and row crops), Salem Road

ND - Not Determined

Site Information

Site No:	03024009
Stream:	Middle Pitman Creek
County:	Green
Location:	Just upstream of mouth
Latitude:	37° 20' 03"
Longitude:	85° 29' 05"
Stream Order:	IV
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	0.2
Sampling Dates:	July 10, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	3 to 9 m
Pool Depth:	.15 to .8 m
Pool Substrate:	Primarily pebble/cobble/gravel
Riffle Width:	3 to 6 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Primarily cobble/pebble/gravel
Bank Height:	.9 to 6 m
Bank Slope:	40 to 60%

Riparian Vegetation - %

Trees:	50
Shrubs:	20
Herbs:	20
Root Mats:	5

Site Information

Exposed:	5
Width:	0 to 30 + m
Canopy over Stream - %	75 to 100
Bank Stability:	Excellent
Erosion:	Small area with 0 buffer has bank failure
Sedimentation:	Slight to moderate
Imbeddedness:	1/2
Periphyton Abundance:	Moderate
Stream Habitat:	Pool, riffle, run, undercut banks, rock ledges, submerged roots and logs, drift piles, large boulders, gravel bars, various substrates
Hydraulic Structures:	Gravel bars, ford, log jams
Physical Impacts:	None
Nonpoint Sources:	Agricultural (pastures and row crops)

ND - Not Determined

Site Information

Site No:	03024010
Stream:	Buck Horn Creek
County:	Taylor
Location:	Just upstream of Campbellsville WWTP
Latitude:	37° 20' 52"
Longitude:	85° 22' 45"
Stream Order:	I
USGS Topo Quad:	Greensburg, KY
DOW Map No.:	7-37
RMI:	.11
Sampling Dates:	July 2, 1984
Type Sampling:	Biological, Physicochemical
Stream Gradient:	High
Pool Width:	3 to 6 m
Pool Depth:	.15 to .3 m
Pool Substrate:	Primarily exposed bedrock
Riffle Width:	.3 to .9 m
Riffle Depth:	.07 to .15 m
Riffle Substrate:	Primarily exposed bedrock with some cobble to gravel sizes
Bank Height:	.9 to 3 m
Bank Slope:	60 + %

Riparian Vegetation - %

Trees:	60

Shrubs:	5
	Site Information
Herbs:	20
Root Mats:	5
Exposed:	10 (typcially rock areas)
Width:	0 to 30 + m
Canopy over Stream - %	75 to 100
Bank Stability:	Fair
Erosion:	Bank failure in areas of 0 buffer
Sedimentation:	Slight
Imbeddedness:	1/4
Periphyton Abundance:	Moderate
Stream Habitat:	Pool, riffle, undercut banks, rock ledges, submerged roots various substrates
Hydraulic Structures:	None
Physical Impacts:	Artifical rock bank with no woody vegetation around WWTP
Nonpoint Sources:	Agricultural (pastures and row crops)

ND - Not Determined

Appendix B

Riparian Vegetation for the
Big Pitman Creek System

Taxa	Stations								
	24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9	24-10
Acer negundo box elder	X	X	X	X	X	X	X	X	-
A. saccharinum silver maple	-	X	X	-	X	X	-	X	X
A. saccharum sugar maple	-	-	X	-	-	-	X	X	X
Aesculus sp. buckeye	-	-	-	-	-	-	X	X	-
Ambrosia trifida giant ragweed	-	-	-	-	-	-	X	X	-
Anemone virginiana thimbleweed	-	-	-	-	-	-	X	X	-
Asclepias sp. milkweed	X	-	-	-	-	-	-	-	-
Boehmeria cylindrica false nettle	-	-	X	X	-	X	X	X	X
Campsis radicans trumpet vine	X	-	X	X	X	-	-	-	-
Carpinus caroliniana American hornbeam	-	-	-	-	-	-	X	X	-
Carya ovata shagbark hickory	-	-	-	-	-	-	-	X	-
C. sp. hickory	X	-	-	-	-	-	-	-	-
Celtis laevigata sugarberry	-	-	-	-	-	-	X	-	-
C. occidentalis hackberry	-	-	-	-	-	-	-	X	-
Cercis canadensis redbud	X	-	-	-	-	-	X	-	X
Chrysanthemum leucanthemum ox-eye daisy	-	X	X	-	-	-	-	-	-
Commelina communis dayflower	-	-	-	-	-	-	X	-	-
Conium maculatum poison hemlock	-	X	X	-	-	-	-	-	X
Cornus sp. dogwood	-	-	-	-	-	-	X	-	-
Datura stramonium jimsonweed	-	-	-	X	-	-	-	-	-
Daucus carota Queen Annes lace	-	X	-	-	X	-	-	-	-
Erigeron sp. fleabane	X	X	-	X	X	-	-	-	-
Fraxinus pennsylvanica green ash	X	X	-	-	X	-	X	-	X

Riparian Vegetation for the Big Pitman Creek System

Taxa	Stations								
	24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9	24-10
F. quadrangulata blue ash		-	-	-	-	-	-	X	-
Galax aphylla galax	-	-	-	-	-	-	-	X	-
Glechoma hederacea ground ivy	-	-	-	-	-	-	-	X	-
Gleditsia triacanthos honeylocust	-	-	-	-	-	-	X	-	-
Hystrix patula bottle-brush grass	-	-	-	-	-	-	X	-	-
Impatiens sp. jewelweed	-	-	X	-	-	-	X	X	-
Ipomea sp. morning-glory	X	-	X	X	-	X	X	X	-
Juglans nigra black walnut	X	X	X	-	-	X	X	X	X
Juniperus virginiana eastern red cedar	X	-	-	-	-	-	-	-	-
Justicia americana water-willow	-	-	-	-	-	-	-	X	-
Laportea canadensis stinging nettle	X	-	-	-	-	-	-	-	-
Lepidium virginicum pepper grass	-	X	-	-	X	-	-	-	-
Lindera benzoin spice bush	-	-	-	-	-	-	X	X	-
Liriodendron tulipifera tulip poplar	-	-	-	-	-	-	X	-	-
Lonicera sp. honeysuckle	-	-	X	-	X	-	-	-	-
Lysimachia nummularia moneywort	-	-	X	-	-	-	-	-	-
Melilotus alba white sweet clover	X	-	-	-	-	-	-	-	-
M. officinalis yellow sweet clover	-	-	-	-	X	-	-	-	-
Morus sp. mulberry	X	-	-	-	-	-	-	-	-
Oxalis sp. wood sorrel	-	X	X	X	-	X	-	-	X
Phytolacca americana pokeweed	-	X	X	-	-	-	-	X	-
Plantago rugelii common plantain	X	X	-	X	-	-	X	-	-
Platanus occidentalis sycamore	X	X	X	X	X	X	X	X	X

Riparian Vegetation for the
Big Pitman Creek System

Taxa	Stations								
	24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9	24-10
Polygonum sp. smartweed	X	X	X	X	X	X	X	X	X
Polypodiaceae fern	-	-	-	-	-	-	X	X	X
Prunus serotina black cherry	-	-	-	-	-	-	X	-	-
Quercus alba white oak	-	-	-	-	-	-	X	-	X
Q. borealis red oak	X	-	-	-	-	-	-	-	-
Q. muehlenbergii chinquapin oak	-	-	-	-	-	-	-	X	-
Q. sp. oak	-	-	-	-	-	-	X	-	-
Q. velutina black oak	-	X	-	-	-	-	-	-	-
Rhus sp. sumac	-	-	-	-	X	-	-	-	-
Rosa multiflora multiflora rose	X	-	-	-	-	-	-	-	-
R. sp. rose	-	-	-	-	-	-	X	-	-
Rubus sp.	-	-	-	X	X	-	-	-	-
Rumex sp. dock	X	X	X	X	X	X	X	-	-
Salix nigra black willow	X	X	-	-	-	-	-	-	X
Sambucus canadensis elderberry	-	-	-	-	X	X	X	X	-
Saponaria officinalis bouncing bet	-	-	-	-	-	-	X	-	-
Smilax rotundifolia greenbrier	-	-	-	-	-	-	-	X	-
Solanaceae nightshade	-	X	-	-	-	-	-	-	-
Solidago sp. goldenrod	X	X	X	X	-	X	X	X	-
Sorgum halepense johnson grass	-	X	-	-	-	-	-	X	-
Stellaria sp. chickweed	-	-	X	-	-	-	-	-	-
Symphoricarpus orbiculatus buckberry	-	X	X	-	-	-	X	-	-
Tiarella cordifolia foam flower	-	-	-	-	-	-	-	X	-

Riparian Vegetation for the
Big Pitman Creek System

Taxa	Stations								
	24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9	24-10
Toxicodendron radicans poison ivy	-	-	-	-	-	-	-	-	X
Trifolium pratense red clover	X	X	-	-	-	-	-	-	-
Ulmus alata winged elm	-	-	-	-	-	-	X	-	-
U. americana American elm	-	-	-	-	-	-	X	-	X
U. rubra slippery elm	-	X	-	X	X	X	X	X	-
Verbascum thapsus woolly mullein	-	-	-	-	-	-	-	-	X
Viola sp. violet	-	-	-	-	-	-	X	X	X
Vitis sp. grape	X	-	-	-	-	-	X	X	-
Xanthium strumarium cocklebur	-	-	-	X	-	X	-	X	-
Total Species	23	23	20	15	16	13	37	31	17

Total Taxa: 78

Appendix C

Diatom Relative Abundance,
Diversity, and Equitability for Station 24-1 (2 week exposure)

Taxa	Relative Abundance (%)
Nitzschia frustulum	24.1
Achnanthes linearis	16.9
Nitzschia palea	10.2
Nitzschia amphibia	4.3
Navicula confervacea	3.7
Melosira varians	3.2
Navicula spp.	2.7
Nitzschia sinuata var. *tabellaria*	2.7
Gomphonema parvulum	2.5
Navicula heufleri var. *leptocephala*	2.5
Cymbella affinis	2.2
Navicula cryptocephala var. *veneta*	2.0
Cocconeis placentula var. *euglypta*	1.8
Navicula cryptocephala	1.8
Achnanthes minutissima	1.7
Navicula gregaria	1.7
Navicula symmetrica	1.3
Achnanthes deflexa	1.0
Navicula capitata	1.0
Nitzschia apiculata	1.0
Cocconeis pediculus	0.8
Gomphonema acuminatum	0.8
Navicula tantula	0.8
Gomphonema affine	0.7
Navicula arvensis	0.7
Navicula hustedtii	0.7
Nitzschia intermedia	0.7
Surirella ovata	0.7
Achnanthes lanceolata var. *dubia*	0.5
Cyclotella atomus	0.5
Gomphonema subclavatum var. *mexicanum*	0.5
Navicula luzonensis	0.5
Navicula menisculus var. *upsaliensis*	0.7
Rhoicosphenia curvata	0.5
Gyrosigma spencerii	0.3
Nitzschia acicularis	0.3
Nitzschia dissipata	0.3
Nitzschia tryblionella var. *victoriae*	0.3
Surirella angusta	0.3
Amphora submontana	0.2
Navicula pupula	0.2
Nitzschia sp.	0.2
Nitzschia acula	0.2
Nitzschia fonticola	0.2
Nitzschia recta	0.2
Diversity ($\bar{d}$)	4.182
Equitability (e)	0.592
Total Taxa	45

Diatom Relative Abundance,
Diversity, and Equitability for Station 24-4 (2 week exposure)

Taxa	Relative Abundance (%)
Melosira varians	16.8
Nitzschia amphibia	11.9
Nitzschia palea	8.9
Cocconeis placentula var. *euglypta*	8.8
Navicula confervacea	6.8
Nitzschia frustulum	6.6
Navicula luzonensis	5.2
Navicula tantula	4.7
Achnanthes linearis	4.4
Navicula symmetrica	3.8
Cyclotella meneghiniana	2.6
Navicula cryptocephala var. *veneta*	1.7
Cocconeis pediculus	1.4
Navicula heufleri var. *leptocephala*	1.4
Navicula cryptocephala	1.2
Navicula rhynchocephala	1.2
Amphora submontana	0.9
Surirella angusta	0.9
Gomphonema parvulum	0.7
Rhoicosphenia curvata	0.7
Navicula spp.	0.5
Navicula salinarum var. *intermedia*	0.5
Achnanthes lanceolata var. *dubia*	0.3
Cymbella affinis	0.3
Navicula cincta	0.3
Navicula gregaria	0.3
Navicula hustedtii	0.3
Navicula lanceolata	0.3
Navicula mutica	0.3
Navicula radiosa var. *tenella*	0.3
Nitzschia apiculata	0.3
Nitzschia fonticola	0.3
Nitzschia lorenziana var. *subtilis*	0.3
Surirella ovalis	0.3
Amphora ovalis var. *pediculus*	0.2
Amphora submontana	0.2
Aulacosira grannulata	0.2
Caloneis bacillum	0.2
Cocconeis placentula var. *lineata*	0.2
Cyclotella atomus	0.2
Gomphonema affine	0.2
Gomphonema sp.	0.2
Navicula arvensis	0.2
Navicula capitata	0.2
Navicula menisculus var. *upsaliensis*	0.2
Navicula notha	0.2
Nitzschia sp.	0.2
Nitzschia acicularis	0.2

Diatom Relative Abundance,
Diversity, and Equitability for Station 24-4 (2 week exposure)

Taxa	Relative Abundance (%)
Nitzschia filiformis	0.2
Nitzschia thermalis	0.2
Pinnularia sp.	0.2
Surirella ovata	0.2
Synedra rumpens var. fragillarioides	0.2
Diversity ($\bar{d}$)	4.353
Equitability	0.558
Total Taxa	54

Diatom Relative Abundance,
Diversity, and Equitability for Station 24-3 (2 week exposure)

Taxa	Relative Abundance (%)
Nitzschia frustulum	21.0
Cyclotella meneghiniana	16.2
Navicula confervacea	12.3
Navicula tripunctata	7.9
Achnanthes linearis	5.8
Nitzschia palea	5.3
Cocconeis placentula var. *euglypta*	4.9
Nitzschia amphibia	3.2
Melosira varians	2.8
Navicula luzonensis	2.1
Navicula tantula	1.8
Navicula symmetrica	1.6
Navicula pupula	1.4
Gomphonema parvulum	1.1
Navicula rhynchocephala	1.1
Surirella ovalis	1.1
Navicula cryptocephala var. *veneta*	0.9
Cocconeis pediculus	0.7
Navicula cryptocephala	0.7
Navicula heufleri var. *leptocephala*	0.7
Navicula spp.	0.7
Cyclotella striata var. *ambigua*	0.5
Navicula capitata	0.5
Nitzschia calida	0.5
Surirella angusta	0.5
Thalassiosira weissflogii	0.5
Achnanthes lanceolata var. *dubia*	0.3
Amphora submontana	0.3
Caloneis bacillum	0.3
Gomphonema subclavatum var. *mexicanum*	0.3
Nitzschia apiculata	0.3
Nitzschia intermedia	0.3
Rhoicosphenia curvata	0.3
Cocconeis placentula var. *lineata*	0.2
Cymbella triangulum	0.2
Navicula hustedtii	0.2
Navicula menisculus var. *upsaliensis*	0.2
Navicula salinarum var. *intermedia*	0.2
Nitzschia dissipata	0.2
Nitzschia fonticola	0.2
Nitzschia levidensis	0.2
Nitzschia tryblionella var. *victoriae*	0.2
Nitzschia sp.	0.2
Surirella ovata	0.2
Synedra pulchella	0.2
Synedra ulna	0.2
Diversity ($\bar{d}$)	4.059
Equitability (e)	0.530
Total Taxa	46

Diatom Relative Abundance,
Diversity, and Equitability for Station 24-5 (2 week exposure)

Taxa	Relative Abundance (%)
Navicula tripunctata	24.2
Nitzschia frustulum	12.6
Achnanthes linearis	12.1
Nitzschia palea	8.0
Nitzschia amphibia	5.3
Navicula luzonensis	3.4
Navicula symmetrica	3.2
Thalassiosira weissflogii	3.2
Surirella ovalis	2.8
Cyclotella meneghiniana	2.7
Navicula tantula	2.5
Navicula gregaria	2.3
Navicula rhynchocephala	1.6
Nitzschia calida	1.2
Achnanthes lanceolata var. *dubia*	0.9
Amphora submontana	0.9
Cocconeis placentula var. *euglypta*	0.9
Melosira varians	0.7
Navicula confervacea	0.7
Gomphonema parvulum	0.5
Navicula cryptocephala	0.5
Navicula cryptocephala var. *veneta*	0.5
Navicula spp.	0.5
Nitzschia apiculata	0.5
Nitzschia fonticola	0.5
Rhoicosphenia curvata	0.5
Surirella ovata	0.5
Amphora perpusilla	0.3
Cymbella minuta	0.3
Navicula arvensis	0.3
Navicula capitata	0.3
Navicula heufleri var. *leptocephala*	0.3
Navicula hustedtii	0.3
Navicula pupula	0.3
Nitzschia intermedia	0.3
Nitzschia sigma	0.3
Amphora ovalis var. *pediculus*	0.2
Cocconeis pediculus	0.2
Cymatopleura solea	0.3
Gomphonema sp.	0.2
Gyrosigma spencerii	0.2
Navicula cincta	0.2
Navicula menisculus var. *upsaliensis*	0.2
Navicula notha	0.2
Novicula radiosa var. *tenella*	0.2
Nitzschia acula	0.2
Nitzschia coarctata	0.2
Surirella angusta	0.2
Surirella linearis var. *hevetica*	0.2
Diversity ($\bar{d}$)	4.146
Equitability (e)	0.519
Total Taxa	50

Appendix D

Macroinvertebrate Synoptic List for the Big Pitman Creek System

Taxa	Stations 24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9
Tubifix sp.	X	-	-	-	-	-	-	-
Limnodrilus sp.	X	-	-	-	-	-	X	X
Branchura sowerbyi	-	-	-	-	-	-	-	X
Lumbriculus sp.	-	-	-	-	-	-	-	-
Physella sp. 1	-	-	-	-	-	-	X	-
P. sp. 2	-	-	-	-	-	-	X	
Lymnea sp.	-	-	X	-	-	-	X	-
Elimia sp. 1	X	-	-	-	X	-	-	X
E. sp. 2	-	-	-	-	-	-	-	X
Lirceus fontinalis	X	X	X	-	X	X	X	X
Gammarus sp.	-	-	-	-	-	-	X	-
Orconectes sp.	X	X	-	X	X	X	X	X
Stenonema femoratum	X	-	-	-	-	-	X	X
S. mediopunctatum arwini	X	-	-	-	X	X	X	X
S. pulchellum	-	-	-	-	X	X	-	X
S. vicarium	-	-	-	-	-	-	X	X
Heptagenia sp.	-	-	-	X	X	X	X	X
Stenacron interpunctatum	-	-	-	-	X	-	-	X
Isonychia sp.	X	X	-	X	X	X	X	X
Baetis sp.	X	X	-	-	X	X	X	X
Caenis sp.	X	X	-	X	X	X	X	X
Tricorythodes sp.	-	-	-	-	-	X	-	-
Hexagenia limbata	X	-	-	-	-	X	-	X
Isoperla sp.	-	-	-	-	-	-	X	-
Perlesta placida	-	-	X	-	-	-	X	X

Macroinvertebrate Synoptic List for the Big Pitman Creek System

Taxa	Stations 24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9
Phasgonophora capatita		-	-	-	-	-	X	-
Neoperla sp.	X	-	-	-	-	X	X	-
Boyeria vinosa	-	-	-	-	-	-	X	X
Enallagma sp.	-	-	-	-	-	-	X	-
Stenelmis crenata	X	X	X	X	X	X	X	X
S. sexlineata	-	-	X	X	X	X	-	X
S. sp. (larva)	X	-	-	X	X	X	-	-
Optioservus trivittatus	-	X	-	X	-	X	X	-
Dubiraphia sp.	-	-	-	-	-	-	X	X
Macronychus sp.	-	-	-	-	-	-	X	X
Scirtes tibialis	-	-	-	-	-	-	-	X
Hydroporus sp.	-	-	-	-	-	-	X	X
Dytiscus sp.	-	-	-	-	-	-		
Psephenus herricki	X	X	X	-	-	X	X	X
Helichus sp.	-	-	-	-	-	-	X	X
Corydalus cornutus	-	-	-	X	-	X	-	X
Nigronia serricornis	X	X	X	X	X	X	X	X
Sialis sp.	-	X	-	-	-	-	-	-
Hemerodromia sp.	X	X	X	X	-	X	X	-
Simulium sp.	X	X	X	X	-	-	X	X
Tipula sp.	-	-	X	-	-	-	X	-
Hexatoma sp.	-	-	-	X	X	X	X	X
Tabanus sp.	-	-	X	-	-	X	X	-
Corynoneura tarsis	X	-	-	-	-	-	-	-
Polypedilium convictum	X	X	-	X	X	X	-	-
P. aricips	X	-	-	-	-	-	-	-
P. halterale	-	X	X	-	-	-	-	-
P. illinoense	-	-	X	-	-	-	-	-
Thienemannimyia sp. 1	X	X	X	X	X	X	-	-
T. sp. 2	X	X	X	-	-	-	-	-

Macroinvertebrate Synoptic List for the Big Pitman Creek System

Taxa	Stations 24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9
Cryptochironomus fulvus	X	X	-	X	-	X	-	-
Diamesa sp.	X	-	-	-	-	-	-	-
Phaenopsectra flanipes	X	-	-	-	-	-	-	-
Microtendipes caelum	-	X	-	X	-	-	-	-
Tanytarsus quarlus	-	X	-	X	X	-	-	-
T. glabracens	-	X	-	X	-	-	-	-
Cricotopus bicinctus	-	X	X	-	-	-	X	X
C. tremulus	-	-	X	X	-	-	-	-
Pseudochironomus articaudes	-	-	-	-	X	-	-	-
Dicrotendipes neomodestus	-	-	X	-	X	-	-	-
Rheotanytarsus exiguus	-	-	-	-	X	-	-	-
Eukiefferiella sp.	-	-	-	-	X	-	X	-
Procladius subletti	-	-	X	-	-	-	X	X
Ablabesmyia mallocki	-	-	X	-	-	-	X	-
Hydropsyche betteni	X	-	X	-	-	-	X	X
Hydropsyche chelonis	-	X	-	X	X	-	-	X
Hydropsyche simulans	-	-	-	-	X	-	-	-
Hydropsyche valanis	-	-	-	-	-	X	-	-
Cheumatopsyche sp.	X	X	X	X	X	X	X	X
Chimarra sp.	X	X	X	X	X	X	X	X
Polycentropus sp.	X	-	X	-	-	-	X	-
Ochrotrichia sp.	-	X	-	-	X	-	X	X
Agraylea sp.	-	X	-	-	-	-	-	-
Oecetis sp.	-	-	-	-	-	-	-	X
Hydroptila sp.	-	-	-	-	X	-	-	-
Total Number of Taxa	30	26	24	23	28	27	42	38
Species Diversity ($\bar{d}$)	3.5547	2.9349	1.7698	2.8647	3.7993	3.9254	4.1500	3.2507
Equitability (e)	0.5641	0.3972	0.2002	0.4424	0.7221	0.8203	0.7438	0.4517

Appendix E

Fish Synoptic List
for Big Pitman Creek System

	24-1	24-3	24-4	24-5	24-6	24-7	24-8	24-9
Catostomus commersoni	-	-	-	-	-	-	3	-
Hypentelium nigricans	1	-	-	-	1	1	1	-
Moxostoma duquesnei	-	-	-	-	-	1	-	-
Moxostoma erythrurum	-	-	-	2	-	-	-	-
Moxostoma sp. (juvenile)	-	-	-	-	1	-	-	-
Campostoma anomalum	8	53	9	13	1	3	9	8
Notemigonus crysoleueus	-	-	-	-	-	-	2	-
Notropis ardens	-	8	-	26	-	-	16	13
Notropis atherinoides	-	-	-	-	13	-	-	-
Notropis chrysocephalus	1	85	-	57	52	2	18	17
Notropis spilopterus	-	-	-	-	-	-	-	2
Phoxinus erythrogaster	3	-	-	-	-	-	3	-
Pimephales notatus	13	14	-	1	25	1	18	4
Semotilus atromaculatus	5	-	4	2	-	-	20	4
Ictalurus melas	1	-	-	-	-	-	-	-
Ictalurus natalis	1	-	2	-	-	-	-	-
Noturus elegans	-	-	-	-	-	1	-	1
Fundulus catenatus	5	2	-	7	-	-	8	-
Cottus carolinae	10	3	-	-	2	14	3	7
Labidesthes sicculus	-	-	-	-	2	-	-	-
Ambloplites rupestris	-	-	-	1	-	-	8	3
Lepomis cyanellus	2	1	-	-	-	-	1	1
Lepomis gulosus	1	-	-	-	-	-	-	-
Lepomis macrochirus	5	2	-	1	1	-	4	-
Lepomis megalotis	5	11	-	8	5	4	1	2
Micropterus dolomieui	-	-	-	-	-	1	-	-
Micropterus punctulatus	-	1	-	2	7	2	-	-
Etheostoma bellum	-	-	-	-	1	12	-	21
Etheostoma blennioides	2	1	-	1	1	1	7	3
Etheostoma caeruleum	4	-	-	-	-	4	24	1
Etheostoma flabellare	-	-	-	-	-	-	4	2
Etheostoma rafinesquei	5	-	-	-	-	1	-	3
Etheostoma squamiceps	4	-	-	-	-	-	24	-
Etheostoma zonale	-	-	-	2	5	5	-	6
# of species	18	11	3	13	14	15	19	17
# of individual	76	181	15	123	117	53	174	93
IBI (Karr) class	G	F	VP	F	G	G	G	G

Appendix F

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