Fleming Creek Watershed Nonpoint Source Demonstration Project

Final Report

Kentucky Division of Water
Water Quality Branch
Nonpoint Source Section
May 2000

Natural Resources and Environmental
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Kentucky Department for Environmental Protection
Division of Water
Water Quality Branch
Nonpoint Source Section
Frankfort, Kentucky

Technical Report No. 5
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EXECUTIVE SUMMARY

The Fleming Creek Watershed Nonpoint Source (NPS) Demonstration Project was initiated by a group of local land owners concerned about the water quality of Fleming Creek. These local landowners formed the Fleming Creek Water Quality Committee, which was dedicated to assessing the needs and interests of all local citizens. Early in project development, this committee coordinated with local farmers and government agencies. As the project evolved, the Community Farm Alliance (CFA) became the principal grassroots coordinating organization.

The principal land use within the Fleming Creek watershed was livestock production (KDOW 1996). The high density of farm animals in the watershed resulted in water quality degradation. In response to this pollution problem and the local interest in remedying the problem, the U.S. Department of Agriculture (USDA) requested and received funding for animal waste pollution control for the watershed.

The NPS Section of the Kentucky Division of Water (KDOW) gathered physicochemical, bacteriological and biological data designed to target the worst animal waste pollution problems within the Fleming Creek watershed and to establish pre-Best Management Plan (BMP) water quality conditions. Monitoring continued after the installation of animal waste BMPs (post-BMP) to document and demonstrate water quality changes resulting from the implementation of BMPs.

The Kentucky Division of Conservation (KDOC) and the Natural Resources Conservation Service (NRCS) tracked the implementation of livestock BMPs and the number of BMP funding sources within the Fleming Creek watershed. The number of conservation practices and funding sources during the period 05/01/1990 – 06/01/1999 increased to 8 ponds, 2,100 ft of fencing, 314 troughs or tanks, 2 sediment basins, 4 waste storage ponds, 25 waste management systems, and 13 waste storage facilities. In addition, 608 acres of land received some type of BMP since 05/01/1990. Concurrently, the number of dairy cattle in the watershed was reduced by 36% from 1991 to 1998 and the total number of cattle was reduced by 5.2%. These BMPs and livestock reductions may be the initial steps in controlling NPS pollution in the Fleming Creek watershed. However, due to the size of the watershed, many more practices will need to be implemented before water quality improvements in the entire watershed can be demonstrated.

Pre-BMP water quality monitoring efforts began in the spring of 1992, and continued until the fall of 1994. Post-BMP monitoring was conducted during 1998 and 1999. Monitoring was conducted in three phases. The focus of Phase I monitoring was on bacteriological analysis; however, water nutrient samples for analyses were also collected. The initial purpose of Phase I monitoring was to document existing conditions within the watershed with respect to point and nonpoint pollution sources, and to target those portions of the watershed most impacted from animal waste runoff. This was accomplished by conducting surveys at 27 bacteriological/physicochemical stations, plus one additional physicochemical station. Many of these stations were located on the Fleming Creek mainstem, upstream and downstream of confluences with major tributaries, and at the mouths of those tributaries. Additional stations were established as needed at 3- to 5-mile intervals within the mainstem down to the mouth. The number of stations not meeting Primary Contact Recreation (PCR) uses declined at five sites during post-BMP low- and high-flow sampling. However, this may not indicate that an improvement in water quality occurred, as indicated by the extremely high fecal coliform (FC) levels found in the post-BMP high flow samples. These high-flow post-BMP FC levels indicated animal waste runoff was still a major water quality impact in the watershed.

Post-BMP high-flow FC levels were significantly higher ($p<.001$) than pre-BMP high flow levels. However, pre-BMP low-flow FC levels were significantly higher ($p<.01$) than post-BMP levels. These contradictory results can best be explained by examining the amount of rainfall that occurred before sampling. Post-BMP high-flow data were collected after a full month of heavy precipitation, while rain during the pre-BMP sampling was not as heavy. The opposite was true for the low-flow data. Post-BMP low-flow data was collected during an unusually dry period while pre-BMP data was collected after an unusually wet period. Because sampling conditions varied between pre and post-BMP collections, conclusions about water quality changes cannot be supported using only FC levels.

The elevated FC colony counts observed for the storm-event samples indicated that runoff containing animal waste was the principal source of bacteria contamination within Fleming Creek. However, the FC data may be of limited use in assessing water quality trends because it was collected on only four occasions, from 1992 to 1998, and environmental conditions (i.e., temperature and stream flow) were not similar during the times of collection.

Phase II monitoring involved long-term physicochemical monitoring at five stations located at areas with high concentrations of feedlots. The purpose of Phase II monitoring was to document a trend in water quality changes resulting from implementations of BMPs. Six sets of pre-BMP, storm-event, physicochemical data and four sets of low-flow/normal-flow physicochemical data were collected for this project. Nutrient levels were not detected at significantly high concentrations on a consistent basis. However, logistical problems associated with long-distance storm-event sampling and a relatively small sample size (20 sets of data over seven years) resulted in data too few and sporadic to analyze statistically and had questionable usefulness for depicting true case scenarios.

Phase III monitoring involved collecting biological (macroinvertebrates and fish) data from three of the more impacted sites, based on Phase I and Phase II pre-BMP data. Two of these stations, Allison Creek (05029020) and Craintown Branch (05029015) were located near areas that received BMPs. The third station was located in the mainstem of Fleming Creek (05029031).

Three sets of pre-BMP biological data were collected, and one set of post-BMP data was collected. Sampling methods and levels of effort were identical from station to station using KDOW (1993) protocol. The Index of Biotic Integrity (IBI) was used to assess the fish community at these sites to give an indication of the water quality in the Fleming Creek watershed. The IBI indicated Craintown Branch (05029015) and Fleming Creek (05029031) increased in water quality while Allison Creek (05029020) water quality decreased.

The macroinvertebrate data for Craintown Branch and Fleming Creek implied that water quality has remained relatively unchanged throughout this study. The macroinvertebrate data indicated that the water quality of Allison Creek (05029020) became more degraded during the post-BMP sampling event, which may indicate a problem with excessive nutrient loading and/or BMP failure or mismanagement. A future study in Fleming Creek should collect macroinvertebrates during the month of May and make an additional collection during July to make a comparative study with the 1998 collection. A study that is intended to evaluate the effectiveness of BMPs should be longer-lived, conducted on a smaller watershed, and should have an equal number of pre- and post-BMP sampling events that occur during the same seasons of each successive year.

The numbers of BMPs and funding sources increased from the period of 05/01/1990 to 06/01/1999, which indicated a higher level of water quality awareness in the watershed. Also, the total number of cattle and dairy operations decreased. These practices should begin to control nonpoint source pollution in the project watershed. Due to the large size of the Fleming Creek watershed, there will have to be more practices implemented before significant improvements in water quality can be demonstrated.

INTRODUCTION

The Fleming Creek Watershed Nonpoint Source (NPS) Demonstration Project was initiated by a group of local land owners concerned about the water quality of Fleming Creek (the Fleming Creek Water Quality Committee). This committee was dedicated to assessing the needs and interests of all local citizens. Early in project development, this committee coordinated with local farmers and government agencies. As the project evolved, the Community Farm Alliance (CFA) became the principal grassroots coordinating organization (KDOW 1996).

The principal land use within the Fleming Creek watershed was livestock production. The high density of farm animals in the watershed resulted in severe water quality degradation (KDOW 1996). In response to the pollution problem and the local interest in remedying it, the U.S. Department of Agriculture (USDA) requested and received funding for animal waste pollution control in the watershed.

In Federal Fiscal Year (FFY) 1992, the USDA allocated $200,000 through the Agricultural Conservation Program (ACP) for the purpose of providing cost-share monies for animal waste management systems. The USDA awarded another $17,500 to the project for the installation of a constructed wetland. During FFY 1994, farmers within the Fleming Creek watershed received $152,000 in USDA Water Quality Incentive Program (WQIP) funds for the implementation of non-structural agricultural Best Management Practices (BMPs). The WQIP funds were used for items such as animal exclusion (from streams), manure management, and agronomic activities. State cost-share funds were also allocated to this project for the construction of animal waste management systems (KDOW 1996).

The KDOW Nonpoint Source Section received §319(h) funds from the U.S. Environmental Protection Agency (USEPA) during FFYs 1991, 1992, and 1993 for documenting and demonstrating the effectiveness of the BMPs in improving water quality within the Fleming Creek watershed. The main pollutants of concern were identified as nutrients and fecal coliform (FC) bacteria (KDOW 1996). In order to fulfill project water quality monitoring objectives, a three-phased sampling approach was employed.

Phase I involved a pre-BMP and post-BMP bacteriological/water quality survey on a watershed-wide basis. Phase II consisted of long-term physicochemical water sampling at selected locations, and Phase III employed biological sampling. Specific monitoring objectives of this project included: 1) a determination of water quality conditions prior to the installation of animal waste BMPs within the watershed and 2) documentation of changes in water quality as a result of this BMP installation (post-BMP). The details of the water quality data collection for this project are outlined under the water quality monitoring program section.

Best Management Plan implementation data were collected by the Kentucky Division of Conservation. This information was used for the purpose of establishing a correlation between BMP implementation and water quality.

STUDY AREA DESCRIPTION

Location Information

The Fleming Creek watershed is located in Fleming County in northeastern Kentucky (Figure 1); however, a short reach at the mouth flows into Nicholas County. Flemingsburg, the largest town within Fleming County, is situated in the eastern portion of the watershed, approximately 37 km northwest of Morehead, Kentucky.

Geologic Information

The Fleming Creek drainage lies primarily within the Bluegrass and Outer Bluegrass physiographic regions (Quarterman and Powell 1978). The landscape is characterized by gently sloping ridgetops to steep and moderately steep hillsides. Elevations within the watershed range from 176.8 m above sea level at the mouth to 243.8 m above sea level in the headwaters (Peck 1969).

The geology of the watershed is unique in that it varies dramatically within a short distance. The uppermost headwaters of Fleming Creek transect the Upper Devonian and Lower and Middle Silurian systems (Morris 1965). The major portion of the remaining watershed overlies Ordovician rock (Peck 1969). The Upper Devonian system is characterized by a dark gray to black, highly carbonaceous stratum known as the Ohio Shale (Morris 1965). The Lower and Middle Silurian systems are comprised of clayey shale and alternating limestone and shale layers of the Crab Orchard and Brassfield Formations (Morris 1965). The Ordovician system is dominated by limestone (Peck 1969). There are karst areas within the Fleming Creek watershed where sinkholes are common (Peck 1969).

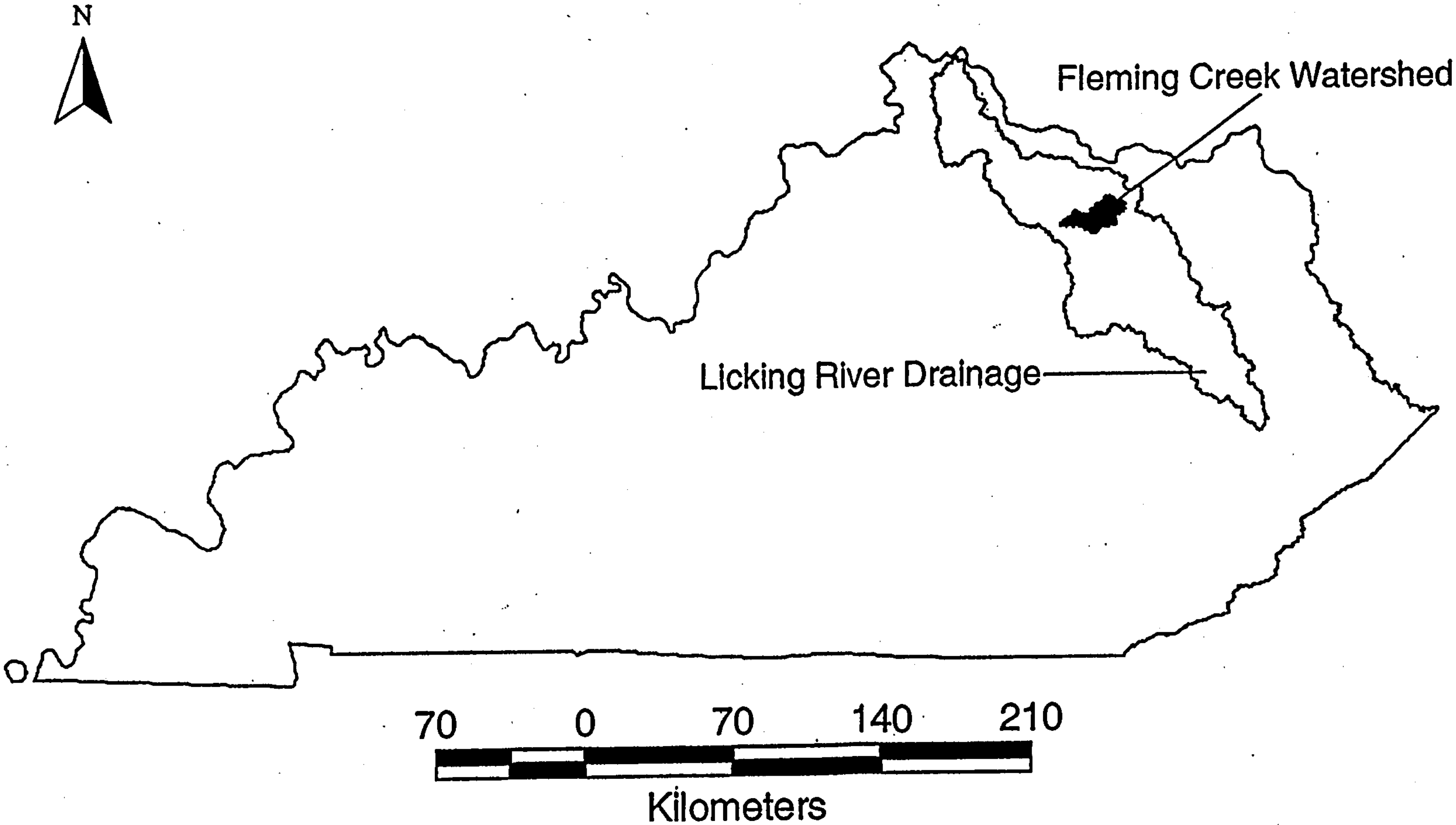

Figure 1. Location of the Fleming Creek Watershed

Soils Information

Most of the soils on the ridgetops and hillsides within the study area were formed from residual limestones, siltstones and shales, and overlying clayey subsoils (USDA 1992). Soil types found in these areas include the Lowell, Beasley, Faywood and Shrouts. Some ridgetop soils were formed with a silty mantle of loess over clay weathered from residual limestones, siltstones and shales. Associated soil types at such locations are the Sandview, Nicholason and Crider. In addition, soils on some steep hillsides were weathered from interbedded limestones, siltones and shales (Eden, Faywood and Cynthiana soil types). These steep hillside soils tend to be shallower than other soils in the watershed (Peck 1969).

Hydrologic Information

The Fleming Creek drainage flows east to west to its confluence with the Licking River (river km 172.0) in northeastern Nicholas County. The mainstem is 62.8 km long, draining an area of 24,957 ha (KDOW 1984). The average gradient for the stream is 12.4 km per mile. According to Proctor, Davis and Ray (no date), the estimated seven-day, ten-year low flow (7Q10) within the mainstem at river km 19.6 near Hilltop, KY was 0.12 m^3/s.

Land Use Information

From 1992 to 1996 the predominant land use within the Fleming Creek watershed was agriculture, and 31 percent (7,736 ha) of the watershed area was used for cropland, with corn and tobacco the principal row crops (KDOW 1996). Other land in the watershed is managed for hayland and pasture, primarily to support dairy operations (KDOW 1996). Fleming County was ranked one of the top three counties in total number of dairy cows statewide (Kentucky Agriculture Statistical Service [KASS] 1998).

The total dairy cow population in Fleming County exceeded 10,000 head in 1991, with an average herd size of 50 cows. The number of dairy cows dropped to 6,400 for the 1997–98 year (KASS 1998). The total number of cattle has also dropped from approximately 48,500 in 1991–92 to 46,000 during the 1997 – 98 year (KASS 1998). In 1992, an estimated 518,160 m^3 of animal waste had the potential to be washed into area streams annually from dairies alone (USDA 1992). Nine percent (20,969 ha) of the remaining land within the watershed was wooded, and only one percent (249.7 ha) was urban. The majority of the county's population resides in Flemingsburg, with a population of approximately 2,800 people. Flemingsburg uses Town Branch as a municipal water supply. Jones (1970) reported that Fleming Creek received heavy fishing pressure, especially from the mouth to about 20 miles upstream. Angler success was reported as fair to good for game species. According to the Kentucky Department of Fish and Wildlife Resources (KDFWR) (no date), both muskelunge (*Esox masquinongy)* and walleye (*Stizostedion vitreum*) may occur at the mouth of Fleming Creek.

MATERIALS AND METHODS

BMP Implementation Tracking

The Kentucky Division of Conservation (KDOC) and the NRCS tracked BMP installations and the number of BMP funding sources within the Fleming Creek watershed for the purpose of comparing water quality data with implemented BMPs to determine their effectiveness. Fleming Creek agriculture statistics for number of cattle in the watershed were also compiled for the years of the project (KASS 1998).

Water Quality Monitoring

Beginning in 1992, the KDOW NPS Section established 27 sites (Figure 2, Appendix A) in the Fleming Creek watershed and employed bacteriological (Phase I), physicochemical (Phase II), and biological (Phase III) monitoring to document changes in water quality. Pre-BMP water quality monitoring efforts began in the spring of 1992 and continued until the spring of 1994. Post-BMP monitoring was conducted during 1998 and 1999. The pre-BMP data were used to target areas within the watershed that were the most severely impacted by animal waste and to establish baseline water quality conditions. Monitoring continued after the installation of animal waste BMPs to document and demonstrate water quality changes resulting from BMP implementations.

Sampling techniques and chain of custody procedures followed in the KDOW quality assurance/quality control guidelines and standard operating procedures manuals (KDOW 1987, 1993) and USEPA approved field and laboratory methods and procedures were followed, where appropriate. All field equipment was calibrated according to the manufacturer's recommendations prior to sampling. Duplicates or splits were collected and analyzed for at least 10 percent of the water samples. Taxonomic verifications for the fish and macroinvertebrate samples were performed by KDOW biologists. A log was maintained for all water and biological samples.

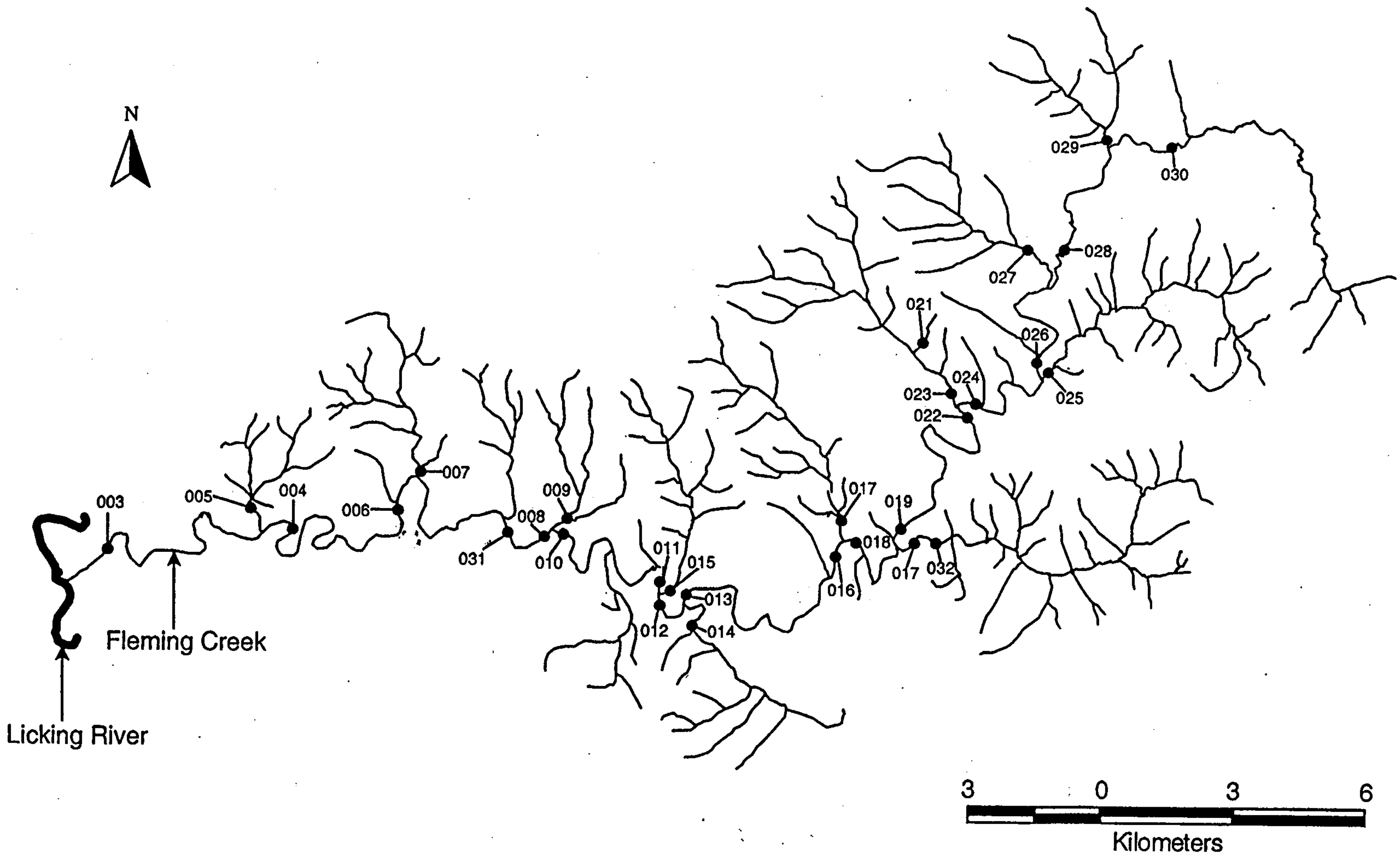

Figure 2. Monitoring station locations for the Fleming Creek Demonstration project (prefix to all site numbers is 05029).

Phase I (Bacteriological Survey)

Twenty-seven bacteriological and 28 chemical stations were established throughout for Phase I sampling (Appendix A). Many of these stations were located in the Fleming Creek mainstem upstream and downstream of confluences with major tributaries, and at the mouths of those tributaries. Additional stations were established as needed at three- to five-mile intervals within the mainstem down to the mouth. Phase I sampling was conducted prior to and after BMP installation to assess water quality changes resulting from BMP implementation. This strategy was used so that various portions of the watershed could be evaluated separately. Bacteriological and chemical data collections for Phase I included high-flow and low-flow pre-BMP (18 May 1992 and 18 August 1992, respectively) and high-flow and low-flow post-BMP (23 May 1998 and 12 October 1998, respectively) events.

Water samples for high- and normal-flow bacteriological monitoring were collected with the surface grab technique following KDOW protocol (1995) from mainstem and tributary monitoring stations. Samples were kept on ice until they were delivered to the laboratory, and sample holding times were kept to a minimum. Samples were analyzed using the membrane filter analysis technique (KDOW 1993) for fecal coliform colonies to determine primary contact recreation (PCR) use support. The data was then analyzed using a non-parametric Mann-Whitney statistical test to determine whether significant differences existed between pre-and post-BMP FC data.

Water samples for nutrient analysis, Kjeldahl nitrogen, ammonia-ammonium nitrogen, nitrate-nitrite nitrogen, total phosphorus, were also collected as part of Phase I monitoring activities during pre-BMP. Bacteriological data from 1992 were considered pre-BMP, and those from 1998 were considered post-BMP. If one or both of the fecal coliform values (FC/100 ml) for high- and normal-flow samples at a particular station were at or below the upper limit of the standard for PCR (400 colonies per 100 ml, see KDOW 1994), that station was considered to support those uses. If both the high- and normal-flow values were above the upper limit, the station was judged nonsupportive of PCR. Information obtained from pre-BMP Phase I data was made available to NRCS to assist in BMP placement and was used to compare pre- and post-BMP results to demonstrate changes in water quality.

Phase II (Long-term Physicochemical Monitoring)

From the initial (Phase I) stations, five long-term water quality monitoring sites was selected (Appendix A). The selection of these five stations were based upon areas with a high concentration of feedlots, apparent impact from feedlot operations within subwatersheds (from Phase I pre-BMP data), and proposed placement of BMPs (from initial USDA BMP sign-ups). The purpose of Phase II monitoring was to document trends in water quality changes resulting from the implementation of BMPs.

Phase II stations were established on Allison Creek (05029020), Logan Run (05029029), and Craintown Branch (05029015) because these tributaries were found to be impacted from animal waste runoff based upon preliminary water quality investigations (KDOW 1996) and because animal waste management systems were proposed for these subwatersheds. Another station was established on Fleming Creek at the Flemingsburg-Beechburg Road (Highway 3301) (05029028) bridge to isolate the headwater portion of the project area for evaluation. A fifth Phase II station was established on Fleming Creek at the Highway 170 bridge (05029031), which is downstream of all proposed animal waste systems, to assess the effectiveness of BMPs in the watershed.

Phase II monitoring centered on storm-event sampling. Some low-flow data were also collected. Water samples for physicochemical analysis were collected by depth-integrated sampling following protocols outlined in KDOW (1993). Water temperature, pH, dissolved oxygen (D.O.), conductivity, and turbidity were measured in situ using portable meters. Laboratory analyses included total Kjeldahl nitrogen, ammonia-ammonium nitrogen, nitrate-nitrite nitrogen, total phosphorus, total suspended solids, total organic carbon, and 5-day biochemical oxygen demand (BOD). Since initial measurements were consistently low, BOD_5 analyses were discontinued. As water levels allowed, stream flow was measured at each station using a Marsh-McBirney analog flow meter. The flow data were used to estimate loading of various constituents within the watershed.

Phase III (Biological Monitoring)

Biological data were collected at three of the more impacted sites (Appendix A), based on Phase I pre-BMP data. Two stations (Allison Creek [05029020] and Craintown Branch [05029015]) were located near the mouth of impacted tributaries that received BMPs. The third station was located in Fleming Creek (05029031) downstream of all BMPs. Pre-BMP data were collected during 1992–1994 for Allison Creek and Fleming Creek and 1993 and 1994 for Craintown Branch. Post-BMP data were collected in 1998 only, due to flood conditions in the spring and drought conditions in the summer of 1999.

Fishes were collected by seine for one hour at each Phase III station from all habitats present and preserved in a 10% formalin solution (KDOW 1995). Fishes were identified to the lowest taxonomic level possible, usually species.

The Index of Biotic Integrity (IBI) originally proposed by Karr (1981) and modified for Kentucky (KDOW 1997) was used to evaluate fish communities. The IBI is calculated using 12 equally weighted metrics that are grouped into three general categories: species richness and composition, trophic composition, and fish abundance and condition. Each metric is assigned a 5, 3, or 1 value depending upon whether the obtained value strongly approximates the expected value (5), somewhat approximates the expected value (3), or does not approximate the expected value (1).

The 12 individual metric values are then summed to provide an IBI score, which will range between 12 to 60 or no fish (0). A classification based on IBI scores is then assigned to describe the quality of the fish community at a given location.

Macroinvertebrates were collected at each station using an adaptation of the traveling kicknet method (TKN) (Hornig and Pollard 1978) following KDOW protocol (1993, 1995). In addition, selective sampling was performed in all available habitat types present at each station. The samples from these two methods were field picked, combined into one jar, and returned to the laboratory where they were sorted and identified to the lowest possible taxonomic level, usually genus or species.

Data evaluation included the analysis and interpretation of the biological, physicochemical, bacteriological, and BMP land-use data. Macroinvertebrate biological metrics that described community structure and health were used to document differences in water quality between pre-BMP and post-BMP. The biological indices or metrics that were used to analyze the macroinvertebrate data and make comparisons between collections were the Macroinvertebrate Bioassessment Index, Taxa Richness, Ephemeroptera-Plecoptera-Trichoptera (EPT) Index, the Hilsenhoff Biotic Index, Percent Contribution of Dominant Taxa-5, Percent EPT, Jaccard's Similarity Index, and the Proportional Similarity Index.

The Macroinvertebrate Bioassessment Index (MBI) was originally developed to use a basic core of four metrics and at least two additional metrics depending on the type of impact, ecoregion, etc., to analyze macroinvertebrate data for wadeable streams in Kentucky (KDOW 1993). The MBI has since been revised (KDOW unpublished report) for streams of the Interior Plateau Ecoregion and includes Taxa Richness, EPT, HBI, PCD_5, and %EPT. The results obtained for these metrics are assigned a value from 1 to 5 (Table 1) based on their percentile score. These values are then summed to provide an overall water quality classification (Table 2). Taxa Richness is the number of distinct taxa present in the sample. The Ephemeroptera-Plecoptera-Trichoptera Index is an enumeration of the taxa from these generally pollution-intolerant insect orders. It is expected that the values for these two metrics will increase as water quality improves (KDOW 1993). The Hilsenhoff Biotic Index (HBI) is a measure of the overall organic pollution tolerance of a stream arthropod community using macroinvertebrate tolerance values that have been modified for streams of the southeastern United States (Lenat 1993, KDOW unpublished data) to assess impacts from organic pollution. The HBI ranges from 0.00 (Excellent Water Quality) to 10.00 (Very Poor Water Quality) (Hilsenhoff 1987). The Percent Contribution of Dominant Taxa-5 (PCD_5) is a measure of evenness and redundancy that sums the relative percent abundance of the five dominant taxa. Communities that are highly dominated by a few taxa may reflect an impaired condition (KDOW 1993). Percent EPT (%EPT) is a measure of the abundance of the pollution intolerant EPT organisms (KDOW unpublished report).
The HBI is intended to characterize the overall pollution tolerance of a benthic macroinvertebrate community (Lenat 1988 and 1993). A pollution tolerance value (a_i) is assigned to each taxon within a sample. The total number of individuals within each taxon, up to 25, is multiplied by the tolerance value for that taxon (Lenat 1993). All products are then summed and divided by the total number of individuals to derive the HBI value. HBI values can range from 0 to 10.0, and HBI interpretations are adjusted by ecoregion. Higher HBI values indicate poor water quality and lower values indicate good water quality.

Table 1. Metric criteria for the Macroinvertebrate Biotic Index (MBI) derived from percentiles of 3rd and 4th order streams in the Interior Plateau ecoregion (KDOW unpublished report).

Percentile	>90%	70-90%	40-70%	20-40%	<20%
Score	5	4	3	2	1
TR	≥59	45-58	30-44	24-29	≤23
EPT	≥17	13-16	9-12	5-8	≤4
HBI	≤5.16	5.17-5.72	5.73-6.33	6.34-7.08	≥7.09
PCD-5	≤42	42.1-56.0	56.1-66.9	67.0-75.3	≥75.4
%EPT-TOT	≥59.3	46.4-59.2	30.4-46.3	19.8-30.4	<19.7

Table 2. Macroinvertebrate Biotic Index (MBI) scores for 3rd and 4th order streams of the Interior Plateau ecoregion (KDOW unpublished report).

Percentile	>95%	70-90%	40-70%	20-40%	<20%
Classification	Excellent	Good	Fair	Poor	Very Poor
Score	21-25	17-20	14-16	10-13	≤9

Jaccard's Similarity Index and the Proportional Similarity Index are used for biological trend monitoring to indicate similarity of communities to determine temporal shifts in community structure (KDOW 1993). These indices range from 0 (no similar) to 100%. These indices were used to indicate whether the fauna at each site changed from pre-BMP to post-BMP.

RESULTS AND DISCUSSION

BMP Implementation Tracking

In an ideal study, no BMPs would have been functioning in the Fleming Creek watershed before the pre-BMP (pre-1995) period of this study. However, there were several landowners who had BMPs in place (eight types) before 1995 (Table 3). During the period 06/01/1994 – 06/01/1999, 14 additional types of BMPs were installed in the watershed, initiated with two new sources of funding (Table 4). Six of these BMPs were new to the watershed. A total of 8 ponds, 2,100 ft of fencing, 314 troughs or tanks, 2 sediment basins, 4 waste storage ponds, 25 waste management systems, 13 waste storage facilities were implemented in the watershed since 05/11/1990. In addition, 608 acres of land received BMPs since 05/01/1990. The number of dairy cattle in the Fleming Creek watershed was reduced by 36% from 1991 to 1998 (Table 5). Also, the total number of cattle was reduced by 5.2% (Table 5).

Water Quality Monitoring

Phase I (Bacteriological Survey)

Twenty-seven high-flow water samples for Fecal Coliform (FC) analysis were collected on 18 May 1992 to provide baseline data for the pre-BMP study (KDOW 1996) (Table 6). Twenty-three of these samples had high (>400) fecal coliform levels. Twenty-eight low-flow water samples were collected on 18 August 1992 (Table 6). Nine of these sites had high (>400) FC levels (KDOW 1996). A total of eight pre-BMP sites were judged as having FC levels unsuitable for PCR (KDOW 1996) (Table 6). Nine of these sites had high (>400) FC levels.

Twenty-four high-flow water samples for FC analysis were collected 23 May 1998. All of these samples had high FC levels (>400). Low-flow water samples were collected 12 October 1998.

Table 3. Best Management Practices implemented in the Fleming Creek Watershed from 05/01/1990 to 06/01/1994 (NRCS unpublished data).

Type of BMP	Funding Source [a]	Unit
Trough or Tank	FSA	124 no.
Waste Management System	LTA, WSP	16 no.
Diversion	LTA	244 m
Fence	LTA	366 m
Waste Storage Pond	LTA	1 no.
Heavy Use Area Protection	LTA	0.4 ha
Waste Utilization	LTA, WSP	43 ha
Filter Strip	WSP	0.8 ha

[a] FSA - Food Security Act
LTA - Long Term Agreement
WSP - Water Quality Special Project

Table 4. Best Management Practices implemented in the Fleming Creek Watershed from 06/01/1994 to 06/01/1999 (NRCS unpublished data).

Type of BMP	Funding Source [a]	Unit
Waste Management System	CTA, FSA, LTA, WQSP	9 no.
Waste Storage Facility	CTA, FSA, LTA, WQSP	13 no.
Cover and Green Manure Crop	CTA	28 ha
Pond	CTA, FSA	8 no.
Fence	CTA, WSP	274 m
Trough or Tank	CTA, FSA, WQP	190 no.
Waste Utilization	CTA, FSA, WQSP	97 ha
Filter Strip	FSA	1.6 ha
Use Exclusion	FSA	45 ha
Prescribed Grazing	FSA	12 ha
Heavy Use Area Protection	FSA, WQSP	2 ha
Nutrient Management	FSA	16 ha
Sediment Basin	LTA	2 no.
Waste Storage Pond	WQSP	3 no.

[a] CTA Conservation Technical Assistance
FSA Food Security Act
LTA Long Term Agreement
WQSP Water Quality Special Project
WQP Water Quality Demonstration Project

Table 5. All cattle and total dairy cattle present in the Fleming Creek watershed from 1991–1998 (KASS 1998).

Year	All cattle	% of 91–92 numbers	# Dairy Cows	% of 91–92 numbers
97-98	46000	94.8	6400	64.0
96-97	47500	97.9	7000	70.0
95-96	49000	101.0	7600	76.0
94-95	48500	100.0	7700	77.0
93-94	48000	99.0	9000	90.0
92-93	47500	97.9	9400	94.0
91-92	48500	100.0	10000	100.0

Table 6. Fecal coliform colonies/100 ml and monitoring stations in the Fleming Creek watershed.

	PRE-BMP HIGH FLOW	PRE-BMP LOW FLOW	POST-BMP HIGH FLOW	POST-BMP LOW FLOW
STATION NO.	18 MAY 1992	18 AUG 1992	23 MAY 1998	12 OCT 1998
05029003	400	20/30	>16,000	50
05029004	560	60	>16,000	10
05029005	9,200	100	11,000	10
05029006	4,600	100	>16,000	10
05029007	9,200	260	>16,000	80
05029008	750	60	>16,000	60
05029009	5,000	80	NS	NS
05029010	740	140	>16,000	10
05029011	250	120	NS	NS
05029012	460	30	>16,000	ND
05029013	520	90	>16,000	60
05029014	500	10	NS	NS
05029015	500	130	>16,000	130
05029016	210	210	>16,000	10
05029017	2,400	10	>16,000	ND
05029018	500	270	NS	NS
05029019	>16,000 [a]	>16,000 [a]	>16,000	ND
05029020	420	250	>16,000	ND
05029021	ND	3,600	>16,000	ND
05029022	15,000 [a]	1,000 [a]	>16,000 [a]	450 [a]
05029023	>16,000 [a]	6,800 [a]	>16,000 [a]	600 [a]
05029024	500 [a]	1,100 [a]	>16,000	270
05029025	5,600 [a]	720 [a]	>16,000 [a]	6,000 [a]
05029026	1,400 [a]	530 [a]	>16,000	150
05029027	16,000 [a]	500 [a]	>16,000	120
05029028	12,000	200	>16,000	200
05029029	>16,000	100	>16,000	70
05029030	3,200 [a]	530 [a]	>16,000	30

[a] exceeded PCR criteria
ND = No data
NS = Not sampled

Three of these sites had high (>400) FC levels. The post-BMP FC collection results indicated that three sites did not support PCR designated uses (Table 6).

The number of stations not meeting PCR uses declined by five sites from pre- to post-BMP. However, this may not be indicative of improvements in water quality, as indicated by the high FC levels, found in the post-BMP high-flow water samples, which indicated animal waste runoff was still a major water quality impact.

Post-BMP high-flow FC levels were significantly higher ($p<.001$) than pre-BMP high flow levels and pre-BMP low-flow FC levels were significantly higher ($P<.01$) than post-BMP FC low-flow levels. These contradictory results can best be explained by examining the amount of rainfall that occurred prior to sampling. Post-BMP high-flow samples were collected after a full month of heavy precipitation while rainfall during the pre-BMP high-flow sampling was not as heavy and was sporadic throughout the water shed as indicated by various rain gauges in the area. The opposite was true for the low-flow data. Post-BMP low-flow data were collected during an unusually dry period while pre-BMP low-flow data were collected after an unusually wet period. Because sampling conditions varied between pre- and post-BMP collections, comparisons concerning water quality based on bacteriological data are difficult to make. However, the data do indicate there are problems with animal waste runoff following large storm events throughout the watershed.

Phase II (Long-term Physicochemical Monitoring)

Ten sets of pre-BMP Phase II data (Appendix B) were collected from 1992 – 1994. A total of nine sets (Appendix B) of data were collected for post-BMP physicochemical monitoring from 1997 – 1999. Using Phase II data, we could not document a trend in water quality changes resulting from BMP implementation. In addition, nutrient levels were not detected at high concentrations on a consistent basis (>400 fecal coliform colonies during high- and low-flow sampling events).

Only a few storm-event flow measurements were obtained because water levels were often too high for safe entry. In many cases, periods of peak nutrient loads and storm events were missed. Long-distance storm event sampling may be inherently flawed because of the distance researchers must travel to collect samples and because weather patterns over long distances are not predictable.

Twenty sets of data over a seven year period cannot accurately depict the true nutrient levels of these five sites. The data were too few and sporadic to analyze using statistical methods and have questionable usefulness for depicting true and worse case scenarios

Phase III (Biological Monitoring)

Fish Data. A synoptic list of fish species for all collection sites is provided in Appendix C. Pre-BMP IBI scores for Allison Creek (05029020) ranged from 24 to 34 (KDOW 1996) (Figure 3), which was an indication of poor to very poor water quality conditions (Karr 1981). Only one year of post-BMP data was collected due to drought conditions in 1999. A fish kill occurred in Allison Creek in 1998 just prior to the time of sampling, resulting in an IBI score of 0. The fish kill was apparently caused by excessive nutrient loading.

Craintown Branch (05029015) pre-BMP IBI scores ranged from 30 to 36 (Figure 4), which was an indication of poor to poor-fair water quality conditions. The post-BMP score for Craintown Branch was 54, an indication of good-excellent water quality.

Pre-BMP IBI scores for the Fleming Creek mainstem station (05029031) ranged from 38 to 47 (Figure 5), which was an indication of poor-fair to good-fair water quality conditions. The post-BMP score for the Fleming Creek mainstem station was 50, an indication of good water quality conditions.

The IBI score for Fleming Creek (05029031) indicated a slight improvement in water quality, and Craintown Branch (05029015) exhibited a notable increase in water quality. The water quality of Allison Creek (05029020) became more degraded from pre- to post-BMP sampling.

Macroinvertebrate Data. Pre-BMP macroinvertebrate samples for Allison Creek (05029020) were collected on 05/12/92, 05/12/93, and 05/10/94. A total of 2,259 macroinvertebrates were collected and identified (Appendix D). HBI values ranged from 5.23 (good/some pollution) to 6.83 (poor/highly polluted) (KDOW 1996). MBI values ranged from 11 (poor) to 13 (poor). Taxa Richness fluctuated from a low of 36 in 1994 to a high of 51 in 1993. The EPT Index and % EPT indicated that the pre-BMP macroinvertebrate community was

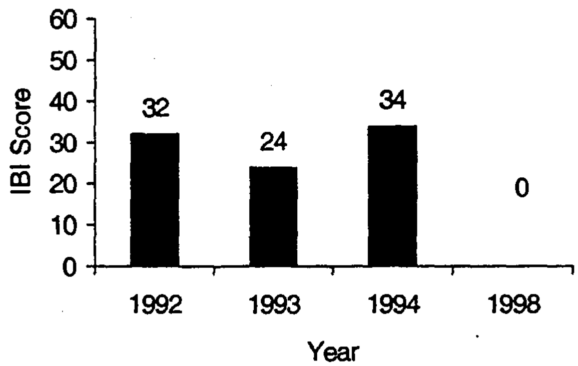

Figure 3. Index of Biotic Integrity (IBI) scores for Allison Creek (05029020) Fishes (pre-BMP data from KDOW 1996).

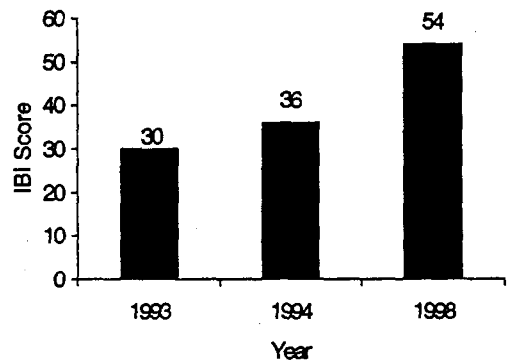

Figure 4. Index of Biotic Integrity (IBI) scores for Craintown Branch (05029015) fishes (pre-BMP data from KDOW 1996).

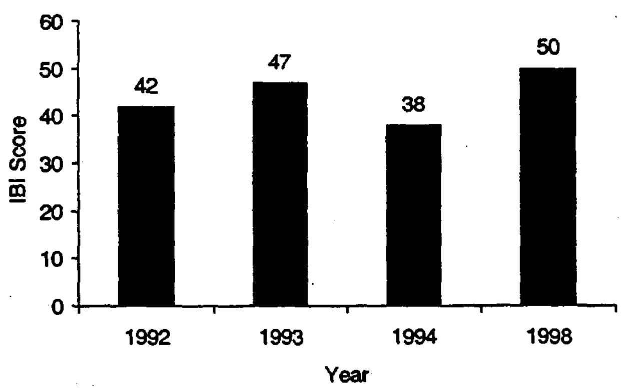

Figure 5. Index of Biotic Integrity (IBI) scores for Fleming Creek (05029031) fishes (pre-BMP data from KDOW 1996).

dominated by non-EPT taxa (KDOW 1996). The HBI, EPT, PCD_5, and % EPT values indicated that this site was dominated by a few pollution-tolerant taxa (Figure 6). All of the metrics indicated very poor to fair water quality. Despite a low Jaccard's Similarity Index value (Table 7) in Allison Branch, a high Proportional Similarity Coefficient (Table 8) was found between 1993 and 1994 collections. This could be attributed to very similar abundances of a few of the dominant taxa (See Appendix D). The post-BMP metrics indicated a highly degraded and polluted environment that had a diverse community of pollution-tolerant macroinvertebrates (Figure 6). The water quality of Allison Creek (05029020) became more degraded during the course of this study, which may indicate a problem with excessive nutrient loading and/or inadequate BMP performance or placement.

Pre-BMP macroinvertebrate data for Craintown Branch (05029015) were collected on 05/12/93 and 05/10/94. A total of 1,214 macroinvertebrates were collected and identified (Appendix D). The HBI scores were 6.58 (poor/very significant pollution) and 6.41 (poor/very significant pollution) respectively (Figure 7). The MBI values were 11 (poor) and 9 (very poor). Taxa Richness, EPT, % EPT, and PCD_5 values all indicated a degraded and polluted system with degraded habitat and poor water quality.

Post-BMP macroinvertebrate data were collected 07/09/98 for Craintown Branch. A total of 781 macroinvertebrates were collected and identified (Appendix D). Because the pre- and post-BMP data were collected in different seasons Jaccard's Similarity Index (Table 9) and the Proportional Similarity Coefficient (Table 10) indicated the pre- and post-BMP samples did not have similar macroinvertebrate faunas. The community similarity indices also indicated considerable temporal variability over time. Despite a low Jaccard's Similarity Index value (Table 9) in Craintown Branch, a high Proportional Similarity Coefficient was found between 1993 and 1994 collections. This could be attributed to very similar abundances of a few of the dominant taxa (See Appendix D). The EPT Index and the % EPT indicated there was a high percentage of tolerant EPT taxa, such as *Cheumatopsyche* sp. and *Stenacron interpunctatum* (Appendix D) present during post-BMP. The PCD_5 (Figure 7) indicated that other pollution-tolerant taxa such as *Lirceus fontinalis,* also dominated the community. This assemblage of pollution tolerant taxa attributed to the increase in the post-BMP MBI score (which is not solely calculated using tolerance

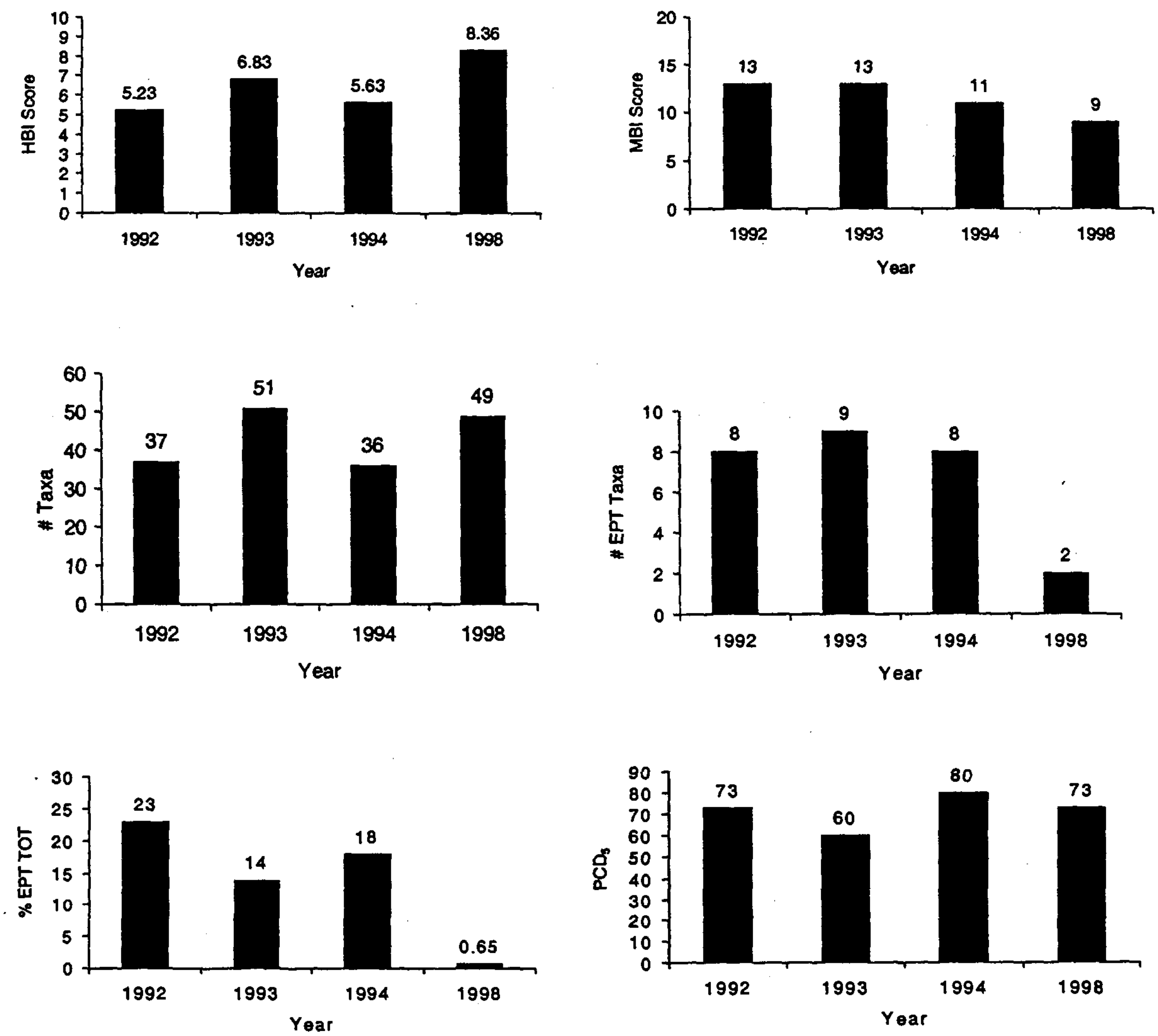

Figure 6. Allison Creek (05029020) macroinvertebrate metrics (pre-BMP data from KDOW 1996).

Table 7. Jaccard's Similarity Index for Allison Creek (05029020) macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTION DATE	05/12/92	05/12/93	05/10/94	07/07/98
05/12/92	--	26.6	24.1	6.8
05/12/93		--	38.7	24.1
05/10/94				10.5

Table 8. Proportional Similarity Coefficient for Allison Creek (05029020) macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTION DATE	05/12/92	05/12/93	05/10/94	07/07/98
05/12/92	--	60.4	35.6	16.7
05/12/93		--	42.7	23.7
05/10/94			--	3.2

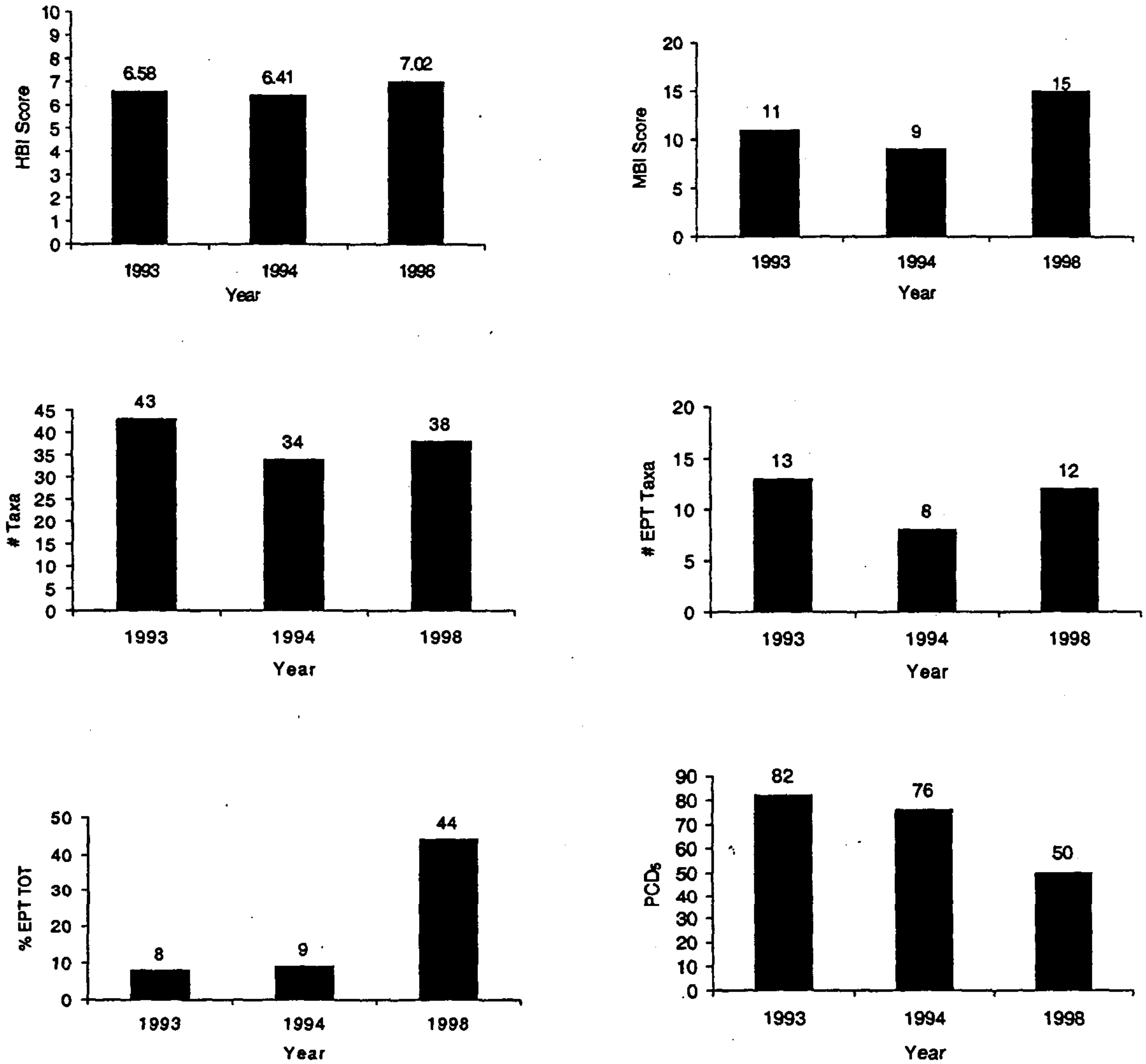

Figure 7. Craintown Branch (05029015) macroinvertebrate metrics (pre-BMP data from KDOW 1996)

Table 9. Jaccard's Similarity Index for Craintown Branch (05029020) macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTION DATE	05/12/93	05/10/94	07/09/98
05/12/93	--	33.3	15.7
05/10/94	--	--	14.5

Table 10. Proportional Similarity Coefficient for Craintown Branch macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTION DATE	05/12/93	05/10/94	07/09/98
05/12/93	--	65.7	23.3
05/10/94		--	24.2

values). This high percentage of tolerant organisms also attributed to the lower post-BMP HBI score (Figure 7), which is calculated solely with Tolerance Values. However neither the HBI values nor the MBI fluctuated greatly from pre- to post-BMP implementation. These results implied the water quality in Craintown Branch did not change greatly from pre- to post-BMP implementation.

Pre-BMP macroinvertebrate data for Fleming Creek (05029031) were collected on 05/12/92, 05/12/93, and 05/10/94. A total of 1,790 macroinvertebrates were collected and identified (Appendix D). The HBI values ranged from 5.19 to 5.53 (good/mild organic pollution present) (Figure 8). The MBI values ranged from 13 (poor) to 15 (fair). Taxa Richness, EPT, % EPT, and PCD_5 (Figure 8) indicated poor to good water quality over the years of the pre-BMP monitoring.

Post-BMP macroinvertebrate data for Fleming Creek were collected on 07/09/98. A total of 905 macroinvertebrates were collected and identified (Appendix D). The HBI value was 5.59 (good/mild organic pollution) (Figure 8). The MBI value was 16 (fair) (Figure 8). Because the pre- and post-BMP data were collected in different seasons, Jaccard's Similarity Index (Table 11) and the Proportional Similarity Coefficient (Table 12) indicated the pre and post-BMP macroinvertebrate faunas were not highly correlated. Despite a low Jaccard's Similarity Index value (Table 11) in Allison Branch, a high Proportional Similarity Coefficient (Table 12) was found between 1993 and 1994 collections. This could be attributed to very similar abundances of a few of the dominant taxa (See Appendix D). However, the HBI and MBI values did not fluctuate a great deal (Figure 8), which indicated the water quality remained relatively unchanged throughout this study. Another possible scenario for the stability in water quality may be due to the amount of dilution that occurs in a stream of this size.

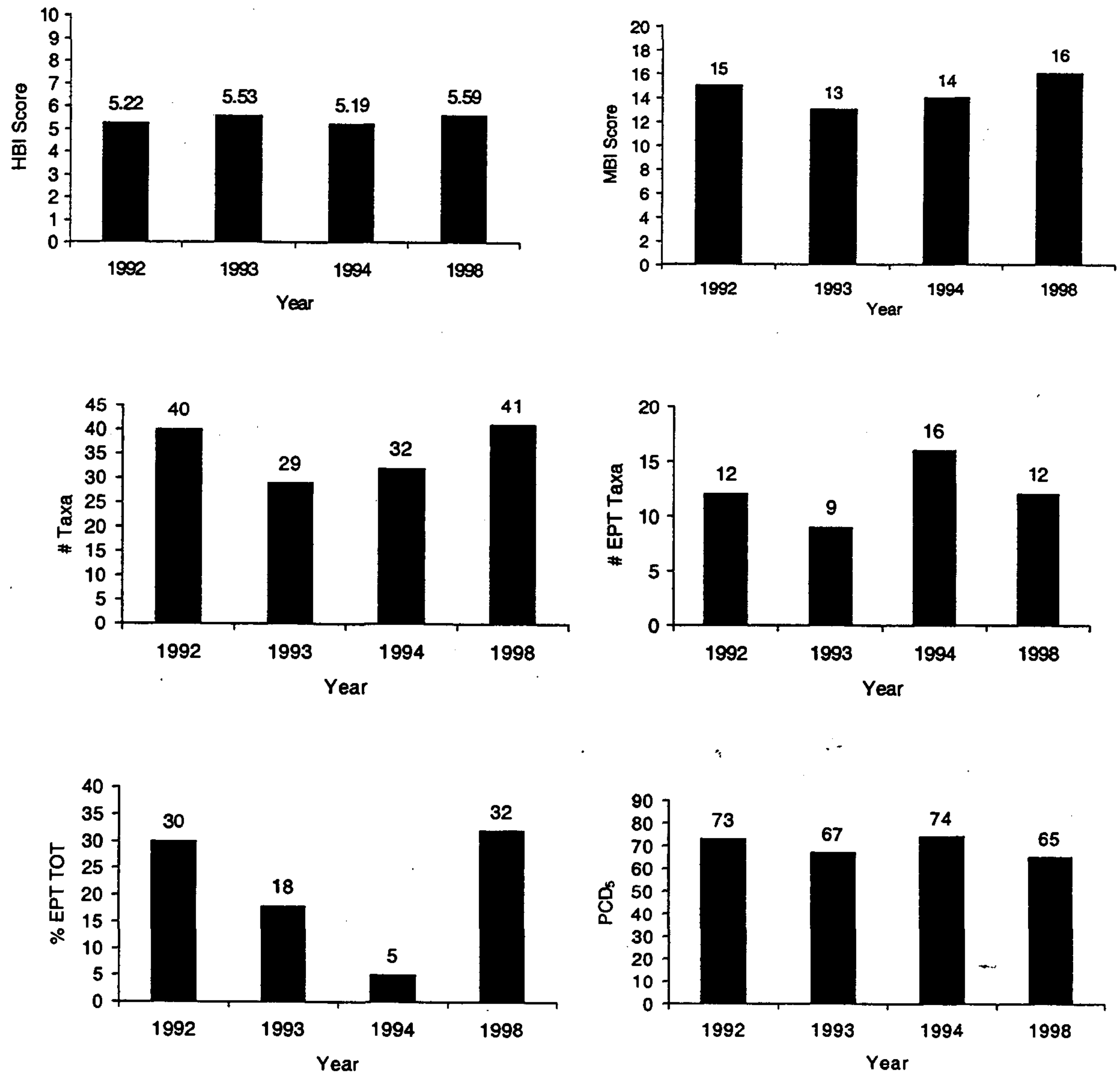

Figure 8. Fleming Creek (05029031) macroinvertebrate metrics (pre-BMP data from KDOW 1996).

Table 11. Jaccard's Similarity Index for Fleming Creek (05029031) macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTION DATE	05/12/92	05/12/93	05/10/94	07/09/98
05/12/92	--	36.7	22.8	11.1
05/12/93		--	43.9	19.0
05/10/94			--	16.1

Table 12. Proportional Similarity Coefficient for Fleming Creek (05029031) macroinvertebrates (pre-BMP data from KDOW 1996).

COLLECTING DATE	05/12/92	05/12/93	05/10/94	07/09/98
05/12/92	--	42.5	42.9	8.3
05/12/93		--	67.9	28.5
05/10/94			--	24.1

SUMMARY AND CONCLUSIONS

The number of conservation practices and funding sources during the period 05/01/1990 – 06/01/1999 increased by a total of 8 ponds, 2,100 ft of fencing, 314 troughs or tanks, 2 sediment basins, 4 waste storage ponds, 25 waste management systems, and 13 waste storage facilities. In addition, 608 acres of land received a BMP since 05/01/1990. Concurrently, the number of dairy cattle in the Fleming Creek watershed was reduced by 36% from 1991 to 1998 and the total number of cattle was reduced by 5.2%. These practices and dairy reductions may be the initial steps in controlling NPS pollution in the Fleming Creek watershed. However, due to the large size of the Fleming Creek watershed, many more practices will need to be implemented before water quality improvements can be demonstrated.

Post-BMP FC (Phase I) results indicated that five sites supported PCR designated uses (compared to nine pre-BMP sites). However, this may not indicate an improvement in water quality has occurred, as indicated by the extremely high FC levels found in the high-flow periods during the post-BMP study. The high flow post-BMP FC levels indicated that animal waste runoff was still a major water quality impact. However, relatively few FC samples were collected during the project and collections that were made were not collected under comparable environmental conditions. Therefore, conclusions about water quality changes can not be supported using only FC levels.

The physicochemical data (Phase II) (20 sets of data over a seven year period) could not accurately depict the true nutrient levels of these five sites. The data were too few and sporadic to analyze using statistical methods and had questionable usefulness for depicting true case scenarios. More weight was given to the Phase III (Biological) data to assess water quality trends.

Phase III monitoring involved collecting macroinvertebrates and fish from three of the more impacted sites, based on Phase I and Phase II pre-BMP data. The IBI was used to assess the fish community at these sites to give an indication of the water quality in the Fleming Creek watershed. The IBI indicated Craintown Branch (05029015) and Fleming Creek (05029031) increased in water quality while Allison Creek (05029020) water quality decreased.

Jaccard's Similarity Index and the Proportional Similarity Coefficient indicated the faunas of the pre- and post-BMP collections were not similar, which is most likely because the pre- and post-BMP macroinvertebrate data were collected in different seasons. The water quality of Allison Creek (05029020) became more degraded during the post-BMP sampling event, which indicated a problem with excessive nutrient loading and/or BMP non-compliance. Based on the macroinvertebrate data, water quality in Craintown Branch (05029015) and Fleming Creek (05029031) has remained relatively unchanged throughout the study.

Due to the questionable nature of the FC data and the lack of any useable physicochemical data, the assessment of the BMPs must rely almost entirely on the biological data. The fauna is the best indicator of the overall health of a system; however, this project was designed to incorporate FC, physicochemical, and biological monitoring in order to depict an all-encompassing view of the water quality in the Fleming Creek watershed. Because of problems associated with long-distance traveling and other project logistics, none of the data may be unquestionably used. A more accurate evaluation could be made if a future study used automatic samplers to collect physicochemical data. Storm-event sampling of Fecal Coliforms should be collected by researchers living in the vicinity of the sites in order to make more uniform and comparable samples. Also multiple FC and physicochemical samples should be taken each month of the study, and macroinvertebrates should be collected during similar seasons each year of a project.

A future study in Fleming Creek should collect macroinvertebrates during the month of May and make an additional collection during July to make a comparative study with the 1998 collection. A study trying to evaluate the effectiveness of BMPs should be longer-lived, done on a smaller size watershed, and should have an equal number of pre- and post-BMP sampling events that occur during the same seasons of each successive year.

The numbers of BMPs and funding sources increased from the period of 05/01/1990 to 06/01/1999, which indicated a higher level of water quality awareness in the watershed. The total number of cattle and dairy operations also decreased. These practices may be the initial steps in controlling NPS pollution. Due to the large size of the Fleming Creek watershed, there will have to be more practices implemented before significant improvements in water quality can be demonstrated.

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Appendix A
Fleming Creek watershed project station locations and type of data collected

Site #	Site Locality	Type of Monitoring
05029003	Fleming Creek mainstem at Hwy 32 bridge, Nicholas County.	Bacteria (Phase I)
05029004	Fleming Creek mainstem adjacent to Yin Road, Fleming County.	Bacteria (Phase I)
05029005	Unnamed trib to Fleming Creek adjacent to Hammonds Road, Fleming County.	Bacteria (Phase I)
05029006	Fleming Creek mainstem adjacent to Pike Bluff Road, Fleming County.	Bacteria (Phase I)
05029007	Poplar Creek at mouth, Fleming County.	Bacteria (Phase I)
05029008	Fleming Creek mainstem just downstream of Doty Creek confluence, Fleming County.	Bacteria (Phase I)
05029009	Doty Creek at mouth, Fleming County.	Bacteria (Phase I)
05029010	Fleming Creek mainstem just upstream of Doty Creek confluence, Fleming County.	Bacteria (Phase I)
0502911	Fleming Creek mainstem just downstream of Craintown Branch confluence adjacent to Hwy 57, Fleming County.	Bacteria (Phase I)
05029012	Fleming Creek mainstem just upstream of Craintown Branch confluence at Hwy 57 bridge, Fleming County.	Bacteria (Phase I)
05029013	Fleming Creek mainstem just upstream of Flat Run confluence, Fleming County.	Bacteria (Phase I)
05029014	Flat Run near mouth, Fleming County.	Bacteria (Phase I)
05029015	Craintown Branch at mouth, Fleming County.	Bacteria (PhaseI) Physicochemical (Phase II) Biological (Phase III)
05029016	Fleming Creek mainstem just downstream of Cassidy Creek confluence, Fleming County.	Bacteria (Phase I)
05029017	Cassidy Creek at Hwy 11 bridge, Fleming County.	Bacteria (Phase I)
05029018	Fleming Creek mainstem just upstream of Cassidy Creek confluence, Fleming County	Bacteria (Phase I)
05029019	Fleming Creek mainstem just upstream of Allison Creek confluence, Fleming County.	Bacteria (Phase I)

Site #	Site Locality	Type of Monitoring
05029020	Allison Creek just downstream of Smith's dairy near Hwy 697, in Fleming County.	Bacteria (Phase I) Physicochemical (Phase II) Biological (Phase III)
05029021	Flemingsburg Treatment Plant effluent on Town Branch, in Fleming County.	Bacteria (Phase I)
05029022	Fleming Creek mainstem just downstream of Town Branch confluence, in Fleming County.	Bacteria (Phase I)
05029023	Town Branch at mouth, in Fleming County.	Bacteria (Phase I)
05029024	Fleming Creek mainstem just upstream of Town Branch confluence at Hwy 32 bridge, in Fleming County.	Bacteria (Phase I)
05029025	Wilson Run near mouth, just downstream of Hwy 559 bridge, in Fleming County.	Bacteria (Phase I)
05029026	Fleming Creek mainstem at Hwy 559 bridge, just upstream of Wilson Run confluence.	Bacteria (Phase I)
05029027	Sleepy Run downstream of Hwy 57 bridge, in Fleming County.	Bacteria (Phase I)
05029028	Fleming Creek mainstem at Hwy 3301 bridge, in Fleming County.	Bacteria (Phase Physicochemical (Phase II)
05029029	Logan Run at mouth adjacent to Hwy 57, in Fleming County.	Bacteria (Phase I) Physicochemical (Phase II)
05029030	Fleming Creek mainstem just above Logan Run confluence near Hwy 57, in Fleming County.	Bacteria (Phase I)
05029031	Fleming Creek mainstem just downstream of Hwy 170, in Fleming County.	Physicochemical (Phase II), Biological (Phase III)
05029032	Allison Creek just upstream of Smith's dairy near Hwy 697, in Fleming County.	Physicochemical (Phase II)

Appendix B

Fleming Creek watershed nonpoint source demonstration project physicochemical data

Fleming Creek at Highway 3301 Bridge (05029028)

Parameter	Sampling Event 5/8/92	5/18/92	8/18/92	1/5/93	2/21/93	3/4/93	3/17/93	8/29/97	10/2/97
Water Temperature (°C)	13.6	20.6	18.8	8.5	NS	5.5	3.1	22.1	13.0
Dissolved Oxygen (mg/l)	10.5	7.4	5.8	11.2	NS	11.6	12.0	5.60	5.14
Turbidity (NTU)	32.0	71.0	18.0	188.5	>200	>200	122	16.0	5.82
Conductivity (mS/cm)	350	376	396	256	152	178	184	0.33	0.258
pH	7.1	7.6	6.9	7.0	7.5	7.1	6.5	8.3	7.68
Total Suspended Solids (mg/l)	10.0	40.0	7.0	88.0	930.0	138.0	106.0	29	2.00
Total Organic Carbon (mg/l)	3.8	3.7	3.7	12.7	9.6	9.6	7.9	5.25	5.94
Ammonia-nitrogen (mg/l)	ND@0.05	0.086	ND@0.05	0.050	0.186	0.146	0.127	ND@0.05	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	0.563	0.700	0.061	1.20	4.01	1.78	0.962	0.846	0.651
Nitrate (mg/l)	0.165	0.659	0.618	1.59	0.889	1.29	1.06	0.120	0.023
Phosphorus, Total (mg/l)	0.029	0.061	0.041	0.181	1.03	0.276	0.201	0.059	0.037
Flow (cfs)	4.46	NS	NS	96.84	NS	NS	NS	0.0	0.0

Parameter	Sampling Event 11/11/97	1/7/98	2/19/98	3/17/98	4/30/98	7/17/98
Water Temperature (°C)	8.5	11.2	6.5	NS	14.2	24.2
Dissolved Oxygen (mg/l)	4.21	9.52	11.28	NS	9.81	5.59
Turbidity (NTU)	10.0	750	21	13.5	142	6.35
Conductivity (mS/cm)	0.236	0.180	0.158	NS	0.144	0.430
pH	8.62	7.9	8.1	NS	7.6	7.5
Total Suspended Solids (mg/l)	3	410	30	11	100	6
Total Organic Carbon (mg/l)	5.10	9.1	4.88	2.00	9.19	5.24
Ammonia-nitrogen (mg/l)	ND@0.05	0.181	0.395	ND@0.05	0.137	0.092
Total Kjeldhal Nitrogen (mg/l)	0.541	3.41	1.19	0.264	1.45	1.56
Nitrate (mg/l)	0.059	3.25	2.31	1.39	0.726	0.357
Phosphorus, Total (mg/l)	0.038	0.729	0.177	0.018	0.235	0.039
Flow (cfs)	0.0	NS	NS	6.94	NS	0.0

NS - Not Sampled; ND - Not Detected at the level indicated

Logan Run at Mouth, Adjacent to Highway 57 (05029029)

Parameter	Sampling Event 5/8/92	5/18/92	8/18/92	1/5/93	2/21/93	3/4/93	3/17/93	8/29/97	10/2/97
Water Temperature (°C)	13.7	18.7	20.1	8.0	NS	5.8	4.4	22.5	16.7
Dissolved Oxygen (mg/l)	10.4	8.6	8.2	11.5	NS	11.8	11.8	7.6	10.47
Turbidity (NTU)	66.0	310.0	15.0	91.5	>200	>132	82.0	24.0	45.9
Conductivity (mS/cm)	398	330	555	331	142	203	228	0.60	0.504
pH	6.6	7.6	6.9	7.0	7.4	7.1	6.4	8.2	8.37
Total Suspended Solids (mg/l)	30.0	116.0	7.0	40.0	618.0	99.0	46.0	67	64.0
Total Organic Carbon (mg/l)	3.9	7.5	2.3	5.6	12.2	7.6	5.3	4.76	11.5
Ammonia-nitrogen (mg/l)	ND@0.05	0.068	ND@0.05	ND@0.05	0.109	ND@0.05	0.060	ND@0.05	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	0.681	1.45	ND@0.05	0.700	3.21	1.30	0.786	0.916	4.64
Nitrate (mg/l)	0.135	1.08	1.20	1.98	0.880	1.27	1.30	0.016	0.043
Phosphorus, Total (mg/l)	0.061	0.151	0.019	0.100	0.628	0.176	0.135	0.068	0.323
Flow (cfs)	3.60	NS	NS	17.46	NS	65.60	13.02	0.0	0.0

Parameter	Sampling Event 11/11/97	1/7/98	2/19/98	3/17/98	4/30/98	7/17/98
Water Temperature (°C)	8.4	11.0	NS	NS	14.1	26.9
Dissolved Oxygen (mg/l)	9.14	9.8	NS	NS	10.14	8.3
Turbidity (NTU)	5.3	270	7.1	6.7	59.9	5.78
Conductivity (mS/cm)	0.583	0.150	NS	NS	0.198	0.509
pH	8.1	7.9	NS	NS	7.7	7.8
Total Suspended Solids (mg/l)	ND@1	180	10	5	50	12
Total Organic Carbon (mg/l)	5.70	9.4	2.75	1.32	5.74	5.00
Ammonia-nitrogen (mg/l)	ND@0.05	0.054	0.161	ND@0.05	ND@0.05	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	0.543	2.08	0.690	ND@0.05	0.927	0.595
Nitrate (mg/l)	0.115	2.59	3.18	1.73	0.901	0.246
Phosphorus, Total (mg/l)	0.033	0.631	0.076	0.010	0.122	0.025
Flow (cfs)	0.0	NS	NS	1.03	NS	0.0

NS - Not Sampled; ND - Not Detected at the level indicated

Allison Creek Downstream of Smith's Dairy (05029020)

	Sampling Event								
Parameter	5/8/92	5/12/92	5/18/92	8/18/92	1/5/93	2/21/93	3/4/93	4/17/93	5/12/93
Water Temperature (°C)	13.8	17.8	22.9	25.0	8.3	NS	6.0	4.9	22.7
Dissolved Oxygen (mg/l)	10.4	11.0	8.1	10.2	11.5	NS	11.8	11.7	8.2
Turbidity (NTU)	46.0	11.2	9.0	1.3	67.0	>200	169.0	106.0	5.0
Conductivity (mS/cm)	524	522	447	NS	480	146	210	293	389
pH	6.8	7.5	7.6	6.8	7.5	7.6	7.0	6.7	7.3
Total Suspended Solids (mg/l)	142.0	5.0	6.0	6.0	38.0	658.0	106.0	42.0	16.0
Total Organic Carbon (mg/l)	16.6	5.3	5.3	11.6	8.2	13.0	10.0	5.4	14.9
Ammonia-nitrogen (mg/l)	0.919	0.208	1.09	0.512	ND@0.05	0.222	0.084	0.071	1.60
Total Kjeldhal Nitrogen (mg/l)	3.920	0.819	1.29	0.567	0.846	3.92	1.26	0.748	3.07
Nitrate (mg/l)	0.048	0.209	0.070	0.098	1.40	0.869	0.827	0.808	0.177
Phosphorus, Total (mg/l)	0.603	0.078	0.237	1.430	0.161	1.54	0.324	0.171	0.446
Flow (cfs)	10.36	3.29	NS	NS	39.98	NS	367	102.9	6.24

	Sampling Event								
Parameter	5/10/94	8/29/97	10/2/97[a]	11/11/97	1/7/98	2/19/98	3/17/98	4/30/98	7/17/98
Water Temperature (°C)	17.0	32.5	NS	11.6	12.6	7.1	NS	14.4	31.1
Dissolved Oxygen (mg/l)	10.8	8.99	NS	15.98	9.51	12.03	NS	10.25	7.8
Turbidity (NTU)	10.5	5.7	NS	28.8	600	18	4.8	136	18.0
Conductivity (mS/cm)	432	0.47	NS	760	0.156	0.250	NS	0.214	0.493
pH	7.9	8.6	NS	8.59	7.8	8.1	NS	7.7	7.8
Total Suspended Solids (mg/l)	18.0	19	NS	12	260	32	8	170	26
Total Organic Carbon (mg/l)	NS	8.60	NS	29.6	11.4	6.13	2.38	9.61	33.6
Ammonia-nitrogen (mg/l)	1.13	0.222	NS	2.79	0.221	0.485	0.053	0.146	2.84
Total Kjeldhal Nitrogen (mg/l)	1.94	1.19	NS	7.15	4.12	2.12	0.318	2.14	5.29
Nitrate (mg/l)	0.637	0.057	NS	0.115	1.53	1.57	0.534	0.816	0.756
Phosphorus, Total (mg/l)	0.429	0.255	NS	4.00	1.23	0.294	0.030	0.499	0.487
Flow (cfs)	8.23	NS	NS	0.0	NS	NS	3.20	NS	1.24

[a] Not sampled, stream dry; NS - Not Sampled; ND - Not Detected at the level indicated

Craintown Branch at mouth (05029015)

Parameter	Sampling Event								
	5/8/92	5/18/92	8/18/92	1/5/93	2/21/93	3/17/93	4/3/93	5/12/93	5/12/94
Water Temperature (°C)	13.0	24.4	24.6	8.3	NS	4.4	6.7	22.9	NS
Dissolved Oxygen (mg/l)	11.3	10.3	7.1	11.5	NS	11.8	11.3	12.6	8.8
Turbidity (NTU)	34.2	NS	NS	67.0	>200	82.0	199.0	4.6	6.4
Conductivity (mS/cm)	452	300	281	480	148	228	232	243	466
pH	5.8	8.4	7.3	7.5	7.6	6.4	7.2	8.0	7.9
Total Suspended Solids (mg/l)	12.0	ND@0.05	4.0	34.0	597.0	44.0	126.0	6.0	9.0
Total Organic Carbon (mg/l)	5.2	3.7	3.8	4.1	11.4	8.4	12.6	4.8	NS
Ammonia-nitrogen (mg/l)	0.058	ND@0.05	ND@0.05	ND@0.05	0.222	0.152	0.227	ND@0.05	0.066
Total Kjeldhal Nitrogen (mg/l)	0.737	0.333	0.053	0.661	4.050	1.480	2.090	0.633	ND@0.05
Nitrate (mg/l)	0.227	0.109	0.071	2.80	0.937	1.410	1.050	0.011	1.050
Phosphorus, Total (mg/l)	0.187	0.030	0.047	0.343	2.920	0.521	1.070	0.099	0.136
Flow (cfs)	2.20	NS	NS	17.95	NS	24.54	68.80	6.81	3.63

Parameter	Sampling Event							
	8/29/97	10/2/97	11/11/97	1/7/98	2/19/98	3/17/98	4/30/98	7/17/98
Water Temperature (°C)	21.9	12.5	8.2	11.2	7.5	11.7	13.7	24.9
Dissolved Oxygen (mg/l)	4.03	4.58	4.80	10.51	12.07	14.6	11.3	6.94
Turbidity (NTU)	65.1	10.3	2.6	220	42	3.5	187	3.42
Conductivity (mS/cm)	0.494	0.400	0.406	0.298	0.284	0.312	0.216	0.439
pH	7.79	7.76	7.7	8.03	7.8	8.53	7.75	7.64
Total Suspended Solids (mg/l)	57	144	ND@1	180	53	6	170	14
Total Organic Carbon (mg/l)	6.41	4.31	5.99	6.7	2.53	2.10	11.4	5.94
Ammonia-nitrogen (mg/l)	0.071	ND@0.05	ND@0.05	0.282	ND@0.05	ND@0.05	0.729	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	1.08	0.581	0.647	4.09	1.11	0.526	3.64	0.975
Nitrate (mg/l)	0.464	0.118	0.072	3.94	3.06	0.993	1.28	0.279
Phosphorus, Total (mg/l)	0.195	0.125	0.081	0.887	0.305	0.054	1.25	0.117
Flow (cfs)	0.16	0.0	0.07	NS	NS	1.24	NS	0.2

NS - Not Sampled; ND - Not Detected at the level indicated

Fleming Creek Just Downstream of Highway 170 (05029031)

Parameter	Sampling Event								
	5/8/92	5/12/92	5/18/92	8/18/92	1/5/93	2/21/93	3/4/93	3/17/93	5/12/93
Water Temperature (°C)	14.8	21.8	23.4	22.4	9.4	NS	6.1	3.9	22.9
Dissolved Oxygen (mg/l)	11.0	10.5	7.5	10.3	11.0	NS	11.8	11.9	4.47
Turbidity (NTU)	9.0	17.0	7.7	0.8	>200	>200	>200	197.0	NS
Conductivity (mS/cm)	463	499	439	456	321	200	228	244	351
pH	6.4	7.5	7.5	7.6	7.7	7.7	7.2	6.8	7.0
Total Suspended Solids (mg/l)	2.0	10.0	ND@0.05	3.0	208	777	225	146	13.0
Total Organic Carbon (mg/l)	3.5	3.9	3.1	4.8	12.1	11.2	10.3	5.8	5.5
Ammonia-nitrogen (mg/l)	0.050	ND@0.05	ND@0.05	ND@0.05	ND@0.05	0.332	0.153	0.110	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	0.310	0.367	0.392	0.064	1.56	4.14	1.79	1.42	0.717
Nitrate (mg/l)	0.089	1.190	0.406	0.560	1.82	1.08	1.25	1.09	0.113
Phosphorus, Total (mg/l)	0.057	0.078	0.053	0.093	0.513	1.99	0.603	0.376	0.87
Flow (cfs)	17.40	59.40	NS	NS	NS	NS	NS	NS	39.58

Parameter	Sampling Event								
	5/10/94	8/29/97	10/2/97	11/11/97	1/7/98	2/19/98	3/17/98	4/30/98	7/17/98
Water Temperature (°C)	17.8	NS	14.7	8.4	10.7	7.4	7.5	13.7	23.3
Dissolved Oxygen (mg/l)	7.9	NS	5.98	7.01	10.0	11.7	13.06	10.13	5.64
Turbidity (NTU)	11.8	17.6	19.2	4.2	120	50	4.6	230	6.59
Conductivity (mS/cm)	460	NS	0.460	0.782	0.248	0.224	0.302	0.277	0.449
pH	7.7	NS	8.00	7.7	8.2	7.7	7.98	7.58	7.6
Total Suspended Solids (mg/l)	13.0	14	30	13	77	41	4	340	8
Total Organic Carbon (mg/l)	NS	5.4	5.56	5.68	6.5	5.82	2.15	11.9	5.64
Ammonia-nitrogen (mg/l)	ND@0.05	0.073	ND@0.05	ND@0.05	0.112	0.095	ND@0.05	0.208	ND@0.05
Total Kjeldhal Nitrogen (mg/l)	ND@0.05	0.667	0.598	0.235	1.39	1.25	ND@0.05	2.59	1.03
Nitrate (mg/l)	1.53	0.484	0.142	0.026	3.66	2.15	1.06	0.836	2.08
Phosphorus, Total (mg/l)	0.123	0.071	0.118	0.062	0.274	0.171	0.027	0.841	0.126
Flow (cfs)	84.32	3.36	0.10	0.0	NS	NS	22.7	NS	8.0

NS - Not Sampled; ND - Not Detected at the level indicated

Appendix C. Fleming Creek watershed nonpoint source demonstration project fish data

Taxa	Allison Creek				Craintown Branch				Fleming Creek			
	1992	1993	1994	1998[b]	1992[c]	1993	1994	1998	1992	1993	1994	1998
Luxilus chrysocephalus	22		19			8	61	1	34		41	41
Lythrurus fasciolaris												12
L. umbratilis	20	4	29				2		34	101	33	27
Notropis stramineus									5	18		
N. photogenis										6	11	
N. vollucellus												1
Pimephales notatus	36	31	3			16	93	79	53	56	3	47
P. promelas	36	16	34			11	3	4	1			
Carassius auratus	1											
Campostoma anomalum	2		7			2	25		10	6	2	9
Semotilus atromaculatus	10					1	8	20	3			
Catostomus commersoni		7					1					
Moxostoma erythrurum							1	1				
Minytrema melonops								1				
Labidesthes sicculus									1			1
Noturus flavus												2
Ameurus natalis						1						
Lepomis cyanellus	13	3	4			82	10	38	5	9		1
L. macrochirus			2			6	14		9	2		7
L. megalotis						2	1	3	2	3		4
L. megalotis x cyanellus[a]									1			
L. megalotis x macrochirus[a]						1						
Micropterus salmoides						1						
M. dolomieu						1						

Taxa	Allison Creek 1992	1993	1994	1998[b]	Craintown Branch 1992[c]	1993	1994	1998	Fleming Creek 1992	1993	1994	1998
M. punctulatus								1				3
Ambloplites rupestris									1	5	2	3
Percina caprodes								1		1		2
Etheostoma blennioides								6	1	2		12
E. nigrum								11		1		
E. flabellare						5	7		5	1	3	6
E. caeruleum	3							3	2	1		4
E. spectabile	17	17	18			7	22	6		1	2	
Total Number of Individuals	160	71	116			145	248	180	225	233	97	183
Taxa Richness	10	5	8	0[b]		12	13	16	15	17	8	17

[a] Not included in species counts
[b] Fish kill observed, no live fish collected
[c] Fish not sampled

Appendix D

Fleming Creek watershed nonpoint source demonstration project macroinvertebrate data

Taxa	Allison Creek 1992	Allison Creek 1993	Allison Creek 1994	Allison Creek 1998	Craintown Branch 1993	Craintown Branch 1994	Craintown Branch 1998	Fleming Creek 1992	Fleming Creek 1993	Fleming Creek 1994	Fleming Creek 1998
Ferrissia rivularis								6			
Lymnaea sp.						1					
Physa sp.	35	27	4	24	5	34	32	2			1
Elimia sp.	1	1		25	2				34	13	47
Pleurocera sp.	8							40			
Gyraulus parvus	1	6				1		2			
Helisoma sp.				14							
H. anceps anceps						1					
Musculium sp.				15							
Pisidium sp.								3			
Sphaerium sp.		4			4	17			18	16	
Enchytraeus sp.					1						
Eclipidrilus sp.							7				
Lumbriculus sp.			1								
Unidentified Lumbriculid						18					
Branchiura sowerbyi				1						2	2
Limnodrilus hoffmeisteri				2							
Tubifex tubifex		3	8			1					
Unidentified Glossiphoniid				4			6				
Mooreobdella fervida					1						
Haemopis grandis	1										
H. marmorata		5	2		1						
Stenacron sp.					3					1	90
S. interpunctatum							65				
Stenonema sp.	16	1			2			16	1		

Taxa	Allison Creek 1992	Allison Creek 1993	Allison Creek 1994	Allison Creek 1998	Craintown Branch 1993	Craintown Branch 1994	Craintown Branch 1998	Fleming Creek 1992	Fleming Creek 1993	Fleming Creek 1994	Fleming Creek 1998
Stenonema femoratum		8		4			36		11	5	12
Hexagenia sp.					1			1			
Serratella sp.					8			25	34	5	
Caenis sp.	35	35	2		12	3		20	9	4	
C. latipennis				2			20				17
Acentrella ampla										3	
Baetis sp.	7	2	1		6	1	11	40	21	12	10
B. brunneicolor							4				
B. flavistriga							33				
B. intercalaris							22				67
Paraleptophlebia sp..	4	7	12			1		1			
Isonychia sp.					1			4			8
Heptagenia sp.			3								
Leucrocuta sp.		11				1					
Amphiagrion saucium								4			
Argia sp.		2				1		1	3		
A. bipunctulata											3
Enallagma sp.				38				10	14	5	
Ischnura sp.	1						25				
Calopteryx maculata											7
Hetaerina americana									2		
Aeshna sp.								1			
Boyeria sp.								1	1		
B. vinosa											3
Gomphus sp.										1	

Taxa	Allison Creek 1992	Allison Creek 1993	Allison Creek 1994	Allison Creek 1998	Craintown Branch 1993	Craintown Branch 1994	Craintown Branch 1998	Fleming Creek 1992	Fleming Creek 1993	Fleming Creek 1994	Fleming Creek 1998
Neurocordulia sp.	1										
Erythemis simplicicollis	1					1	2				
Libellula sp.		11	1								
Sympetrum ambiguum				4							
Isoperla sp.	1		1								
I. bilineata										4	
Amphinemura sp.										2	
Leuctra sp.										1	
Agnetina capitata										1	
Neoperla sp.								1			
Perlesta sp.	85	38	40			20		85	42	64	
Hesperocorixa sp.		11			2				1	3	
Trichocorixa sp.								1			
Unidentified Corixid				54							
Microvelia sp.			2				2				
Rhagovelia sp.		2			1				1		2
Mesovelia sp.				3							1
Neoplea striola				1							
Belostoma sp.	4	4	2	26		2		2			
Gerris sp.				1							
Metrobates hesperius				1							
Trepobates sp.					1		2				
Corydalus cornutus					2			2	5		5
Sialis sp.							1				
S. americana											3

Taxa	Allison Creek 1992	Allison Creek 1993	Allison Creek 1994	Allison Creek 1998	Craintown Branch 1993	Craintown Branch 1994	Craintown Branch 1998	Fleming Creek 1992	Fleming Creek 1993	Fleming Creek 1994	Fleming Creek 1998
Hydroptila sp.							2				
Leucotrichia pictipes					1						
Orthotrichia sp.		1	32		2	6			1	1	
Ceraclea transversa											1
Rhyacophila sp.	27							1			
R. glaberrima		11	9		5	5				5	
Ceratopsyche sp.	10										
C. bifida											1
Cheumatopsyche sp.					7		104				73
Hydropsyche sp.					1	6		27	9	1	
H. betteni							29				3
Chimarra sp.					13			3	3	16	
C. obscura							2				3
Polycentropus sp.							13			1	
P. sp. 1											7
Petrophila sp.											26
Helichus sp.								1			
Peltodytes sp.	4	8	6		17	8		1	8		
P. lengi				4							
Cyphon sp.				4							2
Elodes sp.		24	1								
Berosus sp. (larvae)	1										
B. pantherinus				6							
B. peregrinus				22							
Cymbiodyta sp.		1		1							

Taxa	Allison Creek				Craintown Branch			Fleming Creek			
	1992	1993	1994	1998	1993	1994	1998	1992	1993	1994	1998
Enochrus sp.	1	3									
Helochares sp.				1							
Hydrobius tumidus			1								
Tropisternus sp. (larvae)	5	11	1	33	6	1		1			
T. collaris				4							
T. natator				15							
Micralymma sp.			1								
Psephenus herricki	1				24	1	3	4	29	5	31
Dineutus sp.		5									
Unidentified Curculionid				1							
Acilius semisulcatus				1							
Hydroporus sp.		5			1	5					
Laccophilus sp.		1	6	3	2						
L. maculosus maculosus				8							
Ancyronyx variegatus								11	1		
Dubiraphia bivittata											50
D. vittata				1			14				
Macronychus glabratus											2
Microcylloepus pusillus									1		
Stenelmis sp. (larvae)	48	15	20		152	124	97	134	195	107	117
Stenelmis sexlineata				4			71				237
Culex sp.				174							
Hexatoma sp.											3
Limonia sp.							1				
Pseudolimnophila sp.			1								

Taxa	Allison Creek				Craintown Branch			Fleming Creek			
	1992	1993	1994	1998	1993	1994	1998	1992	1993	1994	1998
Tipula sp.								1			
Tipula abdominalis										1	
Chironomus sp.	69	119	4	370	2	1	3				
Clinotanypus sp.						1					
Cricotopus sp.				7	1						
C. sylvestris gr.				4							
Cricotopus/Orthocladius gr.				2							
Cryptochironomus sp.		1									
Dicrotendipes sp.		3		8			5				
D. nervosus											1
Einfeldia sp.							1				
Eukiefferiella sp.			250								
Glyptotendipes sp.				4							
Microtendipes sp.		4				2					
M. pedellus gr.											2
Orthocladius sp.		1	17								
O. sp. 1		1									
O. sp. 2		1									
Parachaetocladius sp.			1								
Parachironomus sp.							3				
Parametriocnemus sp.					1	18					
Paratanytarsus sp.		2									
Paratendipes sp.							1				
P. albimanus				2							
Phaenopsectra sp.		8									

Taxa	Allison Creek 1992	Allison Creek 1993	Allison Creek 1994	Allison Creek 1998	Craintown Branch 1993	Craintown Branch 1994	Craintown Branch 1998	Fleming Creek 1992	Fleming Creek 1993	Fleming Creek 1994	Fleming Creek 1998
Polypedilum sp.		4					3	4		1	
P. convictum gr.				10							11
P. scalaenum gr.											2
Procladius sp.		1									
Psectrocladius sp.			1							1	
Psectrotanypus sp.			1	1							
Rheotanytarsus sp.											2
Stictochironomus sp.		54	1		4	3					
S. devinctus											2
Tanytarsus sp.		21						1			
Thienemannimyia gr. sp.		6		2	13		5		7	3	16
Unidentified Larvae	96					2	2	1			
Unidentified Pupae	6	1	1		2		3	2			
Ptychoptera sp.							1				
Prosimulium sp.	23										
Simulium sp.	8										2
S. vittatum		20	3		5						
Stratiomys sp.				1							
Tabanus sp.				1	1				1		
Bezzia sp.		2			1						
Unidentified Ceratopogonid				2							
Crangonyx sp.	10	34	48		73	57		2	10	15	2
Gammarus sp.							79				
Lirceus fontinalis	298	233	155	4	318	138	52	249	105	110	22
Cambarus sp.	2				2	1					

Taxa	Allison Creek				Craintown Branch			Fleming Creek			
	1992	1993	1994	1998	1993	1994	1998	1992	1993	1994	1998
C. robustus			1								
Orconectes rusticus		12	14	1	17	8	19		25		9