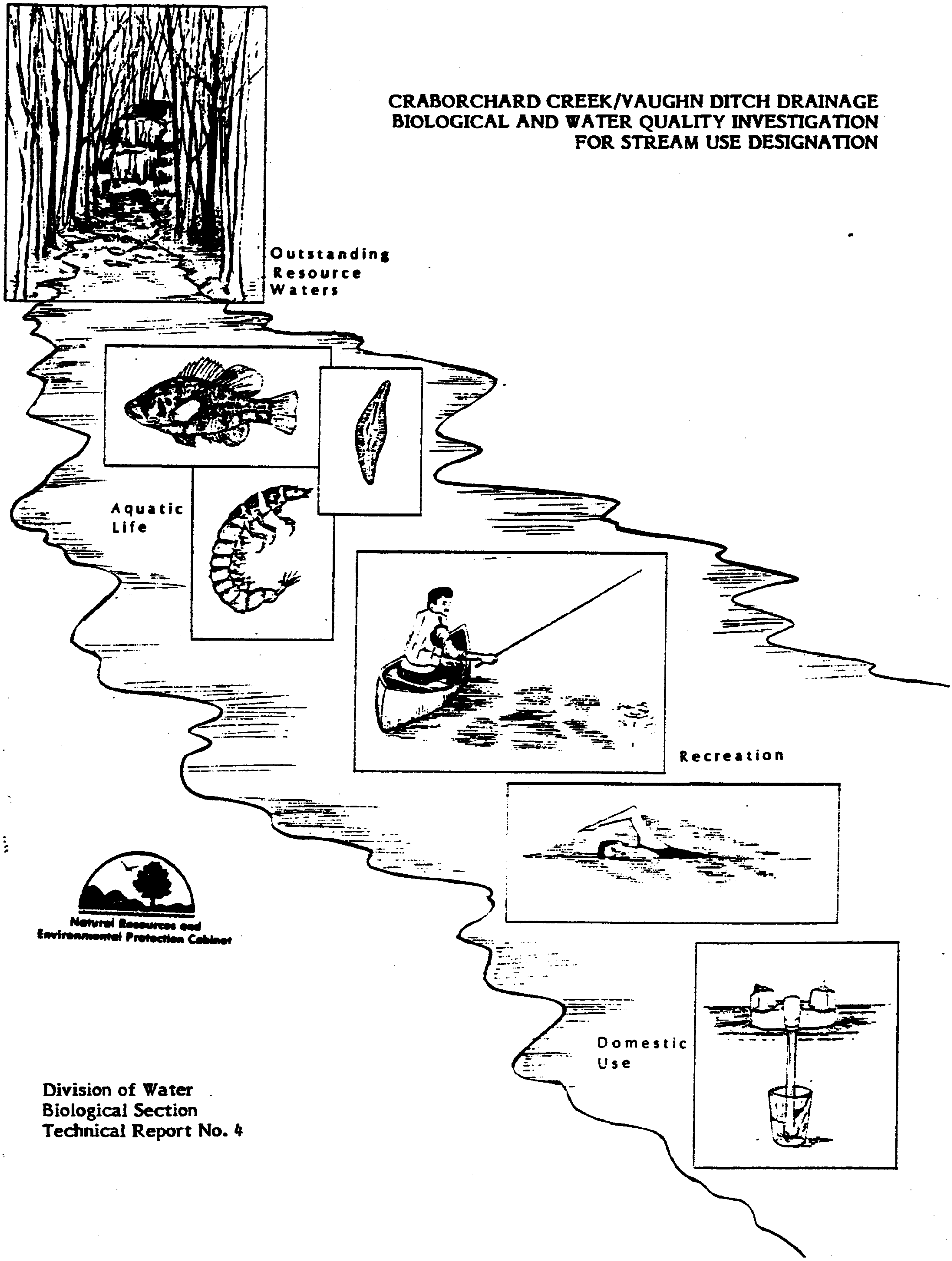
CRABORCHARD CREEK/VAUGHN DITCH DRAINAGE BIOLOGICAL AND WATER QUALITY INVESTIGATION FOR STREAM USE DESIGNATION



Natural Resources and Environmental Protection Cabinet

Division of Water
Biological Section
Technical Report No. 4

Craborchard Creek-Vaughn Ditch Drainage
Biological and Water Quality Investigation

Kentucky Department for Environmental Protection
Division of Water
Biological Section

Technical Report No. 4

Frankfort, Kentucky

This report has been approved for release:

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Abstract

A biological and water quality investigation of the Craborchard Creek/Vaughn Ditch subbasin (Tradewater River Basin) was conducted in December 1981 to determine the existing water quality, aquatic uses, causes of impairments of aquatic uses and what aquatic uses can be attained based on the physicochemical and biological characteristics of the segments.

The segment (10004) lies within the Ohio River Hills and Lowlands Subsection of the Shawnee Hills Section in the Interior Low Plateaus Physiographic Province in Webster and Union counties, Kentucky. Drainage and siltation from coal mining operations, discharge of domestic wastewater and channelization are the major impacts to water quality and aquatic life in the segment. This is the only major subbasin contributing mine drainage in the upper pH range to the Tradewater River. Kentucky Surface Water Standards have been violated for aluminum, mercury, iron, un-ionized ammonia and phthalate esters. The aquatic biota has been adversely affected by the impacts previously mentioned and the communities were dominated by organisms tolerant to a wide range of environmental conditions. It is recommended that the segment be designated for Aquatic Life/Warmwater Aquatic Habitat and Primary and Secondary Contact Recreation. Data from this survey indicate those uses are currently occurring or are attainable with the application of appropriate point source pollution control technologies.

Table of Contents

List of Figures and Tables

Recommendations

1. Based on the diversity of the aquatic biota, it is recommended that the Craborchard Creek/Vaughn Ditch subbasin (segment 10004) 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.

2. Based on the fecal coliform and pH values observed during this survey, 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.

3. Based on the fact that no present or planned withdrawals for domestic water supply exist in this segment, it is not recommended that this segment be designated for Domestic Water Supply (401 KAR 5:031, Section 6).

Summary

1. Drainage and siltation from coal mining operations are the primary impacts to the water quality of the Craborchard Creek/Vaughn Ditch segment. This is the only major subbasin in the Tradewater River system which has mine drainage in the upper pH range (> 7).

2. Domestic wastewater is another major impact to water quality in the lower reach of the segment, i.e. Vaughn Ditch.

3. Channelization has left most of the streams in the segment as ditches. This has reduced the diversity of habitats available for aquatic organisms.

4. Violations of Kentucky Surface Water Standards (401 KAR 5:031, Section 5) were noted for the following parameters: aluminum, mercury, iron, un-ionized ammonia and phthalate esters.

5. Based on the bacteriological data in this study, the water quality of Craborchard Creek/Vaughn Ditch is sufficient to support the use of primary and secondary contact recreation (401 KAR 5:031, Section 7).

6. The aquatic biota of the segment has been adversely affected by mine drainage, stream channelization and domestic wastewater. The aquatic communities were dominated by organisms tolerant to a wide range of environmental conditions.

7. The algal community was speciose and contained a greater percentage of alkaliphilous species than observed in other Tradewater River segments. The abundance of epipelic and soil diatoms suggests siltation impacts.

8. The Craborchard Creek/Vaughn Ditch segment supports a speciose macro-invertebrate fauna. However, the communities were composed of organisms that are either facultative or tolerant to a wide variety of environmental conditions.

9. While this segment does not support a sport fishery, many of the streams are seined for bait fish by local anglers. In addition, the tributaries draining unmined areas serve as spawning and nursery areas and refugia for many species of fishes.

10. No domestic water supplies are taken from this segment.

INTRODUCTION

This segment includes Craborchard Creek, which enters the Tradewater River at RMI 16.5 through Vaughn Ditch, and its tributaries Caney Fork, Slover Creek and Bull Creek. The segment is located mainly in Webster County, with a portion in Union County. The segment is designated as 10 (Tradewater River) 004 (Craborchard Creek).

A survey of Craborchard Creek/Vaughn Ditch was undertaken by the Division of Environmental Services (DES) in December 1981. Two sampling stations were established (Figures 1 and 2) and sampled during a low flow period. The location of these stations, dates sampled and parametric coverage are given in Appendix A. The purposes of this investigation were as follows:

1. to determine the existing water quality of the basin.
2. to determine the aquatic uses currently being achieved in the drainage.
3. to determine the causes of any impairments of the aquatic uses.
4. to determine what aquatic uses can be attained based on the physical, chemical and biological characteristics of the watershed and the application of appropriate point source pollution control technologies.

Literature Review

The only published water quality and biological material that includes Craborchard Creek-Vaughn Ditch is Grubb and Ryder (1972) and McLemore (1975). Historical water quality data for the Tradewater River Basin is provided by Lamar and Laird (1953), Lamar, Krieger and Collier (1955), Collier and Krieger (1958), Grubb and Ryder (1972), USGS Water Resources data for Kentucky (1972 to 1982) and DOW (1981, 1984). Biological information has been presented by Woolman (1892), Clench and van der Schalie (1944), Rhoades (1944), Clay (1975), McLemore

Figure 1: Map of the Tradewater River System
Depicting Segment 10004.

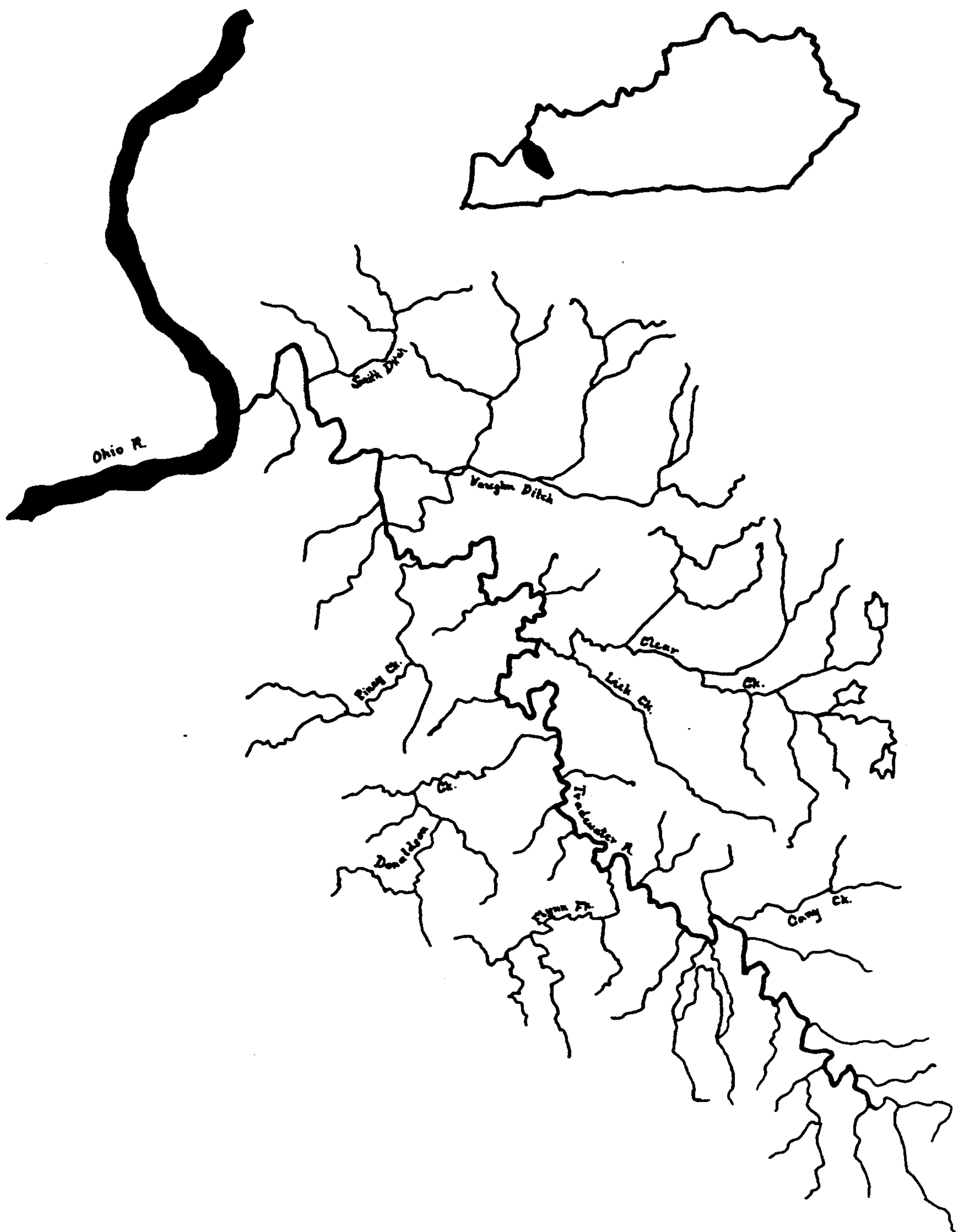
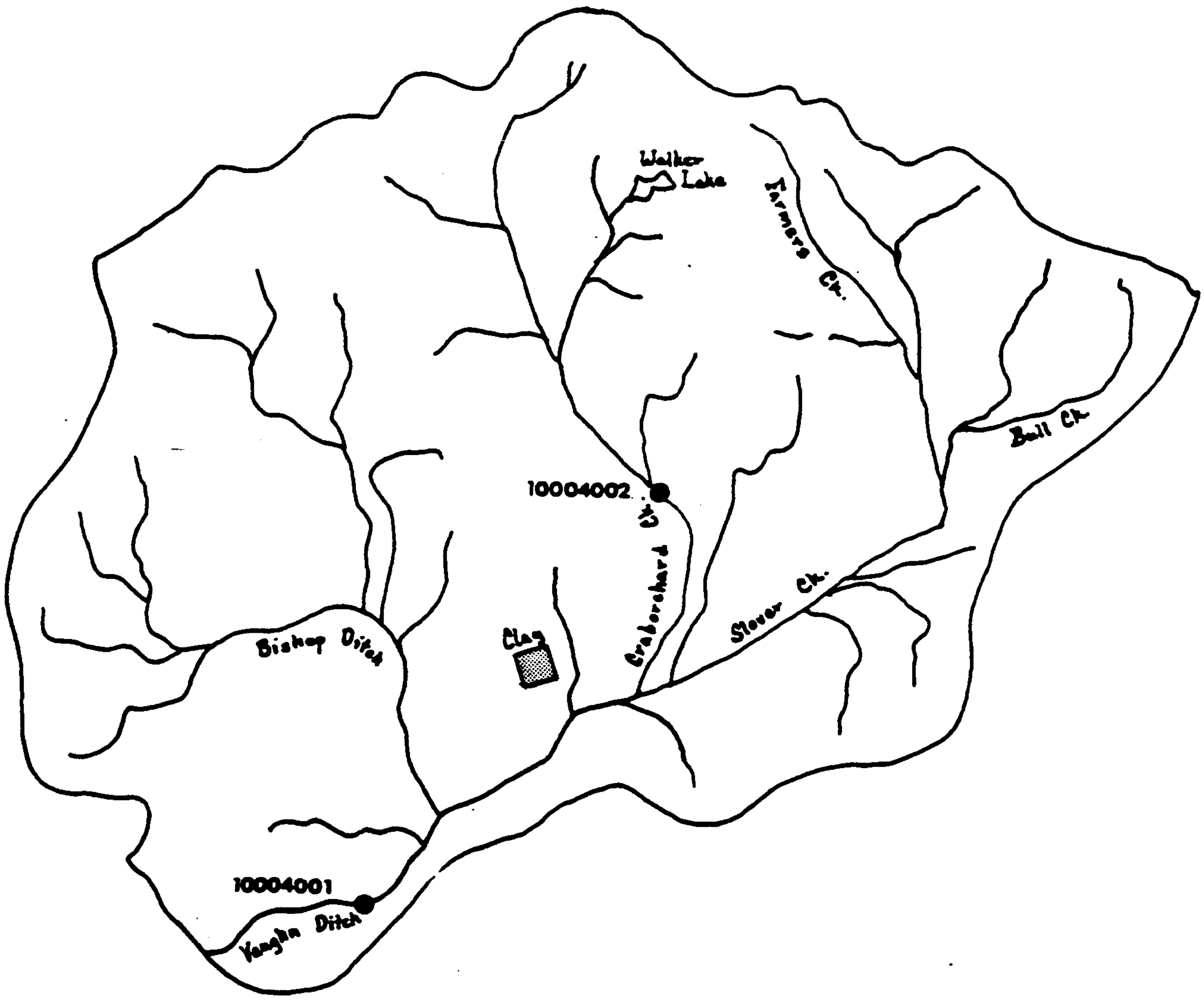


Figure 2: Map of the Craborchard Creek-Vaughn Ditch Stream System (Segment 10004)



(1975), Burr and Mayden (1979), Harker et al. (1980, 1981), Burr (1980), Burr and Retzer (1980) and Warren and Cicerello (1982).

Basin Impacts

Impacts of coal mining in Craborchard Creek (Vaughn Ditch) subbasin are well documented. Grubb and Ryder (1972) conducted a study on the effects of coal mining on the water resources of the Tradewater Basin. Their major conclusions concerning Craborchard Creek (Vaughn Ditch) may be summarized as follows:

1. Craborchard Creek (Vaughn Ditch) is one of the major contributors of coal mine drainage to the Tradewater River below Olney.
2. Vaughn Ditch has a greater concentration of most ions (including substantial amounts of bicarbonate), except fluoride, a greater proportion of sodium to calcium and magnesium, and a relatively high pH of 6.6 as compared to other mined subbasins. The source of this peculiar water was traced to an abandoned strip mine, where water overflows from a lake covering a thick calcareous shale. This shale was shown to have the ability to neutralize acid mine water. Also, an exchange of calcium for sodium ions accounted for the high sodium content of the water.
3. Craborchard Creek (Vaughn Ditch) is the only major subbasin which is a contributor of mine drainage in the upper pH range.
4. Craborchard Creek carries concentrations of sulfate, iron, manganese and dissolved solids much higher than unmined subbasins. However, observed aluminum and silica were less than in other mined basins, possibly due to relatively high pH.

Data from this survey support the findings of Grubb and Ryder (1972).

The city of Clay Wastewater Treatment Plant (WWTP) and several smaller plants discharge to the subbasin (Table 1). The only significant urban developments are the two small communities of Clay (population 1356) and Dixon (population 533). Agricultural runoff also impacts the streams of the drainage.

Land use in the Craborchard Creek basin involves agriculture, silviculture and mining. Coal mining areas, both deep mines and surface mines, are located in the vicinity of Clay. Agricultural products include corn, soybeans, tobacco and livestock. Some oil and gas wells are also located in this segment.

Stream Uses

Since many of the streams in the segment are channelized, recreational areas are limited. The Kentucky Department of Fish and Wildlife Resources reports that very little sport fishing occurs in this segment, but many of the smaller streams are utilized by fisherman for seining bait fish (McLemore 1975). Many wildlife species utilize the streams and adjacent buffer zones for breeding, rearing young and feeding, as well as for water supply. This allows for hunting and trapping in those areas. No surface water withdrawals for water supply are known in the segment.

Table 1
Permitted Discharges to Segment 10004

Facility Number	Name	Design Flow (gallons per day)	RMI
10004001	Clay WWTP	200,000	6.70
10004002	Dixon Coin Laundry	4,400	7.62
10004003	Webster County High School	15,000	7.62
10004004	Dixon Elementary School	17,500	7.62
10004005	Shane Manufacturing Co., Providence	5,000	7.62
10004006	Webster Co. Coal Co.-Dotiki Mine-Bath	2,000	7.62
10004007	Pyro Mining Co. #11 -Bathhouse	6,000	ND
10004008	Pyro Mining Co. #2 (Prep. Plant)	ND	ND
10004009	Webster Co. Coal Corp. (Prep. plant)	ND	ND
10004010	L. W. D. Inc., Providence	1,000,000	ND
10004011	Pyro Mining Co. - Mine #2 -Bathhouse	10,000	ND

ND - Not Determined

METHODS

Water samples were 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.

Biological samples were collected utilizing a variety of techniques. Qualitative algal samples were procurred by selectively scraping or suctioning material from all available habitats. Samples were preserved in the field with 5% buffered formalin and transported to the Division of Water (DOW) biological laboratory for analysis. Diatoms were treated with 30% hydrogen peroxide and potassium dichromate to remove organic material (van der Werff 1955), and several slides randomly scanned for the presence of rare taxa.

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 by the travel-kick method (a 10 ft area for 60 seconds) outlined by Hornig and Pollard (1978). 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 (1982). 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 are generally 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 are generally unable to withstand even moderate reductions of dissolved oxygen.

Diatom and macroinvertebrate species diversity indices ($\bar{d}$) and equitability (e) were calculated using the procedure described by Weber (1973). Diatom relative abundance, $\bar{d}$, and e were generated by counting a minimum of 500 valves. Macroinvertebrate relative abundance was calculated with the pooled quantitative data.

Fish were collected using a 3.4 m by 1.2 m, 0.3 cm mesh, common sense minnow seine. 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 methods of Karr (1981).

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 DOW biological laboratory within six hours. Analyses for fecal coliform and fecal streptococcus bacteria were performed using the membrane filter techniques outlined by Bordner and Winter (1978).

PHYSICAL EVALUATION

Craborchard Creek (Vaughn Ditch) is located mainly in the western portion of Webster County, Kentucky. The stream flows southwesterly for 29.8 km (18.5 mi), emptying into the Tradewater River through Vaughn Ditch at RMI 16.5 near Blackford. Major tributaries in the system include Caney Fork, Slover Creek, and Bull Creek. The drainage area for the Craborchard Creek (Vaughn Ditch) watershed is 378 km^2 (146 mi^2) (Bower and Jackson 1981).

The watershed lies within the Ohio River Hills and Lowlands Subsection of the Shawnee Hills Section in the Interior Low Plateaus Province (Quarterman and Powell 1978). As the name implies, this area is one of rolling to hilly uplands dissected by alluvial and lacustrine valleys. Elevations for the watershed range from 330 ft above mean sea level (msl) at the mouth to 430 ft above msl in the headwaters. Wetland areas are common along Craborchard Creek (Vaughn Ditch) and its tributaries.

The region is underlain by Pennsylvanian shale, sandstone, limestone and coal (Rice et al. 1980). The hilly uplands are formed by the resistant sandstone, while coal beds underlie much of the floodplains, forming what is commonly called the Western Coal Field. Mining of this coal comprises the major land use in the area. Watershed soil types and characteristics are given in Table 2.

Drainage from coal mining areas is believed to sustain flow in Craborchard Creek (Vaughn Ditch) during extended dry periods (Grubb and Ryder 1972). Similar sized streams in unmined areas commonly have no flow during those periods. The estimated seven day ten year low flow (7Q10) of this segment is 0.0 m^3/s (Metcalf and Eddy no date). There are no USGS gaging stations located on the stream.

Table 2
Soils of the Craborchard Creek-Vaugh Ditch Subbasin (10004)

Soil[1] Association	Slope[2] %	Drainage[2] Class	Potential[1] Sediment Runoff	Infiltration[1]	Septic Tank[1] Absorbtion Rating
Falaya	0-3	somewhat poorly drained	Medium	Slow	Severe
Waverly	0-1	poorly drained	High	Very Slow	Severe
McGary	1-3	somewhat poorly drained	Medium	Slow	Severe
Melvin	0-1	poorly drained	High	Very Slow	Severe
Memphis	4-35	well drained	High	Moderate	Slight
Wellston	3-15	well drained	High	Moderate	Moderate
Dekalb	12-75	excessive to well drained	Medium	Moderate	Severe
Uniontown	1-6	well to moderately drained	Medium	Moderate	Moderate
Dekoven	0-1	very poorly drained	High	Very slow	Severe
Henshaw	1-3	somewhat poorly to moderately drained	Medium	Slow	Severe

(1) Metcalf and Eddy (no date)
(2) Bailey and Winsor (1964)

Low gradient (1.06 m/km average) and stream channelization for most of the length has resulted in poorly developed stream habitats. However, areas with diverse habitats occurred in Craborchard Creek, including riffles, root mats, undercut banks, rock ledges, submerged logs and a variety of substrates. An increase in faunal diversity was noted in those areas of well developed habitat. Riparian vegetation was also diverse and well developed, in some areas, providing shade, sediment and erosion control and bank stability, as well as food and cover for invertebrates, fish and wildlife (Karr and Schlosser 1978, Schlosser and Karr 1981, Karr et al. 1981). However, large portions of the stream lacked floral, faunal and habitat diversity.

The following is a brief description of the sampling locations. A detailed evaluation of each site is found in Appendix A. Riparian vegetation observed at each site is listed in Appendix B.

<u>Vaughn Ditch</u>

<u>10004001 (4-1)</u>

This site is located in western Webster County at the KY Rt. 143 bridge. Vaughn Ditch is a low gradient, sixth order stream that lies within a 10 to 20 m deep, channelized gorge. The upper half of the steep shale banks were overgrown with hardwood and herbaceous species, while the lower portions were bare. The area immediately around the site was forested except for a soybean field located on the south side. A large, active, surface coal mine is located upstream in close proximity to the site. The pools were generally long and slow flowing and underlain by shale, which is covered with a moderate to heavy layer of silt. The riffles were small, shallow and composed of pebble-gravel-cobble sized shale.

Craborchard Creek

10004002 (4-2)

This site is located on Craborchard Creek in central Webster County at the bridge on County Road 1340, upstream of Clay, Kentucky. The creek is a channelized, low gradient, fifth order stream. It flows through an area that is intensively farmed with row crops (soybeans and corn). An active coal mining operation occurs approximately 1.5 km to the east of the site. The steep, 2 to 3 m high stream banks and small buffer zone were covered by herbaceous annual and perennial plants and scattered young hardwoods. The pools were long, narrow and shallow and the substrate varies from hard clay to gravel-sand, overlain by silt. The riffles were small and shallow and occur sparsely. The riffle substrate was predominately gravel-sand.

PHYSICOCHEMICAL EVALUATION

Data from this report (Table 3), as well as Grubb and Ryder (1972), indicate that the most severe impact to the drainage is coal mining. The physicochemical parameters, i.e. conductivity, total dissolved solids (TDS), sulfate (SO_4), aluminum (Al), iron (Fe) and manganese (Mn) associated with coal mining activities by Curtis (1972, 1973), Dyer and Curtis (1977), DOW (1981), FWPCA (1968), Herrick and Cairns (1974), Plass (1975) and OAS (1969) were all considerably elevated when compared to streams from unmined watersheds in the Tradewater basin. Hardness at the Vaughn Ditch station (4-1) had increased from the upstream site (4-2); even though the calcium (Ca) concentration decreased, sodium (Na) increased by a factor of 2.5. Grubb and Ryder (1972) observed a similar circumstance occurring in this drainage.

While mining impacts are evident in the subbasin, the data from Vaughn Ditch (4-1) also indicate impacts from the discharge of municipal wastewater. Chloride (Cl^-) and nutrient (NH_3-N, NO_2+NO_3-N, TKN) levels increased dramatically from upstream (4-2) to the downstream (4-1) site. The ammonia (NH_3-N) value in Vaughn Ditch was 15 times that found in Craborchard Creek above Clay. An increase of 5.5 times was seen in the NO_2+NO_3-N and 13 times in the Total Kjeldahl Nitrogen (TKN). Station 4-1 is only about four miles below the Clay WWTP. The short distance and cold water temperature had apparently not allowed complete nitrification of the NH_3 by the time it reached this station.

Concentrations of Cl^- at the Vaughn Ditch site had increased by 2.7 times over the upstream site (4-2). Hynes (1974) states that Cl^- is a universal constituent of wastewater and APHA (1981) reports that Cl^- concentrations are higher in wastewater than in raw water supplies because sodium chloride (NaCl) is a common constituent of diet and passes unchanged through the digestive system. This fact could also contribute to the higher level of Na found in Vaughn Ditch (4-1).

Phthalate esters occur in surface waters in parts per billion, with levels being higher near industrial centers (U. S. EPA 1980). Phthalate esters levels were much higher in the upstream station (4-2) than in Vaughn Ditch (4-1). According to U. S. EPA (1980), a phthalate ester concentration of 940 ug/l can be acutely toxic to freshwater aquatic life, and chronic toxicity may occur at levels as low as 3 ug/l for more sensitive aquatic species. The source of phthalate esters in this stream has not been determined.

Violations of Kentucky Surface Water Standards for aquatic life (401 KAR 5:031, section 5) include: Aluminum (Al) (Stations 4-1 and 4-2); Mercury (Hg) (Stations 4-1 and 4-2; Iron (Fe) (Stations 4-1 and 4-2); Un-ionized Ammonia (NH_3-N) (Station 4-1); Phthalate esters (Station 4-1 and 4-2).

Table 3: Physicochemical data for Craborchard Creek-Vaughn Ditch

Parameter	4-1	4-2
Conductivity (umhos/cm @ 25°C)	3070.0	2170.0
pH	7.4	7.0
Air temperature (°C)	ND	ND
Water temperature (°C)	5.8	6.9
Turbidity (NTU)	18.0	24.0
DO (mg/l)	9.2	9.6
Acidity (mg/l)	53.6	45.0
Alkalinity (mg/l)	140.0	94.0
BOD_5 (mg/l)	2.0	2.1
Chloride (mg/l)	61.4	22.4
COD (mg/l)	21.3	17.6
CN (free) (mg/l)	K.01	K.01
Total Dissolved Solids (mg/l)	2438.0	1786.0
Fluoride (mg/l)	0.46	0.33
Total Hardness (mg/l)	1160.0	1060.0
Sulfide (mg/l)	K0.1	K0.1
Phenols (mg/l)	K0.1	K0.1
Sulfate (mg/l)	1366.0	1126.0
Suspended Solids (mg/l)	15.0	24.0
NH_3-N (mg/l)	12.95	0.83
NO_2 + NO_3 - N (mg/l)	2.32	0.415
TKN (mg/l)	14.5	1.05
Phosphorous (total) (mg/l)	0.051	0.027
Phosphorous (dissolved) Ortho (mg/l)	0.019	0.012
Phthalate Esters (ug/l)	52.0	396.0
Benzyl butyl phthalate (ug/l)	1.0	2.0
Bis (2-ethylhexyl) phthalate (ug/l)	K1.0	K1.0
Bi-n-butal phthalate (ug/l)	17.0	152.0
Di-n-octyl phthalate (ug/l)	K1.0	K1.0
Di-ethyl phthalate (ug/l)	34.0	114.0
Di-methyl phthalate (ug/l)	K1.0	128.0
Al (total)) (ug/l)	740.0	770.0
As (total) (ug/l)	20.0	2.0
Ba (total) (ug/l)	110.6	58.0
Be (total) (ug/l)	K1.0	K1.0
Cd (total) (ug/l)	2.0	2.0
Ca (total) (mg/l)	165.0	238.0
Cr (total) (ug/l)	4.0	4.0
Cu (total) (ug/l)	7.0	7.0
Fe (total) (ug/l)	1230.0	3780.0
Pb (total) (ug/l)	32.0	34.0
Mg (total) (mg/l)	95.0	91.0
Mn (total) (ug/l)	1324.0	2500.0
Hg (total) (ug/l)	0.4	0.4
Ni (total) (ug/l)	52.0	37.0
K (total) (mg/l)	13.5	7.25
Se (total) (ug/l)	4.5	1.0
Ag (total) (ug/l)	3.0	3.0
Na (total) (mg/l)	295.0	115.0
Zn (total) (ug/l)	18.0	26.0
Al (dissolved) (ug/l)	50.0	65.0
Cd (dissolved) (ug/l)	2.0	2.0
Cr (dissolved) (ug/l)	3.0	3.0
Cu (dissolved) (ug/l)	6.0	6.0
Fe (dissolved) (ug/l)	26.0	2980.0
Pb (dissolved) (ug/l)	22.0	32.0
Mn (dissolved) (ug/l)	1198.0	2500.0
Hg (dissolved) (ug/l)	0.3	0.2
Se (dissolved) (ug/l)	4.5	1.0
Zn (dissolved) (ug/l)	ND	ND

K - below detection limit
ND - not determined

BIOLOGICAL EVALUATION

Biological data were collected and analyzed for the following groups of aquatic organisms: fecal coliform and fecal streptococcus bacteria, algae, macroinvertebrates and fish. Site specific data were compared with other sites sampled in the survey, available historical data and appropriate scientific literature regarding the environmental requirements and tolerances of aquatic organisms. It was determined that the aquatic life in Craborchard Creek/Vaughn Ditch has been adversely impacted by coal mine drainage, WWTP effluents and habitat perturbations.

While the Craborchard Creek system still contains somewhat diverse aquatic habitats, that diversity has been reduced by human activities, mainly channelization of many stream reaches. Added to that are the impacts of land disturbance (silt, elevated metals concentrations) by coal mining and agricultural operations. Those activities have resulted in aquatic communities being dominated by organisms tolerant of a wide range of environmental conditions. The discharge of domestic wastewater has further impacted the lower reach of Craborchard Creek/Vaughn Ditch below Clay.

No violations of Kentucky Surface Water Standards for fecal coliform (primary contact recreation) were observed during this survey. However, samples were not taken during the recreational season (May 1 - October 31).

Based on the available data, it is recommended that the entire Craborchard Creek/Vaughn Ditch segment (10004) be designated for Aquatic Life/Warmwater Aquatic Habitat and Primary and Secondary Contact Recreation per 401 KAR 5:031, Sections 5 (1) and 7 and that the criteria listed in those sections apply throughout the segment.

Bacteria

Of the two stations sampled for fecal coliform and fecal streptococcus bacteria in December, 1981 (Table 4), neither sample exceeded the maximum fecal coliform (FC) level listed in Kentucky Surface Water Standards (401 KAR 5:031, section 7 (a)) for primary contact recreation (400 colonies/100 ml). Stations were sampled outside the primary contact recreation season (May 1 - October 31) and no primary contact recreation (i.e. swimming) was observed. Fecal coliform/fecal streptococcus (FC/FS) ratios indicate the source of the fecal pollution to be animal in origin (Table 4). The fecal pollution found is probably due to agricultural runoff. Due to the low bacterial levels found in the analyses, these FC/FS ratios should not be considered a significant indication of non-point source pollution.

Table 4

Bacteriological Data for Craborchard Creek-Vaughn Ditch

Date	Station	Location	Fecal Coliforms per 100 ml	Fecal Streptococci per 100 ml	FC/FS Ratio
8 Dec 81	4-1	Vaughn Ditch	42	60	0.7
8 Dec 81	4-2	Craborchard Creek	40	52	0.7

The bacterial and pH quality of these samples support the use of Vaughn Ditch and Craborchard Creek and their tributaries for primary and secondary contact recreation.

Algae

This segment contained a greater percentage of alkaliphilous taxa than was observed in other segments of the Tradewater River system, suggesting higher pH values. The periphyton community consisted of sparse to moderate growths of filamentous green, blue-green and red algae. The abundance of epipelic (associated with sediments) and soil diatoms at sites in this segment suggests siltation impacts from agricultural and surface mining activities. The algal community was speciose at both sites, with diatom $\bar{d}$ and e values typical of the Tradewater River system (Appendix C). The abundance of halophilic and heterotrophic species is reflective of elevated conductivity at both sites and elevated nutrients and chloride levels at station 4-1. Taxa associated with slightly acidic waters with elevated iron levels were more abundant at station 4-1 than station 4-2.

Vaughn Ditch

Station 4-1

The algal community was characterized by sparse to moderate growths of filamentous green, blue-green, and red algae, dominated by Oedogonium, a taxon tolerant to acid mine drainage (Bennett 1969). The community was speciose and consisted of taxa tolerant to a wide variety of water quality conditions. Periphyton, exclusive of diatoms, consisted of species characteristic of nutrient enrichment (Palmer 1977), as well as other species known to tolerate acid waters (Bennett 1969).

The diatom community was speciose and consisted of a fairly even distribution (e = 0.5147) of taxa characteristic of high conductivity waters (Patrick and Reimer 1966, 1972, Lowe 1974). Species associated with sediments were also common in the community. The presence of alkaliphilous taxa in the algal community suggests higher alkalinity (and perhaps pH) values in this segment, which is reflective of the physicochemical data. The occurrence of halophilic (salt-loving) taxa, notably Navicula cincta (Patrick 1977), is reflective of the elevated chloride and sodium values observed at this site. Species associated with nutrient enrichment, including nitrogen heterotrophic species (Lowe 1974; Patrick

1977), are present in the community but are not particularly abundant, perhaps due to the relative dominance of high conductivity taxa noted previously.

The occurrence of Cyclotella striata var. ambigua, Gomphonema abbreviatum, Navicula exigua var. capitata, Navicula minusculae, Navicula pseudoreinhardti, Nitzschia bremensis, Surirella iowensis, and Synedra fasciculata var. truncata at this and other sites in the drainage represent new collection records for Kentucky (refer to Camburn 1981).

Craborchard Creek

Station 4-2

The periphyton community was characterized by sparse growths of filamentous blue-green and green algae, particularly members of the order Zygnematales. Placoderm desmids were also speciose. The algal community contained an abundance of taxa, due to the diversity of epipelic (occurring on sediments), aerophilic, and soil species.

The diatom community was dominated by taxa associated with elevated conductivity and salinity levels, notably Synedra pulchella (Patrick and Reimer 1966, Lowe 1974). The occurrence of nitrogen heterotrophic species suggests organic enrichment and periodic low dissolved oxygen concentrations. The diversity noted in Eunotia and Pinnularia species is reflective of the elevated total iron levels (Patrick 1977). Diversity values were typical for the watershed, while equitability was somewhat lower due to the dominance of Synedra (37%).

The occurrence of diatoms associated with sediments, as well as soil diatoms, suggests sedimentation impacts correlated with land disturbance activities. While parts of the drainage seem to be under intensive cultivation, the elevated conductivity, sulfates and dissolved solids values noted here indicate influence from surface mining.

Macroinvertebrates

Vaughn Ditch-Craborchard Creek system supports a speciose macroinvertebrate fauna (Appendix D), even though the drainage has been heavily impacted by coal mining operation (Grubb and Ryder 1972). They noted that this system had a circumneutral pH, rather than an acidic pH characteristic of other heavily impacted stream systems in the Tradewater drainage (e.g. Clear Creek, Owens Creek, etc.). The Vaughn Ditch-Craborchard Creek macroinvertebrate fauna was considerably more diverse than those in streams impacted by acid mine drainage (Owens Creek and Tradewater River). Zischke et al. (1983) observed reduced macroinvertebrate densities and diversities when the pH was reduced below circumneutral. Therefore, the circumneutral pH range observed in Vaughn Ditch-Craborchard Creek, at least in part, accounts for the higher macroinvertebrate diversity and densities observed here over that in Owens Creek (10-6) and the Tradewater River (10-12).

The lower half of the mainstem has been influenced by municipal waste. Most of the drainage is intensively farmed in row crops (corn and soybeans). These activities may also impact the macroinvertebrate community.

The invertebrate communities observed in this system were composed of organisms that are known to be facultative or tolerant to a wide variety of environmental conditions. In addition, virtually all major groups of aquatic invertebrates were found and all trophic groups were generally well represented. According to DOW (1983), the taxa richness is considered moderate to high, $\bar{d}$ is moderate and the e is low (Appendix D).

Vaughn Ditch

Station 4-1

The diverse macroinvertebrate fauna (55 taxa) (Appendix D) present at this site is surprising in light of the many elevated physicochemical parameters and the heavy siltation present. However, a perusal of the community members reveals that virtually all organisms observed are either facultative or tolerant to man-induced land perturbations, such as mining and agriculture. The $\bar{d}$ is moderate but the e is low, possibly reflecting the heavy siltation and related water quality impacts occurring there. Equitability is very sensitive to even slight levels of degradation (Weber 1973). In addition, the four taxa with the highest relative abundances are considered tolerant to a wide variety of impacts (Appendix D). Mollusks, annelids, crustaceans and most major groups of aquatic insects were present, with the dipterans being the most speciose and numerically dominant group. Of the 55 taxa observed, 25 were dipterans, primarily chironomids (midges).

The macroinvertebrate community had members of all functional feeding groups. The collectors were the most common trophic level, while the shredders were the least common. The predator groups were also common and generally limited to the odonates and coleopterans.

Craborchard Creek

Station 4-2

This site possessed a moderate diversity of aquatic macroinvertebrates (41 taxa). Mollusks, crustaceans and all major groups of aquatic insects were represented (Appendix D). The community was composed of taxa that are either facultative or tolerant to the perturbations caused by land disturbances. The $\bar{d}$ is moderate, but e is low (Appendix D). The ramifications of these data were previously discussed at station 4-1. Furthermore, the four taxa with the greatest relative abundances are all considered either facultative or tolerant to water quality conditions associated with land-use impacts. All functional feeder groups were represented, with the collectors being the most common. However, the quantity (55%) of shredders was substantially higher than that observed at the downstream site (4-1). This is probably a reflection of habitat suitability for the predominant species, the stonefly Allocapnia vivipara, rather than an environmental change.

Fishes

Previous collections of fishes from the Craborchard Creek drainage have been made by McLemore (1975) and Southern Illinois University (SIU unpublished data). A total of 33 species are known from the subbasin, 21 of which were collected during this survey. McLemore (1975) states that Craborchard Creek does not provide a sport fishery, but many areas are seined for bait fish by local anglers. Furthermore, portions of the segment, especially the upper tributaries draining unmined areas, serve as spawning and nursery areas and refugia for many species of fishes.

Vaughn Ditch

Station 4-1

Vaughn Ditch is a channelized stream, but the substrate consists of various sizes of shale and some silt. Fifteen species, representing eight families and a total of 174 individuals were collected by seining. Red shiners (Notropis lutrensis) and suckermouth minnows (Phenacobius mirabilis) were the most abundant species, with green sunfish (Lepomis cyanellus) and longear sunfishes (L. megalotis) also common.

Most of the fishes collected at this station are tolerant of turbid, organically rich waters. However, both the grass pickerel (Esox americanus) and channel catfish (Ictalurus punctatus) prefer clear water (Smith 1979). At the time of sampling, water levels were low and those species may have been transients. Based on this collection, the ichthyofauna is rated as fair to good (Karr 1981).

Craborchard Creek

Station 4-2

Craborchard Creek at this site is basically a channelized ditch. Fifteen species, representing five families, and a total of 155 individuals were collected by seine. Longear sunfish (Lepomis megalotis) and redfin shiners (Notropis umbratilus) were the most abundant species, with silvery minnows (Hybognathus nuchalis), bluntnose minnows (Pimephales notatus) and green sunfish (Lepomis cyanellus) also common. The majority of the fishes collected are tolerant of a wide range of ecological conditions. However, silverjaw minnows (Ericymba buccata) and suckermouth minnows (Phenacobius mirabilis), two species which are intolerant of silt (Clay 1975, Smith 1979), were also collected. The fish community is rated as fair to good (Karr 1981) and indicates that the stream was somewhat organically enriched and turbid, but was not impacted by heavy silt loads at the time of sampling.

Appendix A

Site Information

Site No:	10004001
Stream:	Vaughn Ditch
County:	Webster
Location:	At KY 143 bridge
Latitude:	37° 30' 19"
Longitude:	87° 53' 50"
Stream Order:	VI
USGS Topo Quad:	Blackford, Kentucky
DOW Map No.:	8-17
RMI:	2.3
Sampling Dates:	9-December-81
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Low
Pool Width:	4.6 to 9.1 m
Pool Depth:	0.3 to 0.8 m
Pool Substrate:	50% cobble, 50% pebble (shale) covered by silt
Riffle Width:	3.0 to 6.1 m
Riffle Depth:	0.09 to 0.2 m
Riffle Substrate:	35% pebble, 30% gravel, 20% cobble, 10% fines, 5% boulders
Bank Height:	4.6 to 7.6 m
Bank Slope:	65 to 75%
Riparian Vegetation - %	
Trees:	70
Shrubs:	20

Site Information

Herbs:	10
Exposed:	0
Width:	ND
Canopy over Stream - %:	25 to 50
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Moderate
Imbeddedness:	1/4 to 1/2
Stream Habitat:	Undercut banks, rock ledges, submerged logs and roots, various substrates
Hydraulic Obstructions:	Bridge abutment, mud bar, log piles
Physical Impacts:	Channelization
Non-point Sources:	Channelization spoil, row crops, surface mines, KY 143, dirt road.

ND - Not Determined

Site Information

Site No:	10004002
Stream:	Craborchard Creek
County:	Webster
Location:	At KY 1340 bridge
Latitude:	37^{o} 29' 16"
Longitude:	87^{o} 46' 00"
Stream Order:	V
USGS Topo Quad:	Providence, Kentucky
DOW Map No.:	8-18
RMI:	11.3
Sampling Dates:	9-December-81
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Low
Pool Width:	2.1 to 3.4 m
Pool Depth:	0.15 to 0.5 m
Pool Substrate:	Large areas of hardpan clay; also gravel, fines and exposed bedrock covered by silt
Riffle Width:	0.9 to 1.5 m
Riffle Depth:	0.05 to 0.10 m
Riffle Substrate:	50% gravel, 50% fines
Bank Height:	3 to 7 m
Bank Slope:	60 to 70%
<u>Riparian Vegetation - %</u>	
Trees:	10
Shrubs:	20

Site Information

Herbs:	65
Exposed:	5
Width:	5 to 10 m
Canopy over Stream - %:	0 to 10
Bank Stability:	Good
Erosion:	Slight to severe in some areas
Sedimentation:	Slight to Moderate
Imbeddedness:	1/4
Stream Habitat:	Mud bars, Undercut banks, submerged roots
Hydraulic Obstructions:	Bridge abutment, mud bars, log piles
Physical Impacts:	Channelization
Non-point Sources:	Tilled fields, surface mines, deep mines, KY 1340, scattered dwellings.

ND - Not Determined

Appendix B

Riparian Vegetation for
Craborchard Creek-Vaughn Ditch

	4-1	4-2
Acer rubrum (red maple)	X	-
Andropogon virginicus (broomsedge)	-	X
Carya ovata (shagbark hickory)	X	-
Chasmanthium latifolium (sea oats)	X	-
Cyperus sp. (nutsedge)	X	-
Elymus sp. (wild rye)	X	X
Eupatorium sp. (horeweed)	-	X
Festuca arundinacea (fescue)	X	X
Fraxinus pennsylvanica (green ash)	-	X
Gleditsia triacanthos (honey locust)	-	-
Juniperus virginiana (eastern red cedar)	-	X
Lonicera japonica (honeysuckle)	X	X
Ludwigia sp. (ludwigia)	-	X
Panicum sp. (panic grass)	X	-
Phytolacca americana (pokeweed)	-	X
Polygonum sp. (smartweed)	-	X
Quercus palustris (pin oak)	-	X
Rubus sp. (blackberry)	-	X
Sambucus canadensis (elderberry)	-	X
Setaria sp. (foxtail)	X	X
Solidago sp. (goldenrod)	-	X
Symphoricarpos orbiculatus (coralberry)	-	X
Tridens flava (purpletop)	-	X
Ulmus americana (American elm)	X	-
Verbascum thaspus (flannel-plant)	X	-
TOTAL SPECIES	15	13

Appendix C

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Chlorophycophyta (Green Algae)		
Ankistrodesmus falcatus	X	X
A. falcatus var. acicularis	-	X
Chlamydomonas sp.	X	-
Cladophora glomerata	X	X
Cl. acerosum	-	X
Cosmarium spp.	-	X
Gonium sociale	-	X
Mougeotia spp.	-	X
Oedogonium spp.	X	X
Rhizoclonium hieroglyphicum	-	X
Sc. quadricauda var. maximum	X	-
Schizomeris leibleinii	-	X
Spirogyra spp.	X	X
Stigeoclonium sp.	X	-
Tetraedron lunula	X	-
Ulothrix sp.	-	-
U. subconstricta	X	-
Chrysophycophyta		
Chrysophysae (Golden Algae)		
Vaucheria sessilis	X	-
Bacillariophysae (Diatoms)		
Achnanthes sp.	X	X
A. lanceolata	X	X

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
A. lanceolata var. dubia	X	X
A. linearis	X	-
A. minutissima	X	-
Amphipleura pellucida	-	X
Amphora submontana	X	X
Anomoeoneis vitrea	X	-
Caloneis bacillum	X	X
Cyclotella atomus	X	-
Cyc. meneghiniana	X	X
Cyc. striata var. ambigua	X	X
Cymbella aspera	-	X
Cym. delicatula	X	-
Cym. minuta	X	X
Cym. minuta var. silesiaca	X	X
Cym. prostrata	-	X
Cym. triangulum	-	X
Diploneis sp.	X	X
D. elliptica	X	-
Entomoneis ornata	X	X
Ent. paludosa	X	X
Eunotia curvata	-	X
E. naegelii	-	X
E. pectinalis var. minor	X	-
E. tenella	X	X

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Fragillaria vaucheriae	-	X
Fr. rhomboides var. capitata	-	X
Fr. vulgaris	X	X
Fr. weinholdii	-	X
Gomphonema spp.	X	X
G. abbreviatum	X	X
G. acuminatum var. pusilla	X	X
G. affine var. insigne	X	-
G. angustatum	X	X
G. gracile	X	X
G. parvulum	X	X
G. subclavatum var. mexicanum	-	X
G. tenellum	X	X
Gyrosigma acuminatum	X	-
Gy. scalproides	X	X
Gy. spencerii var. curvula	X	X
Hantzschia amphioxys	X	X
H. amphioxys f. capitata	X	-
Melosira varians	X	X
Navicula spp.	X	X
Nav. arvensis	-	X
Nav. capitata	X	X
Nav. cincta	X	X
Nav. confervacea	-	X

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Nav. contenta f. biceps	-	X
Nav. cryptocephala	X	X
Nav. cryptocephala var. veneta	X	-
Nav. cuspidata	X	X
Nav. exigua var. capitata	X	X
Nav. gottlandica	X	X
Nav. heufleri var. leptocephala	X	X
Nav. lanceolata	-	X
Nav. luzonensis	X	-
Nav. mutica	X	X
Nav. mutica var. binoides	X	-
Nav. pseudoreinhardti	X	-
Nav. pupula	-	X
Nav. pygmaea	X	-
Nav. rhynchocephala	X	X
Nav. secreta var. apiculata	X	X
Nav. symmetrica	X	X
Nav. tenera	X	X
Nav. tripunctata var. schizonemoides	-	X
Nav. viridula var. rostellata	X	X
Neidium affine	-	X
Nitzschia spp.	X	X
Nit. acicularis	X	X
Nit. amphibia	X	X

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Nit. bremensis	X	X
Nit. brevissima	X	-
Nit. calida	X	X
Nit. clausii	X	X
Nit. coarctata	X	X
Nit. apiculata	X	X
Nit. denticula	X	X
Nit. dissipata	X	-
Nit. filiformis	X	X
Nit. fonticola	X	X
Nit. gandersheimiensis	X	X
Nit. gracilis	-	X
Nit. hungarica	X	X
Nit. inconspicua	X	X
Nit. intermedia	X	X
Nit. linearis	-	X
Nit. lorenziana var. *subtilis*	X	X
Nit. microcephala	X	X
Nit. obtusa var. ?	-	X
Nit. palea	X	X
Nit. paleacea	X	X
Nit. parvula	X	X
Nit. rautenbachiae	X	X
Nit. reversa	X	-

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Nit. romana	X	X
Nit. sigma	X	X
Nit. subcommunis	X	X
Nit. subrostroides	X	X
Nit. tryblionella var. levidensis	X	X
Nit. tryblionella var. victoriae	X	X
Pinnularia spp.	X	X
P. abaujensis var. linearis	X	-
P. abaujensis var. rostrata	-	X
P. biceps	-	X
P. borealis	X	X
P. braunii	X	-
P. subcapitata var. paucistriata	-	X
P. viridis	-	X
Plagiotropis lepidoptera var. proboscidea	X	-
Pleurosigma delicatulum	X	-
Rhopalodia gibba	-	X
R. musculus	X	X
Stauroneis anceps f. gracilis	-	X
Surirella sp.	-	X
Sur. angusta	X	X
Sur. iowensis	X	X
Sur. ovalis	X	X
Sur. ovata	X	X

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
Sur. ovata var. pinnata	X	X
Sur. ovata var. salina	X	X
Synedra fasiculata	X	-
Syn. fasiculata var. truncata	X	-
Syn. pulchella	X	X
Syn. radians	X	-
Syn. rumpens var. familiaris	X	X
Syn. ulna	-	X
Thalassiosira weisflogii	X	X
Rhodophycophyta (Red Algae)		
Audouinella violacea	X	-
Euglenophyta (Euglenoid Algae)		
Ascoglena vaginatus	X	X
Characium falcatum	X	-
Euglena spp.	X	X
Trachelomonas sp.	X	X
T. hispida	-	X
T. volvocina	-	X
Cyanochloronta (Blue-green Algae)		
Anabaena oscillariodes	X	X
Microcoleus lyngbyaceous	X	-
Porphyrosiphon splendidus	X	-
Schizothrix calcicola	X	X
S. friesii	X	-

Algae Synoptic List for

Craborchard Creek-Vaughn Ditch

	4-1	4-2
S. mexicana	X	X
Spirulina subsalsa	X	-
Total Taxa	125	126
Diversity ($\bar{d}$)	4.5505	4.4556
Equitability (e)	0.5147	0.4156

Algae Quantitative Data for Station 4-1

Diatom Species Proportional Count	Relative Abundance
Nitzschia clausii	22.1%
Navicula symmetrica	17.1%
Navicula cincta	6.5%
Gomphonema parvulum	6.1%
Navicula secreta var. apiculata	3.5%
Nitzschia spp.	2.9%
Melosira varians	2.8%
Caloneis bacillum	2.4%
Nitzschia intermedia	2.4%
Surirella angusta	2.0%
Nitzschia apiculata	1.9%
Synedra pulchella	1.9%
Achnanthes spp.	1.8%
Navicula rhynchocephala	1.75
Surirella ovata	1.7%
Navicula spp.	1.65
Nitzschia paleacea	1.3%
Pleurosigma delicatulum	1.2%
Surirella ovalis	1.2%
Surirella iowensis	1.1%
Nitzschia microcephala	1.0%
Nitzschia amphibia	0.8%
Nitzschia sigma	0.8%
Gomphonema tenellum	0.7%

Algae Quantitative Data for Station 4-1

Diatom Species Proportional Count	Relative Abudance
Gyrosigma scalproides	0.7%
Navicula heufleri var. leptocephala	0.7%
Nitzschia subrostroides	0.7%
Synedra rumpens var. familiaris	0.7%
Cymbella minuta	0.65
Nitzschia gandersheimiensis	0.6%
Achnanthes lanceolata	0.5%
Achnanthes minutissima	0.5%
Entomoneis paludosa	0.5%
Gomphonema spp.	0.5%
Navicula tenera	0.5%
Navicula viridula var. rostellata	0.5%
Nitzschia hungarica	0.5%
Nitzschia rautenbachiae	0.5%
Gomphonema abbreviatum	0.4%
Nitzschia acula	0.4%
Nitzschia palea	0.4%
Nitzschia parvula	0.4%
Amphora submontana	0.2%
Frustulia vulgaris	0.2%
Gomphonema angustatum	0.2%
Gomphonema gracile	0.2%
Navicula cuspidata	0.2%

Algae Quantitative Data for Station 4-1

Diatom Species Proportional Count	Relative Abundance
Nitzschia calida	0.2%
Nitzschia dissipata	0.2%
Nitzschia inconspicua	0.2%
Nitzschia romana	0.2%
Nitzschia subcommunis	0.2%
Synedra fasiculata	0.2%
Diversity ($\bar{d}$)	4.5505
Equitability (e)	0.5147

Algae Quantitative Data for Station 4-2

Diatom Species Proportional Count	Relative Abundance
Synedra pulchella	37.2%
Navicula symmetrica	5.2%
Surirella angusta	4.0%
Nitzschia clausii	3.7%
Nitzschia spp.	3.5%
Gomphonema parvulum	2.4%
Cymbella minuta	2.3%
Frustulia vulgaris	2.0%
Achnanthes sp.	1.9%
Synedra ulna	1.8%
Navicula secreta var. apiculata	1.6%
Synedra rumpens var. familiaris	1.6%
Navicula tenera	1.5%
Navicula cincta	1.4%
Nitzschia paleacea	1.4%
Surirella ovata var. salina	1.4%
Navicula heufleri var. leptocephala	1.3%
Gyrosigma scalproides	1.1%
Navicula spp.	1.1%
Nitzschia amphibia	1.1%
Navicula rhynchocephala	1.0%
Nitzschia hungarica	1.0%
Rhopalodia musculus	1.0%
Caloneis bacillum	0.9%

Algae Quantitative Data for Station 4-2

Diatom Species Proportional Count	Relative Abundance
Gyrosigma spencerii var. curvula	0.9%
Nitzschia calida	0.9%
Nitzschia palea	0.9%
Nitzschia microcephala	0.8%
Amphora submontana	0.6%
Gomphonema angustatum	0.6%
Melosira varians	0.6%
Nitzschia lorenziana var. subtilis	0.6%
Nitzschia subrostroides	0.6%
Surirella ovalis	0.6%
Surirella ovata	0.6%
Achnanthes lanceolata	0.5%
Navicula cryptocephala	0.5%
Nitzschia gandersheimiensis	0.5%
Nitzschia gracilis	0.5%
Nitzschia intermedia	0.5%
Nitzschia sigma	0.5%
Nitzschia subcommunis	0.5%
Pinnularia biceps	0.5%
Rhopalodia gibba	0.5%
Cymbella aspera	0.4%
Cymbella triangulum	0.4%
Pinnularia spp.	0.4%
Gomphonema spp.	0.2%

Algae Quantitative Data for Station 4-2

Diatom Species Proportional Count	Relative Abundance
Gomphonema abbreviatum	0.2%
Gomphonema acuminatum var. pusilla	0.2%
Gomphonema tenellum	0.2%
Navicula contenta f. biceps	0.2%
Nitzschia filiformis	0.2%
Nitzschia inconspicua	0.2%
Nitzschia tryblionella var. levidensis	0.2%
Diversity ($\bar{d}$)	4.4556
Equitability (e)	0.4156

Appendix D

Macroinvertebrate Synoptic List
for Craborchard Creek-Vaughn Ditch

Taxa	Stations 4-1	4-2
Gordioidea		
Gordidae		
Gordius sp.	-	X
Oligochaeta		
spp.	X	X
Basommatophora		
Physidae		
Physella sp.	X	X
Planorbidae		
Promenetus sp.	-	X
Heterodonta		
Sphaeriidae		
Sphaerium simile	X	-
Sphaerium transversum	X	-
Schizodonta		
Unionidae		
Anodonta grandis grandis	X	-
Leptodea fragilis	-	X
Uniomerus tetralasmus	-	X
Isopoda		
Asellidae		
Asellus sp.	X	X
Lirceus fontinalis	X	X
Amphipoda		
Talitridae		
Hyalella azteca	-	X
Decapoda		
Cambaridae		
Cambarus diogenes diogenes	X	-
Orconectes kentuckiensis	X	-
Ephemeroptera		
Caenidae		
Caenis sp.	X	X
Ephemeridae		
Hexagenia sp.	X	-
Heptageniidae		
Stenacron interpunctatum	X	-
Stenonema femoratum	-	X
S. integrum	-	X
Odonata		
Coenagrionidae		
Argia sp.	X	-
Enallagma sp.	X	X
Aeschnidae		
Basiaeschna janata	X	-
Nasiaeschna pentacantha	X	-

Macroinvertebrate Synoptic List
for Craborchard Creek-Vaughn Ditch

Taxa	Stations 4-1	4-2
Macromiidae		
Macromia alleghaniensis	X	-
Plecoptera		
Capniidae		
Allocapnia vivipara	-	X
Hemiptera		
Belostomatidae		
Belostoma lutarium	-	-
Coleoptera		
Dytiscidae		
Laccophilus maculosus	X	-
Gyrinidae		
Dineutus spp.	X	X
Gyrinus sp.	-	X
Haliplidae		
Peltodytes sexmaculatus	-	X
Elmidae		
Dubiraphia quadrinotata	X	-
Stenelmis crenata	X	X
Helodidae		
Elodes sp.	-	X
Hydrophilidae		
Berosus sp.	X	X
Enochrus sp.	-	X
Tropisternus collaris	-	X
T. sp.	-	X
Psephenidae		
Psephenus herricki	-	X
Megaloptera		
Corydalidae		
Corydalus cornutus	X	-
Sialidae		
Sialis sp.	X	-
Diptera		
Ceratopogonidae		
Bezzia-*Johannsenomyia*-*Palpomyia* sp.	X	X
Empididae		
Hemerodromia sp.	X	-
Tabanidae		
Tabanus sp.	X	-
Chaoboridae		
Chaoborus sp.	X	-
Chironomidae		
Ablabesmyia mallochi	-	X
A. parajanta	-	X
Chironomus anthracinus	X	-
C.decorus gp.	X	-

Macroinvertebrate Synoptic List
for Craborchard Creek-Vaughn Ditch

Taxa	Stations 4-1	4-2
C. riparius gp.	X	-
Cricotopus bicinctus	X	-
C. tremulus gp.	-	X
Crytochironomus blarina	X	-
C. fulvus gp.	X	X
Dicrotendipes neomodestus	X	X
D. nervosus tp. I	X	-
Eukiefferiella sp.	X	-
Glyptotendipes lobiferus	X	-
G. paripes	X	X
Hydrobaenus pallipes	X	X
Natarsia sp.	X	-
Orthocladius obumbratus	-	X
O. sp.	X	-
Parametriocnemus sp.	-	X
Polypedilum halterale	-	X
P. illinoense	X	-
Pseudochironomus articaudus	X	X
Stictochironomus sp.	X	X
Tanytarsus guerlus gp.	X	-
Thienemannimyia sp.	X	X
Tribelos sp.	X	-
Simuliidae		
Simulium vittatum	X	X
Tipulidae		
Tipula sp.	-	X
Trichoptera		
Hydropsychidae		
Cheumatopsyche sp.	X	X
Hydropsyche simulans	X	-
Leptoceridae		
Oecetis sp.	X	-

Macroinvertebrate Qualitative and Quantitative Data and Relative Abundance (RA) for Vaughn Ditch at Station 4-1

TAXA	QUAL	Quantitative 1	2	3	TOT	RA (%)
Oligochaeta						
species A	3	7	12	10	29	1
species B	-	4	6	4	14	1
Basommatophora						
Physidae						
Physella sp.	23	3	10	-	13	1
Heterodonta						
Sphaeriidae						
Sphaerium simile	-	4	3	1	8	1
Sphaerium transversum	28	10	15	5	30	1
Schizodonta						
Unionidae						
Anodonta grandis grandis	1	-	-	-	-	-
Isopoda						
Asellidae						
Asellus sp.	22	-	8	2	10	
Lirceus fontinalis	1	3	-	-	3	1
Decapoda						
Cambaridae						
Cambarus diogenes diogenes	1	-	-	-	-	-
Orconectes kentuckiensis	27	-	-	-	-	-
Ephemeroptera						
Caenidae						
Caenis sp.	1	1	9	3	13	1
Ephemeridae						
Hexagenia sp.	1	-	-	-	-	-
Heptageniidae						
Stenacron interpunctatum	9	-	5	1	6	1
Odonata						
Coenagrionidae						
Argia sp.	40	-	-	-	-	-
Enallagma sp.	5	-	1	-	1	
Aeschnidae						
Basiaeschna janata	1	-	-	-	-	-
Nasiaeschna pentacantha	1	-	-	-	-	-
Macromiidae						
Macromia alleghaniensis	2	-	-	-	-	-
Coleoptera						
Dytiscidae						
Laccophilus maculosus	1	-	-	-	-	-
Gyrinidae						
Dineutus sp. 1	22	-	-	-	-	-
Dineutus sp. 2.	2	-	-	-	-	-
Elmidae						
Dubiraphia quadrinotata	-	6	3	2	11	

Macroinvertebrate Qualitative and Quantitative
Data and Relative Abundance (RA) for Vaughn Ditch
at Station 4-1

TAXA	QUAL	Quantitative 1	2	3	TOTAL	RA (%)
Stenelmis crenata	-	4	11	5	20	<1
Hydrophilidae						
Berosus sp.	1	1	3	-	4	<1
Psephenidae						
Psephenus herricki	-	-	-	1	1	<1
Megaloptera						
Corydalidae						
Corydalus cornutus	6	-	3	2	5	<1
Sialidae						
Sialis sp.	15	-	2	-	2	<1
Diptera						
Empididae						
Hemerodromia sp.	-	8	7	12	27	<1
Tabanidae						
Tabanus sp.	-	2	-	-	2	<1
Chaoboridae						
Chaoborus sp.	-	-	3	-	3	<1
Chironomidae						
Chironomus anthracinus	1	-	-	-	-	-
C. decorus gp.	7	-	-	-	-	-
C. riparius gp.	6	4	2	5	11	<1
Cricotopus bicinctus	-	1	1	1	3	<1
Cryptochironomus blarina	-	-	1	-	1	<1
C. falvus gp.	-	4	4	3	11	<1
Dicrotendipes neomodestus	2	154	59	21	234	8
D. nervosus tp. I	2	1	1	2	4	<1
Eukiefferiella sp.	-	-	-	1	1	<1
Glyptotendipes lobiferus	21	3	-	-	3	<1
G. paripes	-	2	4	4	10	<1
Hydrobaenus sp. (pallipes)	-	-	-	3	3	<1
Natarsia sp.	-	-	1	1	2	<1
Orthocladius sp.	-	1	2	1	4	<1
Polypedilum illinoense	-	4	2	1	7	<1
Pseudochironomus articaudus	-	-	2	1	3	<1
Stictochironomus sp.	11	4	22	2	28	<1
Tanytarsus guerlus gp.	-	3	-	2	5	<1
Thienemannimyia sp.	2	35	43	34	115	4
Tribelos sp.	-	1	1	1	3	<1
Ceratopogonidae						
Bezzia-Johannsenomyia-Palpomyia sp.	-	1	8	3	12	<1
Simuliidae						
Simulium vittatum	10	348	179	541	1068	36
Trichoptera						
Hydropsychidae						

Macroinvertebrate Qualitative and Quantitative
Data and Relative Abundance (RA) for Vaughn Ditch
at Station 4-1

TAXA	QUAL	Quantitative 1	2	3	TOTAL	RA (%)
Cheumatopsyche sp.	66	293	304	588	1185	40
Hydropsyche simulans	4	1	4	21	26	<1
Leptoceridae						
Oecetis sp.	-	1	-	-	1	<1
TOTAL					2942	

Total Number of Taxa = 55
Species Diversity ($\bar{d}$) = 2.9639
Equitability (e) = 0.3793

Macroinvertebrate Qualitative and Quantitative
Data and Relative Abundance (RA) for Craborchard Creek
at Station 4-2

		Quantitative				
TAXA	QUAL	1	2	3	TOTAL	RA (%)
Gordidae						
Gordius sp.	-	1	2	-	3	<1
Oligochaeta	-	5	5	4	14	2
Basomatophora						
Physidae						
Physella sp.	8	-	1	-	1	<1
Planorbidae						
Promenetus sp.	-	1	-	-	1	F1
Schizodonta						
Unionidae						
Leptodea fragilis	1	-	-	-	-	-
Uniomerus tetralasmus	7	-	-	-	-	-
Amphipoda						
Talitridae						
Hyalella azteca	1	-	-	-	-	-
Isopoda						
Asellidae						
Asellus sp.	1	-	-	-	-	-
Lirceus fontinalis	2	25	7	11	43	5
Ephemeroptera						
Caenidae						
Caenis sp.	-	40	24	81	145	18
Heptageniidae						
Stenacron interpunctatum	-	-	2	-	2	<1
Stenonema femoratum	1	-	-	-	-	-
S. integrum	-	2	-	24	26	3
Odonata						
Coenagrionidae						
Enallagma	5	-	-	-	-	-
Plecoptera						
Capniidae						
Allocapnia vivipara	-	75	166	200	441	55
Hemiptera						
Belostomatidae						
Belostoma lutarium	1	-	-	-	-	-
Coleoptera						
Gyrinidae						
Gyrinus sp.	1	-	-	-	-	-
Haliplidae						
Peltodytes sexmaculatus	1	-	-	-	-	-
Elmidae						
Stenelmis crenata	-	4	3	5	12	1
Helodidae						
Elodes sp.	-	1	-	-	1	<1
Hydrophilidae						

Macroinvertebrate Qualitative and Quantitative Data and Relative Abundance (RA) for Craborchard Creek at Station 4-2

TAXA	QUAL	Quantitative 1	2	3	TOTAL	RA (%)
Berosus sp.	-	2	-	-	2	<1
Enochrus sp.	1	-	-	-	-	-
Tropisternus collaris	2	-	-	-	-	-
T. sp.	3	-	-	-	-	-
Diptera						
Ceratopogonidae						
Bezzia-Johannsenomyia-Palpomyia sp.	-	4	-	-	4	<1
Chironomidae						
Ablabesmyia mallochi	-	-	-	2	2	<1
A. parajanta	-	1	1	-	2	<1
Cricotopus tremulus gp.	-	1	-	-	1	<1
Cryptochironomus fulvus gp.	-	1	-	-	1	<1
Dicrotendipes neomodestus	=	31	3	16	50	6
Glyptotendipes paripes	-	1	-	-	1	<1
Hydrobaenus sp.	-	-	3	-	3	<1
Orthocladius obumbratus	-	2	-	2	4	<1
Parametriocnemus sp.	-	-	1	-	1	<1
Polypedilium halterale	-	-	1	1	2	<1
Pseudochironomus articaudus	-	3	-	1	4	<1
Stictochironomus sp.	-	1	-	2	3	<1
Thienemannimyia sp.	-	1	14	5	20	2
Simuliidae						
Simulium vittatum	-	5	1	1	7	<1
Tipulidae						
Tipula sp.	-	-	2	-	2	<1
Trichoptera						
Hydropsychidae						
Cheumatopsyche sp.	-	-	3	2	5	<1
TOTAL					803	

Total Number of Taxa = 41
Species Diversity (d) = 2.4050
Equitability (e) = 0.2414

Appendix E

Fish Synoptic List
Craborchard Creek-Vaughn Ditch

	4-1 Vaughn Ditch DOW	4-1 Vaughn Ditch KYDFWR	4-2 Craborchard Creek DOW	4-2 Craborchard Creek SIU
Clupeidae				
Dorosoma cepedianum gizzard shad	-	1	-	1
Esocidae				
Esox americanus grass pickerel	1	-	-	1
Cyprinidae				
Ericymba buccata silverjaw minnow	-	-	4	1
Hybognathus nuchalis silvery minnow	2	-	15	-
Notemigonus crysoleucas golden shiner	-	-	-	2
Notropis atherinoides emerald shiner	-	2	-	3
Notropis fumeus ribbon shiner	5	-	-	-
Notropis lutrensis red shiner	77	-	6	2
Notropis umbratilis redfin shiner	-	7	26	13
Notropis whipplei steelcolor shiner	-	-	6	-
Phenacobius mirabilis suckermouth minnow	39	9	6	-
Pimephales notatus bluntnose minnow	1	-	13	2
Semotilus atromaculatus creek chub	-	-	1	-

Fish Synoptic List
for Craborchard Creek-Vaughn Ditch

	4-1 Vaughn Ditch		4-2 Craborchard Creek	
	DOW	KYDFWR	DOW	SIU
Catostomidae				
Catostomus commersoni white sucker	-	-	-	1
Erimyzon oblongus creek chubsucker	-	-	-	1
Minytrema melanops spotted sucker	-	2	-	-
Moxostoma erythrurum golden redhorse	-	1	-	-
Ictaluridae				
Ictalurus melas black bullhead	-	-	-	1
Ictalurus natalis yellow bullhead	-	-	-	1
Ictalurus punctatus channel catfish	1	-	-	-
Noturus gyrinus tadpole madtom	-	-	1	-
Aphredoderidae				
Aphredoderus sayanus pirate perch	1	-	-	-
Cyprinodontidae				
Fundulus olivaceus blackspotted topminnow	7	3	3	6
Poeciliidae				
Gambusia affinis mosquitofish	2	1	1	3

Fish Synoptic List
for Craborchard Creek-Vaughn Ditch

	4-1 Vaughn Ditch DOW	4-1 Vaughn Ditch KYDFWR	4-2 Craborchard Creek DOW	4-2 Craborchard Creek SIU
Centrarchidae				
Lepomis cyanellus green sunfish	16	-	13	-
Lepomis gulosus * warmouth	-	-	-	-
Lepomis humilis orangespotted sunfish	-	-	2	-
Lepomis macrochirus bluegill	3	-	6	3
Lepomis megalotis longear sunfish	13	14	52	2
Micropterus salmoides largemouth bass	-	2	-	-
Pomoxis annularis white crappie	-	-	-	1
Percidae				
Etheostoma gracile slough darter	5	-	-	-
Percina maculata blackside darter	1	-	-	-
No. Species	15	10	15	18
Total Individuals	174	42	155	45

33 species
10 families
*Collected elsewhere in the drainage.

Appendix F

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