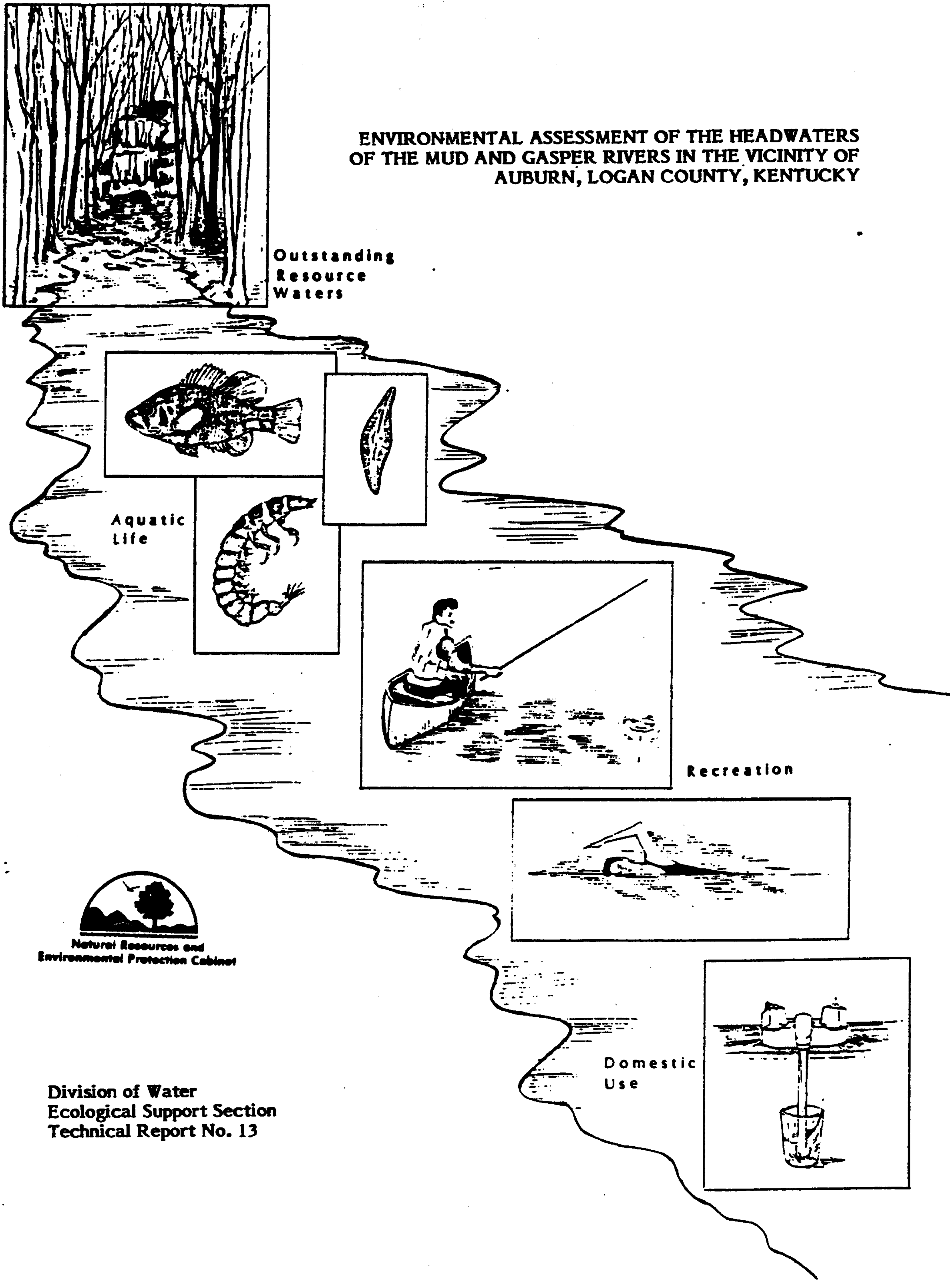
ENVIRONMENTAL ASSESSMENT OF THE HEADWATERS OF THE MUD AND GASPER RIVERS IN THE VICINITY OF AUBURN, LOGAN COUNTY, KENTUCKY



Natural Resources and Environmental Protection Cabinet

Division of Water
Ecological Support Section
Technical Report No. 13

Environmental Assessment of the Headwaters of the Mud and Gasper Rivers in the Vicinity of Auburn, Logan County, Kentucky

Kentucky Department for Environmental Protection
Division of Water
Ecological Support Section
Frankfort, Kentucky

Technical Report No. 13

October, 1987

This report has been approved for release:

Donald F. Harker, Jr.

Donald F. Harker, Jr., Director
Division of Water

Date: 10-15-87

ACKNOWLEDGEMENTS

The Biological Branch of the Division of Water (DOW) would like to extend our appreciation the Organic and Inorganic Branch of the Division of Environmental Services (DES) for conducting the physicochemical laboratory analysis; Dr. H.H. Hobbs, Jr. of the Smithsonian Institute for verifying the crayfish identifications.

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ABSTRACT

The purpose of this report was to determine the effects of runoff from the Caldwell Lace Leather (CLL) Company land disposal site on the the headwaters of the Mud (segment 03012) and Gasper River (segment 03018) systems. In addition, the surface water quality of Black Lick Creek was assessed with regard to the waste discharges from CLL processing plant and the city of Auburn. Water quality data indicate that the waters around the CLL land disposal site may be impacted by surface runoff. Physicochemical data, as well as biological observations indicate that Black Lick Creek is impacted by waste discharges, but is still able to maintain a diverse aquatic flora and fauna.

Physicochemical data from the upper Mud and Gasper river systems indicate that these streams generally have good quality, alkaline, well buffered waters. Elevated values for chloride, ammonia-nitrogen, total kjeldahl nitrogen, nitrate-nitrogen, total phosphorus, barium and manganese were observed at some sampling stations. Violations of Kentucky Surface Water Standards for Warmwater Aquatic Habitat (401 KAR 5:034, Section 4 (1)) were observed for phenols, zinc, mercury and iron at various sampling locations. U. S. EPA chronic toxicity levels for copper and zinc and were commonly exceeded, while acute toxicity criteria for copper was exceeded at two locations. Sediment analyses from selected sites indicate that cadmium, chromium, copper, mercury, nickel and zinc were in the non-polluted category, but contamination by lead, arsenic and barium was observed at some locations.

The headwaters of both the Mud and Gasper rivers support a diverse flora and fauna indicative of high quality streams. A total of 236 taxa of algae, 48 taxa of macroinvertebrates, including a Green River system endemic crayfish, <u>Orconectes barrenensis</u>, and 22 species of fish were collected during this study. Black Lick Creek, though obviously affected by waste discharges, was still capable of maintaining a diverse assemblage of warmwater aquatic organisms.

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RECOMMENDATIONS

1. It is recommended that Mud and Gasper rivers and their tributaries (segments 03012 and 03018) be designated for warmwater aquatic habitat as detailed in Kentucky Surface Water Standards 401 KAR 5:031, Section 4 (1) and that these criteria be applied throughout the segment without modification.
2. It is recommended that Hancock Lake on the Mud River (Russellville's auxiliary water supply) and the "blue hole" on Black Lick Creek (city of Auburn's water supply) be designated for Domestic Drinking Water Supply at the point of withdrawal per 401 KAR 5:031, Section 5 and the criteria be applied throughout the segment without modification.
3. Since subterranean flows and surface water runoff from the CLL land disposal site are known to discharge into the Mud River upstream of the Russellville auxiliary public water supply, and because of the structure of soils and geologic formations in the area, we concur with Dr. Quinlan's recommendation that the present CLL land disposal site be abandoned in favor of a more hydrologically and geologically favorable site.

SUMMARY

1. This report assesses the environmental conditions of the streams surrounding the Caldwell Lace Leather Company (CLL) land disposal site in Logan County, Kentucky during low flow conditions. It also assesses the impacts to Black Lick Creek from the waste discharges of the city of Auburn and Caldwell Lace Leather Company.

2. The Mud River, a fifth order stream, is 113.6 km (70.6 mi) long and drains an area of 971 km^2 (375 mi^2). The Gasper River is a fourth order stream that is 61.1 km (38.0 mi) long and drains an area of 546 km^2 (211 mi^2).

3. The terrain in the upper Mud and Gasper river systems is gently rolling to hilly, which results in streams that are generally low gradient and slow flowing. The study area is a stream-dissected plateau, characterized by sandstone-capped ridges and limestone karst valleys (often dry) with numerous sinkholes. The major streams in the area are the Gasper River with its tributaries (Wiggington and Black Lick Creeks and Clear Fork) and the Mud River.

4. Major land uses in both segments (03012 and 03018) are agriculture (32% in 03012 and 70% in 03018) and silviculture (65% in 03012 and 30% in 03018). Stream uses include recreation, sport fishing and domestic water supply ("blue hole" at Auburn and Hancock Lake near Russellville).

5. The main impacts to the streams of the area are point sources (WWTP and industrial discharges) and potential nonpoint sources (urban and agricultural runoff). Black Lick Creek, which receives municipal and industrial discharges, as well as urban and agricultural runoff, showed signs of being stressed, but still supported diverse aquatic communities.

6. In general, the headwater streams of the Mud and Gasper River systems were considered good quality, alkaline, well buffered streams. Black Lick Creek was the most impacted stream observed in the two systems.

7. The most impacted sites were 12-4 and 12-5 in the Mud River and 18-10 in the Gasper River. Sites 12-4 and 12-5 were possibly impacted by surface runoff and ground water sources from the CLL land disposal site. The source of the impacts to 18-10 may have also have been from CLL.

8. Samples from station 18-16, located at the "blue hole" in the headwaters of Black Lick used for the Auburn municipal water supply, had no violations of Kentucky Surface Water Standards (KSWS), 401 KAR 5:031, Section 5. However, elevated values for oil and grease, NO_3 -N, Al, Cr, Cu and Zn were observed.

9. Station 18-17 on Black Lick Creek, located just below the Auburn and CLL wastewater treatment plants, had elevated values for ammonia-nitrogen, chloride, conductivity, nitrate-nitrogen, total phosphorus, chromium, copper, sodium, and zinc when compared with STORET mean values.

10. Historical data from the Division of Water's Kentucky Pollutant Discharge Elimination System files reveals past problems with heavy metal discharges to Black Lick Creek from CLL and elevated concentrations of oxygen demanding waste from the Auburn WWTP.

11. Violations of Kentucky Surface Water Standards for warmwater aquatic habitat 401 KAR 5:031, Section 4 (1), were observed for mercury at one station, iron at three of the sampled locations and zinc at ten stations.

12. U. S. EPA chronic toxicity values were exceeded for copper at all sampling location, zinc at 50% of the sites (10 stations) and mercury at 15% of the stations (3 sites). Only copper exceed acute toxicity levels (stations 12-2 and 12-4).

13. Surface water parameters exceeded STORET (1979-1983) mean values for barium (62.58 µg/l) at 25% of the sites (5 stations), manganese (221.96 µg/l) at 15% of the stations (3 sites), copper (7.25 µg/l) at all locations, chromium

at 50% of the sampling locations (10 sites), zinc (22.25 µg/l) at all sites and chloride (21.5 mg/l) at 5% of the stations (2 sites).

14. Nitrate-nitrogen was elevated when compared to the STORET (1979-1983) mean (0.69 mg/l) at 70% of the stations (14 sites). Ammonia-nitrogen (NH_3-N) was elevated at 25% of the sites (5 stations) above the STORET mean of .026 mg/l, but did not violate KSWS. Values for total Kjeldahl nitrogen (TKN) were elevated above the STORET mean of 0.64 mg/l at 15% of the stations (3 sites). Total phosphorus was elevated above the STORET mean of 0.156 mg/l at 20% of the stations (4 sites).

15. Sediments samples were moderately polluted with lead at one station (12-4) and moderately polluted with arsenic at three stations (2-4, 18-1, and 18-6). Barium values were moderately polluted at 12-1, 12-7, 18-3, 18-4, 18-8, 18-9 and 18-18 and heavily polluted at the remaining sites.

16. The headwaters and tributaries of the Gasper River supports diverse aquatic communities. The communities at the Mud River site were not as diverse, probably because of habitat limitations rather than water quality impacts.

17. A total of 236 taxa of algae were encountered, most of which were typical stream algae. Wiggington Creek contained 167 taxa, Gasper River had 147 taxa, Black Lick Creek had 129 taxa and Mud River had 91 taxa.

18. Forty eight taxa of macroinvertebrates were collected. Twenty-four species were collected from Wiggington Creek, 25 from the Gasper River, 18 from Black Lick Creek and 15 species from the Mud River. Several viable populations of freshwater mussels were found in Wiggington and Black Lick creeks. One of the Green River drainage endemic crayfishes, <u>Orconectes</u> <u>barrenensis</u>, was observed at one location in the Gasper River system.

19. Twenty two species of fish were collected during the study. Five species of fish were collected from the Mud River site, 15 from Wiggington Creek, 14 from the

Gasper River and 13 from Black Lick Creek. The data show that the members of the fish community observed were capable of occupying a variety of stream habitat types. A good bass and panfish fauna was also observed. Using the Index of Biotic Integrity (IBI), the fish community at all stations where the IBI could be calculated was rate as either good or good to excellent.

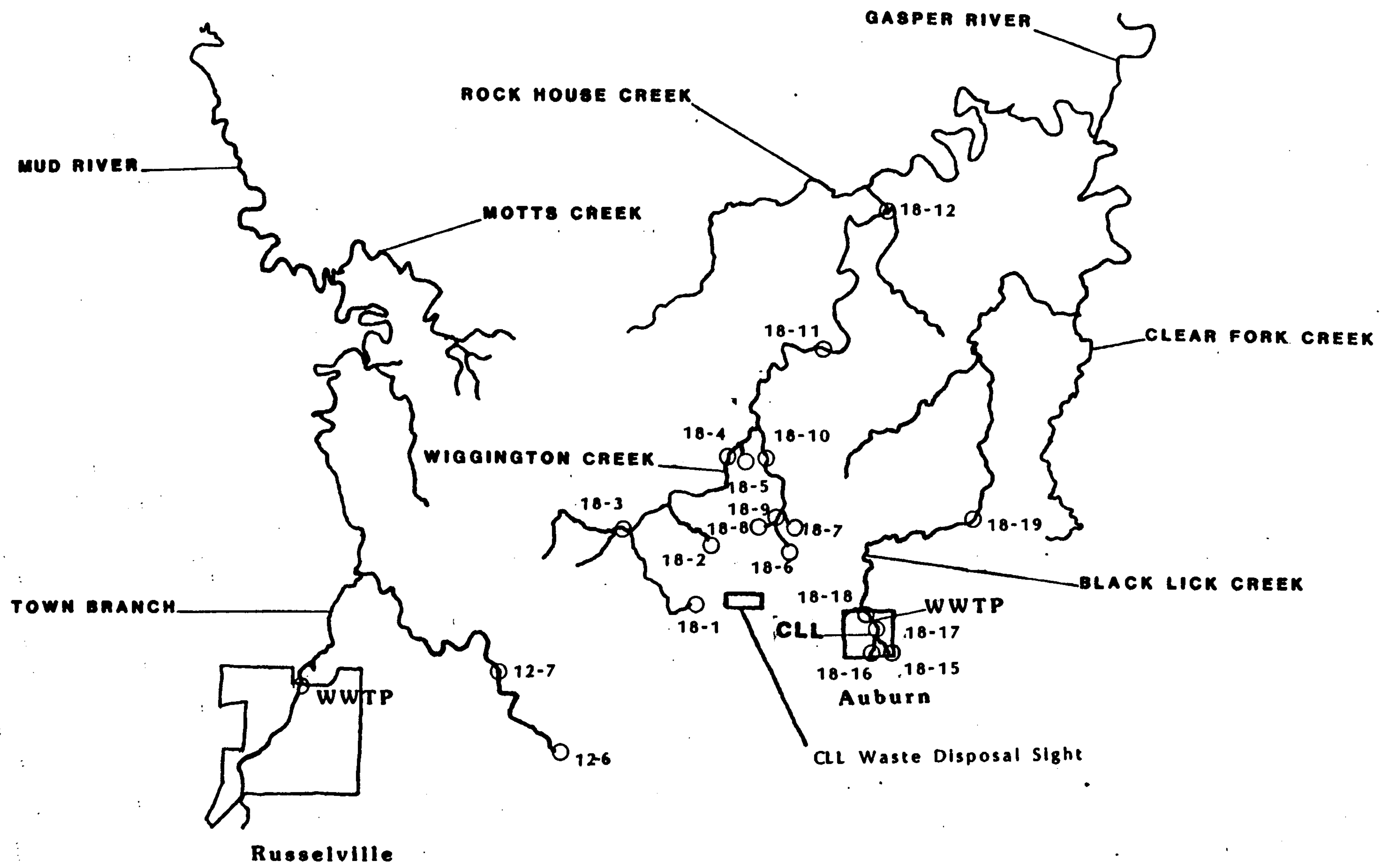
INTRODUCTION

A water quality and biological survey was undertaken by the Division of Water in July, 1983 to assess the environmental conditions in headwaters of the Mud and Gasper rivers which drain the Caldwell Lace Leather (CLL) land disposal area in Logan County, Kentucky, and to assess the impacts to Black Lick Creek from the discharge of waste from the Auburn and the CLL wastewater treatment plants (WWTP). The land disposal area is owned and operated by CLL of Auburn, Kentucky. Drainage of the area is mainly subsurface initially, but dye tests by Quinlan (1982a) and Ewers (1982) indicate water from the area surfaces in two separate stream basins. These basins are the upper Gasper River (segment 03018) to the northeast and the upper Mud River (segment 03012) to the southwest.

Twenty-six sampling stations were established in the area, 19 in the Gasper River basin and seven in the Mud River drainage (Figure 1). Many of these sites were wet weather springs where groundwater from the disposal site is known to surface (refer to Ewers 1982, Quinlan 1982). 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 environmental conditions of the area including existing water quality of the streams.
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.

Figure 1: Map of Study Area with Stream Sampling Locations



Literature Review

Limited published physicochemical and biological data exist on the headwaters of the Mud and Gasper rivers. Quinones et al. (1983) studied the hydrology of the lower portion of the Mud River. The United States Geological Survey (USGS) recorded flow at a partial record station on the Mud River at Lewisburg, Kentucky between 1940 and 1972 (Bettandorff et al. 1983). The Kentucky snubnose darter Etheostoma rafinesquei, recently described by Page and Burr (1982), was taken by the describers from Wiggington Creek, a tributary to the upper Gasper River. Dye studies of sinkholes in the area have been conducted by Ewers (1982) and Quinlan (1982a) to determine the groundwater flow characteristics.

Basin Impacts

Table 1 lists permitted dischargers in the two segments. The major dischargers in the survey area were the city of Russellville (pop. 7,520) WWTP in segment 03012 (Mud River) and the city of Auburn (pop. 1,467) and Caldwell Lace Leather Co. in segment 03018 (Black Lick Creek). Major land uses in segment 12 are agriculture (32%) and silviculture (65%), with several urbanized areas. Segment 18 land uses are agriculture (70%), silviculture (30%), with Auburn being the only major urbanized area.

Stream Uses

Observed stream uses include recreation, sport fishing and domestic water supply. The city of Auburn obtains its drinking water from a "blue hole" spring at the head of Black Lick Creek. Russellville maintains a back-up water supply on Hancock lake, a small impoundment on the Mud River at MP 64.75.

Table 1: Permitted Discharges to Segments 03012 and 03018

Facility #	Facility Name	Design Flow gpd	Receiving Stream	Mile Point
03012002	City of Lewisburg WWTP	125,000	Alum Lick Cr.	2.5
03012003	Chandlers Chapel El. School	3,864	Patterson Cr.	3.2
03012004	Griffen Ind. Ky. Inc.	-	-	
03012005	City of Russelllville WWTP	1,200,000	Town Branch	3.0
03012006	Emerson Electric	-	-	
03012011	I. L. Duncan Jr., Dist.	-	-	
03012012	KY Stone - Russellville	-	-	
03012016	Tradewater Land & Cattle Co.	8,000	-	
03012017	C-R Farms - Hog Farm	-	-	
03012018	Hal Brown Hog Farm	-	-	
03012019	Tarco, Inc. - Tar Sand Extr.	-	-	
03012020	Anaconda Aluminum	-	-	
03012021	Cresset Corp. - Tar Sand Extr.	500	-	
03018001	City of Auburn WWTP	166,000	Black Lick Cr.	12.2
03018002	Caldwell Lace Leather Co.	24,000	Black Lick Cr.	12.2

METHODS

Water and composite sediments samples were analyzed in accordance with 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's (DOW) biological laboratory for analysis. Diatoms were treated with 30% hydrogen peroxide and potassium dichromate to remove organic material (van der Werff 1955). Diatom 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. 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. All macroinvertebrate 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 Sedell (1981). Aquatic macroinvertebrates were placed into one of three pollution categories (i.e. tolerant, facultative and intolerant), generally based on information presented by Weber (1973) and Hart and Fuller (1974). These categories are defined by Beck (1955) and Weber (1973) as follows: tolerant organisms are associated with gross organic contamination and 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.

Fish were collected using a 3.4 m by 1.2 m, 0.3 cm mesh, common sense minnow seine. Pools, riffle areas and all other 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 (Index of Biotic Integrity) was analyzed using the methods of Karr (1981).

PHYSICAL EVALUATION

The study area lies in northeastern Logan County near Auburn, Kentucky. Streams draining this area flow in a northerly direction to join the Green River system. Sampling locations included the headwaters of Mud and Gasper rivers, Black Lick Creek and Wiggington Creek. Site information is provided in Appendix A.

The terrain is gently rolling to hilly. The streams are generally low gradient and slow-flowing. According to Quarterman and Powell (1978) this area lies in the Mammoth Cave Plateau Subsection of Shawnee Hills (a portion of the Interior Low Plateaus Province physiographic region). They describe the area as a hilly upland just south and east of the crest of the Dripping Springs Escarpment. It is a stream-dissected plateau characterized by sandstone-capped ridges and karsted valleys (often dry) with numerous sinkholes.

The underlying rock is part of the Chester Series of Upper Mississippian age (McDowell et al. 1981). Interbedded shale and sandstone, interbedded shale and limestone, and areas solely of sandstone or limestone typify the Chester Series.

Mud River originates as a spring in eastern Logan County. It is a fifth order stream at the mouth, with a total length of 113.6 km (70.6 mi) and a drainage area of 971 km^2 (375 mi^2) (Bower and Jackson 1981). Major tributaries include Town Branch, Wolf Lick Creek, and Rocky Creek. It joins the Green River (MP 108.6) near Rochester, Kentucky at the junction of Muhlenberg, Butler, and Ohio counties. Elevations range from 600 feet above msl in the headwaters to 390 ft above msl at the mouth. Average stream gradient is 0.56 m/km (3.0 ft/mi).

Flow data for Mud River for the period of record (1940 to 1972), collected by USGS at a partial-record station near Lewisburg, Kentucky (MP 44.5), indicates an annual maximum discharge of 216.4 m^3/s (7,640 ft^3/s) (Bettandorff 1983). The estimated seven-day, ten-year low flow (7Q10) of Mud River at its confluence with the Green River is 0.057 m^3/s (2.011 ft^3/s) (R. F. Weston 1975), while at the USGS station at Lewisburg the 7Q10 is 0.00 (Swisshelm 1974, Quinones et al. 1983). During this study it was observed that flow in the headwaters was maintained by groundwater (springs), even during extremely dry weather.

Gasper River originates in northeastern Logan County. It is a fourth order stream with a total length of 61.1 km (38.0 mi) and a drainage area of 546 km^2 (211 mi^2) (Bower and Jackson 1981). Major tributaries include Wiggington Creek and Clear Fork Creek. Black Lick Creek is a tributary to Clear Fork Creek. The Gasper joins the Barren River at MP 8.3 in northwestern Warren County, near Rockland, Kentucky. Elevations range from 640 ft above msl in the headwaters to 400 ft above msl at the mouth. Average stream gradient is 1.2 m/km (6.3 ft/mi).

Flow data from Gasper River for the period of record (1973-1974) collected by USGS at a low-flow partial-record station near Richelieu, Kentucky (MP 25.6), indicates a low-flow discharge of 0.179 m^3/s (6.34 ft^3/s) on October 29, 1973 (USGS 1975). The 7Q10 for Gasper River, near Hadley, Kentucky is 0.02832 m^3/s (1.0 ft^3/s) (Swisshelm 1974).

Wiggington Creek originates in central Logan County. It is a third order stream with a total length of approximately 10.14 km (6.3 mi). It joins the Gasper River (MP 35.2) near Gasper, Kentucky in western Warren County. Elevations range from 580 ft above msl at the mouth to 700 ft above msl in the headwaters. Average stream gradient is 3.5 m/km (18.5 ft/mi).

Clear Fork Creek originates in east-central Logan County. It is a third order stream with a total length of 20.4 km (12.7 mi). It joins the Gasper River (MP 17.05) in west-central Warren County. Elevations range from 580 ft above msl in the headwaters to 470 ft above msl at the mouth. Average stream gradient is 1.6 m/km (8.7 ft/mi).

Black Lick Creek originates as two "blue hole" springs in eastern Logan County near Auburn, Kentucky. No actual flow measurements were made at the time of sampling. However, during this period of extreme drought conditions, it was observed that visible flow was sustained in the stream. This flow, originating at the two blue hole springs, was further enhanced downstream (station 18-19) where groundwater was detected entering the creek. Black Lick Creek is a third order stream with a total length of 20.1 km (12.5 mi). It joins Clear Fork Creek (MP 6.1) near the Logan County and Warren County line. Elevations range from 640 ft above msl in the headwaters to 520 ft above msl at the mouth. Average stream gradient is 1.8 m/km (9.6 ft/mi).

PHYSICOCHEMICAL DISCUSSION

A total of 36 physicochemical parameters were analyzed from surface grab samples taken from 20 locations during this study (Table 2). Six sites were located in headwaters and tributaries of the Mud River (12-1 to 12-7), with the remaining 14 sites placed in the upper reaches of the Gasper River and its tributaries (Wiggington Cr. 18-1 to 18-5, Gasper River 18-8, 18-10 to 18-12, and Black Lick Creek 18-15 to 18-19). Sampling was done during an extreme drought, which resulted in 11 sites being dry. In addition, sediment samples were taken from 23 locations, five in the Mud River system and 18 in the Gasper River drainage. Sediment samples were analyzed for ten metals. In general, water quality data indicated the streams of the upper reaches of the Mud and Gasper rivers were good quality, well buffered, hardwater streams.

Three sites sampled during this study (12-4, 12-5 and 18-10) were impacted. The two Mud River sites (12-4 and 12-5) may be receiving runoff from the Caldwell Lace Leather Company's (CLL) land disposal site. According to Quinlan (1982a), water leaching from this disposal site flows in two different directions, with the majority draining to the southwest into a series of caves and springs that form the headwaters of the Mud River. Sites 12-4 and 12-5 were located on interrupted streams located to the southwest of the CLL disposal site. However, site 12-4 was only a small pothole of water next to U. S. 68 and the data may not be representative of normal conditions. Sampling station 18-10 may also have some subterranean connections to the CLL disposal site, since, according to Quinlan (1982a), some of the runoff flows into the underground water system that eventually discharges to the headwaters of the Gasper River.

Station 18-16 is located near the Auburn municipal water supply withdrawal point. No violations of Kentucky Surface Water Standards (KSWS) for Domestic Water Supply Use (401 KAR 5:031, Section 6) were observed during this

Table 2: Physicochemical Data for the Mud River (Segment 03012) and the Gasper River (Segment 03018).

	Acid mg/l	Alk mg/l	NH_3 mg/l	COD mg/l	Cl mg/l	Cond umhos/cm	Hard mg/l	NO_3 mg/l	pH SU	SO_4 mg/l	TDS mg/l	TKN mg/l	TOC mg/l	TP mg/l	TSS mg/l
Mud River System															
12-2	8.4	202.0	0.04	3.0	11.6	424.0	215.0	1.27	6.9	5.29	260.0	0.95	9.5	0.033	32.0
12-3	12.0	229.0	0.14	3.8	3.0	460.0	240.0	0.58	7.1	7.26	268.0	0.41	10.5	0.026	17.0
12-4	19.0	94.4	0.85	81.2	23.6	283.0	108.0	0.16	7.4	5.29	176.0	0.90	30.0	0.720	242.0
*12-5	13.7	211.0	0.28	30.0	10.6	484.0	253.0	3.9	7.1	6.19	306.0	1.61	28.0	0.340	333.0
**12-6	11.3	190.0	0.07	1.0	8.0	424.0	200.0	4.3	7.3	4.84	270.0	0.05	6.3	0.031	7.0
*12-7	8.4	185.0	0.04	2.7	9.8	424.0	226.0	4.6	7.8	5.74	282.0	0.076	8.4	0.047	10.0
Gasper River System															
*18-1	5.3	117.0	0.05	5.2	3.0	247.0	124.0	0.49	7.3	4.54	142.0	0.386	7.7	0.033	7.0
**18-2	9.3	166.0	0.06	0.3	3.0	339.0	171.0	1.02	7.0	3.05	204.0	0.068	7.7	0.028	44.0
*18-3	6.0	164.0	0.07	4.1	8.6	377.0	184.0	3.9	7.9	5.29	244.0	0.236	7.5	0.021	10.0
*18-4	5.3	166.0	0.11	6.0	9.0	377.0	193.0	3.4	7.8	5.84	236.0	0.528	7.9	0.040	7.0
18-5	12.0	221.0	0.09	0.5	3.0	523.0	264.0	0.40	7.4	48.9	366.0	0.52	8.4	0.012	8.0
18-8	6.8	211.0	0.10	5.4	16.6	494.4	237.0	4.1	7.2	6.04	324.0	0.603	8.8	0.029	4.0
*18-10	14.5	229.0	0.74	31.9	12.0	523.0	278.0	4.5	7.7	9.88	328.0	1.73	21.0	0.515	229.0
*18-11	8.9	188.0	K0.05	5.5	18.7	468.0	212.0	4.7	8.0	9.92	322.0	0.143	9.0	0.17	13.0
*18-12	5.0	183.0	0.10	4.7	16.8	452.0	222.0	4.0	8.1	10.7	320.0	0.068	8.4	0.086	12.0
**18-15	10.3	217.0	0.065	2.5	8.1	483.0	250.0	5.4	7.2	4.69	296.0	K0.05	4.4	0.049	9.0
*18-16	11.5	132.0	K0.05	3.2	6.0	410.0	205.0	4.0	7.2	3.79	242.0	K0.05	5.3	0.041	11.0
*18-17	10.9	194.0	0.307	3.0	13.3	459.0	226.0	4.5	7.5	5.26	290.0	0.463	8.6	0.048	9.0
*18-18	10.1	200.0	0.61	11.5	28.9	539.0	225.0	4.7	7.4	13.8	360.0	0.61	8.2	0.565	13.0
*18-19	10.4	176.0	K0.05	8.0	7.3	365.0	189.0	4.3	8.1	9.57	210.0	0.257	7.7	0.031	16.0

* - stream sites
** - stream origin sites

Table 2 continued

	Al mg/l	As mg/l	Ba mg/l	Cd mg/l	Ca mg/l	Cr mg/l	Cu mg/l	Fe mg/l	Pb mg/l	Mg mg/l	Mn mg/l	Hg mg/l	Ni mg/l	K mg/l	Se mg/l
							Mud River System								
12-2	0.220	0.001	0.030	K0.001	73.0	K0.002	0.210	0.14	0.018	4.53	0.018	K0.0001	0.008	1.02	0.001
12-3	0.090	0.001	0.054	0.001	84.0	0.007	0.019	0.27	0.001	7.38	0.044	0.0001	0.025	1.59	0.001
12-4	2.09	0.001	0.114	K0.001	37.0	K0.002	0.034	1.48	0.044	3.08	1.21	0.0003	0.024	14.2	0.001
12-5	1.77	0.001	0.086	0.001	84.0	0.013	0.025	1.61	0.007	5.58	0.477	0.0002	0.036	5.28	0.001
12-6	0.270	0.001	0.028	0.002	73.0	0.003	0.022	0.08	0.001	4.67	0.016	0.0001	0.027	1.40	0.001
12-7	0.320	0.001	0.093	K0.001	76.0	0.013	0.022	0.15	0.001	4.80	0.046	K0.0001	0.012	2.61	0.001
							Gasper River System								
18-1	0.180	0.001	0.052	K0.001	40.0	0.004	0.022	0.06	0.018	2.25	0.013	K0.0001	0.013	2.18	0.001
18-2	0.400	0.001	0.072	K0.001	65.0	0.010	0.030	0.25	0.001	1.96	0.069	K0.0001	0.020	0.99	0.001
18-3	0.110	0.001	0.002	0.001	66.0	0.002	0.023	0.09	0.001	3.77	0.030	K0.0001	0.008	1.78	0.001
18-4	0.090	0.001	0.006	0.001	65.0	K0.002	0.018	0.08	0.001	4.23	0.046	K0.0001	0.019	2.22	0.001
18-5	0.110	0.001	0.040	0.002	80.0	K0.002	0.020	0.08	0.001	15.3	0.021	K0.0001	0.017	2.89	0.001
18-8	0.100	0.001	0.008	K0.001	89.0	0.007	0.022	0.04	0.001	5.47	0.028	0.0001	0.030	1.52	0.001
18-10	1.58	0.001	0.090	0.003	91.0	0.004	0.029	1.13	0.006	6.85	1.32	0.0002	0.016	7.04	0.001
18-11	0.130	0.001	0.002	K0.001	81.0	K0.002	0.025	0.10	0.003	5.50	0.041	0.0001	0.039	2.19	0.001
18-12	0.290	0.001	0.038	K0.001	73.0	0.015	0.017	0.08	0.001	5.27	0.044	0.0001	0.022	2.22	0.001
18-15	0.100	0.001	0.006	0.002	84.0	0.005	0.027	0.05	0.001	5.63	0.039	K0.0001	0.014	1.56	0.001
18-16	0.100	0.001	0.014	0.002	76.0	0.011	0.023	0.09	0.001	5.91	0.050	K0.0001	0.012	1.74	0.001
18-17	0.080	0.001	0.004	K0.001	79.0	K0.002	0.025	0.09	0.001	5.51	0.045	0.0001	0.038	1.67	0.001
18-18	0.160	0.001	0.002	K0.001	81.0	0.007	0.021	0.11	0.001	6.08	0.043	0.0001	0.022	2.05	0.001
18-19	0.140	0.001	0.002	0.004	63.0	0.013	0.027	0.12	0.008	5.59	0.098	0.0001	0.017	1.38	0.001

Table 2 continued

	Na mg/l	Zn mg/l	BOD_5 mg/l	Cn mg/l	Oil and Grease mg/l	Phenols mg/l	DO mg/l	Air Temp °C	Water Temp °C	Turbidity NTU
						Mud River System				
12-2	7.29	0.103	ND	ND	ND	ND	ND	ND	ND	ND
12-3	3.19	0.033	ND	ND	ND	ND	ND	ND	ND	ND
12-4	8.80	0.173	ND	ND	ND	ND	ND	ND	ND	ND
12-5	4.41	0.044	ND	ND	ND	ND	ND	ND	ND	ND
12-6	3.81	0.033	ND	ND	ND	ND	8.8	40.0	15.5	3.5
12-7	3.54	0.101	ND	ND	ND	ND	9.0	38.0	20.0	3.2
						Gasper River System				
18-1	3.79	0.096	ND	ND	ND	ND	ND	ND	ND	ND
18-2	3.57	0.032	ND	ND	ND	ND	ND	ND	ND	ND
18-3	4.75	0.077	ND	ND	ND	ND	7.5	36.0	23.0	2.6
18-4	4.02	0.037	ND	ND	ND	ND	5.6	37.0	26.0	2.0
18-5	5.58	0.024	ND	ND	ND	ND	ND	ND	ND	ND
18-8	7.25	0.038	ND	ND	ND	ND	ND	ND	ND	ND
18-10	5.00	0.040	ND	ND	ND	ND	ND	ND	ND	ND
18-11	12.0	0.038	0.2	K0.010	ND	0.09	8.5	32.0	22.0	3.4
18-12	10.4	0.048	ND	ND	ND	ND	8.0	38.0	26.0	2.8
18-15	3.29	0.079	0.2	K0.010	0.7	K0.05	6.5	31.0	15.0	2.5
18-16	3.15	0.048	0.1	K0.010	4.2	K0.05	7.5	30.0	15.0	4.4
18-17	8.74	0.065	0.2	K0.010	0.8	K0.05	8.3	29.0	20.0	2.4
18-18	20.9	0.047	2.1	K0.010	K0.1	K0.05	8.0	29.0	22.0	4.5
18-19	3.18	0.030	0.3	ND	0.2	ND	7.4	34.0	ND	3.2

ND - Not Determined

study. However, elevated values of oil and grease, NO_3-N, Cr, Cu and Zn were observed when compared to STORET (1979 - 1983) mean values.

Station 18-18 is located below the Auburn and Caldwell Lace Leather WWTP effluents. This site had elevated values for NH_3-N, Cl^-, conductivity, NO_3-N, TP, Cr, Cu, Na and Zn (see below for discussion of these parameters). This site also had the highest biochemical oxygen demand (BOD_5) and turbidity value observed in this study. A review of the Division of Water's Kentucky Pollutant Discharge Elimination System files reveal that CLL and Auburn WWTPs have discharged elevated levels of metals and oxygen demanding waste which had adversely impacted the Black Lick Creek in the past.

Conductivity and total dissolved solids (TDS) were not considered detrimental to aquatic life at any sampling location. Only sites 18-10 and 18-18 in the Gasper River system slightly exceeded the conductivity value of 500 umhos/cm determined by Ellis (1937) as supporting the most diverse fish faunas. Total dissolved solids concentrations at all sites were well below the 2000 mg/l value reported by McCarraher and Thomas (1968) as inhibiting fish spawning.

Tests for chemical oxygen demand (COD) were performed on samples from all stations at which water was found. Analysis for biochemical oxygen demand (BOD_5) was only conducted on samples from Black Lick Creek (stations 18-15 through 18-19) and one station on Gasper River (18-11). All BOD_5 values, except at station 18-18 (Black Lick Creek), were below the STORET (1979-1983) mean value (1.3 mg/l). Except for stations 12-4 and 12-5 on the Mud River system and 18-10 on the Gasper River, COD values were below the STORET (1979-1983) mean value of 13.4 mg/l. Those stations, especially 12-4, were considerably elevated compared to the other stations sampled.

Chloride (Cl^-) values exceeded the STORET (1979-1983) mean value of 21.5 mg/l at stations 12-4 and 18-18, but did not violate KSWS. The Cl^- concentration of the latter site was elevated over those sites located directly upstream (18-15, 18-16 and 18-17). This was probably because of the municipal waste discharge (Auburn WWTP) located between sites 18-17 and 18-18. Chloride concentrations are higher in domestic sewage than in most freshwaters, primarily because of the dietary use of salt (Dierberg and Brezonik 1983).

With the exception of nitrite + nitrate-nitrogen (NO_2 + NO_3 -N), the nutrients (ammonia (NH_3), total kjeldahl nitrogen (TKN), and total phosphorus (TP)) were only occasionally elevated above STORET (1979-1983) mean values. Ammonia exceeded the STORET (1979-1983) mean value of 0.26 mg/l at 12-4, 12-5, 18-10, 18-17, and 18-18. However, the observed ammonia values did not violate KSWS for un-ionized ammonia during this study. The TKN STORET (1979-1983) mean value of 0.64 mg/l was exceeded at stations 12-4, 12-5, and 18-10. The TP STORET (1979-1983) mean value of 0.156 mg/l was exceeded at stations 12-4, 12-5, 18-10, and 18-18. Elevated TP concentrations are of concern since phosphorus is usually the nutrient most limiting to primary production (Wiebe 1931, Schindler 1971) and increased amounts generally accelerate eutrophication (Winger 1981). Concentrations of phosphorus are usually below 0.1 mg/l, except in streams receiving agriculture runoff (Omernik 1977). Nitrite + nitrate - nitrogen exceed the STORET (1979-1983) mean value of 0.69 mg/l at physicochemical stations 12-5, 12-6, 12-7, 18-2, 18-3, 18-4, 18-10, 18-11, 18-12, 18-15, 18-16, 18-17, 18-18, and 18-19. That was probably a reflection of the extensive agricultural activities that occur in this region (refer to Basin Impacts). Patrick (1950) noted that healthy streams in the eastern United States should not exceed 2.0 mg/l nitrate. Fourteen stations exceeded Patrick's value (Table 2).

Oil and grease determinations were made at station 18-15, 18-16, 18-17, 18-18, and 18-19. Station 18-16 at the city of Auburn's public water supply withdrawal point was the only station that had a substantial concentration of oil and grease. With regard to public water supplies, even small quantities of oil and grease can cause objectionable odors and appearance, resulting in rejection of the water supply before health and treatment problems exist (Holluta 1961, McKee and Wolf 1963). It is recommended that public water supplies be essentially free from oil and grease (CWQC 1972).

The metals data (Table 2) show that copper (Cu) and zinc (Zn) concentrations were above the STORET (1979-1983) mean values of 7.25 ug/l and 22.25 ug/l, respectively, at every sampling location. In addition, chromium (Cr) values were elevated above STORET (1979-1983) mean values of 3.16 ug/l and 1.50 ug/l, respectively, at most stations. Mercury (Hg) values were above STORET (1979-1983) mean values a three stations. Barium (Ba) (STORET mean of 62.58 ug/l) was elevated at stations 12-4, 12-5, 12-7, 18-2 and 18-10; cadmium (Cd) (STORET mean of 3.80 ug/l) at station 18-19, and iron (Fe) and manganese (Mn) (STORET means of 1279.36 ug/l and 221.96 ug/l, respectively) at stations 12-4, 12-5 and 18-10.

Copper is an essential nutrient of plants and animals; however, if the Cu concentration greatly exceeds that required for nutrition, it can be toxic to aquatic organisms (U. S. EPA 1980a). Copper is known to be particularly toxic to algae and mollusks (CWQC 1972). Data presented by Chakoumakos et al. (1979) and Howarth and Sprague (1978) indicate that the life stage may affect the susceptibility of fish to copper toxicity. Copper concentrations of 1 to 10 ug/l are usually reported for unpolluted surface waters in the United States, but concentrations in the vicinity of municipal and industrial discharges may be much higher (U. S. EPA 1980a). Copper concentrations in this study ranged from 17 to 210 ug/l. Acute toxicity of copper to aquatic life depends on alkalinity, pH, organic compounds (U. S. EPA 1976), hardness, and temperature, but at low levels, hardness does not appear to affect chronic toxicity (U. S. EPA 1980a). For total recoverable copper, the criterion to protect freshwater aquatic life is 5.6 ug/l as

24 hour average, and the concentration (in ug/l) should not exceed values given in Table 3 at any time, based on the hardness of the water. Therefore, Cu concentrations observed in this study may pose a chronic toxicity problem to aquatic life at all stations and acutely toxic at stations 12-2 and 12-4. .

Table 3: U.S. EPA Acute Metal Toxicity (in ug/l) Criteria for Protection of Aquatic Life of at Varying Hardnesses

Hardness	Cu	Zn	Cr
25	6.0	101.7	1049.8
50	11.6	180.7	2219.4
75	17.0	253.0	3438.8
100	22.2	321.3	4691.9
150	32.5	449.8	7269.8
200	42.5	571.1	9918.8
250	52.5	687.3	12621.8
300	62.3	799.6	15368.7
350	72.0	908.8	18152.6
400	82.0	1015.3	20968.6

Zinc is a common trace element of natural waters and is required in the metabolism of most organisms. The toxicity of Zn is influenced by hardness, DO, pH (U. S. EPA 1976), and ionic strength (U. S. EPA 1980b). However, the available toxicity data indicate that hardness effects are much less dramatic for chronic toxicity of Zn than for acute toxicity (U.S. EPA 1980b). The KSWS and U.S. EPA criteria for total recoverable Zn, for freshwater aquatic life, is 47 ug/l as a 24-hour average and a concentration (in ug/l) should not exceed the value given in

Table 3, based on hardness. Therefore, the Zn concentration observed at stations 12-2, 12-4, 12-7, 18-1,18-3, 18-12, 18-15, 18-16 and 18-17 may pose chronic toxicity problems for the aquatic life at these locations.

Total chromium (Cr) concentrations did not violate KSWS at any site during this study. However, Cr values exceeded the STORET (1979-1983) mean value of 3.16 ug/l at stations 12-5, 12-7, 18-1, 18-2, 18-10, 18-12, 18-15, 18-16, 18-18, and 18-19.

Mercury violated KSWS (401 KAR 5:031, Section 5(1)(h)(3)) at stations 12-4, 12-5, and 18-10. The U. S. EPA (1980c) established criteria for protecting freshwater aquatic life, for total recoverable Hg, as derived using the guidelines, is 0.20 ug/l as a 24 hour average and concentrations should not exceed 4.1 ug/l at any time. Stations 12-4, 12-5, and 18-10 equaled or exceeded the U. S. EPA's 24 hour average value. Mercury is widely distributed in the environment and has been historically recognized as posing a high toxic potential (U. S. EPA 1976). In addition, data presented by Hannerz (1968) and McKim (1974) show that Hg bioaccumulates in aquatic organisms. The bioaccumulative properties and the highly toxic nature of Hg indicates that concentrations observed in this study are a potential hazard to the aquatic organisms in portions of these segments.

Barium exceeded the STORET (1979-1983) mean value of 62.58 ug/l at stations 12-4, 12-5, 12-7, 18-2 and 18-10. Barium, an alkaline earth metal, occurs in nature chiefly as barite ($BaSO_4$) and witherite ($BaCO_3$), both of which are highly insoluble (U. S. EPA 1976). Experimental data indicate that the soluble Ba concentration in fresh and marine water generally would have to exceed 50 mg/l before toxicity to aquatic life would be expected (U. S. EPA 1976). The U. S. EPA (1976) speculated that in most natural waters there is sufficient sulfate and carbonate to precipitate the Ba present as a virtually insoluble, nontoxic compound. None of the stations sampled had Ba concentrations that closely approximated the 50 mg/l value presented by U. S. EPA (1976).

Iron concentrations observed at stations 12-4, 12-5 and 18-10 exceeded KSWS, 401 KAR 5:031, Section 4 (1)(I)(4). The U. S. EPA (1976) recommended a protective criterion of 1 mg/l, which is equivalent to KSWS, for the protection of aquatic life. However, Warnick and Bell (1969) derived a 96-hour LC_{50} of 320 ug/l of Fe for selected aquatic insects, i.e. certain mayflies, caddisflies, and stoneflies, all of which are important fish food organisms. Therefore, Fe concentrations observed at 12-4, 12-5 and 18-10 may be detrimental to aquatic life.

Manganese concentrations were elevated at three locations (12-4, 12-5, and 18-10) above the STORET (1979-1983) mean value of 221.96 ug/l. Manganese is a micro-nutrient for both plants and animals (U. S. EPA 1976), occurring in natural waters at only low levels as manganous salts and precipitated in the presence of air as manganic oxide (CWQC 1972). Manganese determinations have traditionally been omitted from surface water analyses, except in streams subject to extensive pollution; therefore, there is little information on the normal loads of Mn in stream waters and the way it might vary seasonally (Hem 1970). However, it is improbable that Mn would be found at toxic levels in this study.

Sediment

Sediment samples from 23 locations were analyzed for metals (Table 4) and compared with values determined by the U. S. EPA (1977) for Great Lakes harbor sediments. Analysis for Cd, Cr, Cu, Hg, Ni, and Zn showed all concentrations of these metals within the nonpolluted range. Tests for lead showed one value (station 12-4) in the moderately polluted range, with the remaining stations all in the nonpolluted category. Values for As at stations 12-4, 18-1, and 18-6 were in the moderately polluted range, while the remaining stations were all classified as nonpolluted. Barium values were elevated at every station; sediments were considered moderately polluted with Ba at stations 12-1, 12-7, 18-3, 18-4, 18-8, 18-9, and 18-18, and heavily polluted at the remaining stations.

Table 4: Sediment Data for the Mud River (Segment 03012) and the Gasper River (Segment 03018).

	As mg/kg	Ba mg/kg	Cd mg/kg	Cr mg/kg	Cu mg/kg	Pb mg/kg	Hg mg/kg	Ni mg/kg	Se mg/kg	Zn mg/kg
					Mud River System					
12-1	1.18	56.7	0.639	6.28	6.92	11.7	0.036	6.50	0.959	31.3
12-4	6.43	172.0	1.07	15.5	20.9	62.8	0.060	12.7	0.535	84.6
12-5	1.50	62.1	0.576	11.1	4.27	13.8	0.030	3.22	1.04	13.4
12-6	1.00	64.4	0.553	5.86	4.76	12.1	0.028	4.98	0.111	24.0
12-7	0.628	58.9	0.314	5.50	2.59	7.85	0.060	2.28	K0.08	14.4
					Gasper River System					
18-1	3.24	124.0	0.324	6.72	5.26	16.2	0.036	4.70	K0.08	15.3
18-2	0.477	116.0	0.797	2.55	5.42	9.56	0.030	4.14	0.16	12.4
18-3	0.530	43.5	0.426	9.79	4.26	11.7	0.022	3.52	0.106	11.5
18-4	0.615	46.7	0.493	2.71	4.93	11.1	0.030	3.20	0.123	13.9
18-5	0.595	80.9	0.717	4.30	4.54	14.3	0.035	11.7	0.119	22.9
18-6	4.14	110.0	0.512	4.76	6.56	17.0	0.034	6.00	0.085	20.8
18-7	ND	174.0	1.07	4.39	16.1	34.6	0.049	6.79	0.133	68.1
18-8	2.08	29.7	0.297	0.989	3.46	6.92	0.016	1.58	0.099	7.02
18-9	2.72	59.4	0.594	5.68	5.77	13.6	0.024	6.11	0.085	20.9
18-10	2.48	84.2	0.892	K0.990	6.74	21.8	0.019	6.05	0.099	20.1
18-11	1.73	86.5	1.19	K01.33	6.38	17.3	0.037	5.72	0.133	21.8
18-12	0.876	112.0	1.31	K01.46	7.88	20.4	0.031	6.57	0.146	19.4
18-14	0.966	117.0	0.830	3.74	7.19	18.0	0.049	4.48	0.138	15.5
18-15	2.78	75.5	0.368	23.3	7.37	24.0	0.050	8.25	0.087	36.4
18-16	0.798	94.6	0.796	3.87	11.4	23.8	0.042	4.09	0.114	24.8
18-17	1.12	82.8	0.465	20.5	4.09	25.1	0.027	4.28	0.093	32.2
18-18	0.710	59.9	0.474	10.9	4.26	17.4	0.032	2.99	0.079	23.4
18-19	ND	124.0	1.00	15.3	8.44	32.9	0.044	11.7	ND	41.8
Max	6.43	174.0	1.31	23.3	20.9	62.8	0.060	12.7	1.04	84.6
Min	0.477	29.7	0.297	K0.990	2.59	6.92	0.016	1.58	K0.08	7.02
Mean	1.74	88.5	0.683	ND	6.93	19.3	0.036	5.72	ND	25.9
Median	1.12	82.8	0.594	4.76	5.42	17.0	0.034	4.98	0.113	20.9

Comparing the concentration of the various sediment parameters at each site to the mean and/or median derived from all parameters reveals that station 12-4, 18-7, 18-15 and 18-19 have several substantially elevated values (Table 4). Every parameter was elevated above the mean and/or median at stations 12-4. At station 18-7, Ba, Cd, Cu, Pb and Zn were substantially elevated above mean and/or median values. Station 18-19 had high values for Ba, Cd, Cr, Pb, Ni, and Zn. Stations 12-6, 18-2, 18-4, 18-6, 18-8, 18-9, and 18-10 had atleast one parameter that exceeded the mean and/or median values. Nine of the remaining stations had one or two parameters that exceeded the mean and/or median values (Table 4).

BIOLOGICAL EVALUATION

A biological survey was undertaken by DOW personnel to assess the biological conditions of the surface waters in the area surrounding the CLL land disposal site, and to determine the impacts to Black Lick Creek resulting from waste discharges from the Auburn and CLL WWTPs. Biological data were collected at selected sites and analyzed by DOW personnel for the following groups of organisms: algae, macroinvertebrates, and fish. Site specific data were compared with other sites in the Green River basin, available historical data, and appropriate scientific literature regarding the environmental tolerances and requirements of aquatic organisms.

Data from this survey indicate the headwaters and tributaries of the Gasper River support diverse aquatic communities. The communities at the Mud River site were not as diverse. This was attributed to environmental conditions, i.e. low flow resulting from drought conditions and cooler water temperatures because of groundwater sources and dense canopy, rather than water quality impacts.

A total of 236 taxa of algae were identified, most of which were typical stream algae except at the Black Lick Creek site (18-19). Forty eight taxa of macroinvertebrates were collected and several viable populations of freshwater mussels were observed. Although sampling for fish was difficult and unproductive at several locations, a total of 22 species were collected.

Algae

The analysis of periphyton (attached algae) is an important part of water quality studies. Algae are excellent water quality indicators, provide reoxygenation and nutrient removal in streams, and serve as primary producers in aquatic ecosystems. The headwaters of the Gasper and Mud River systems support very diverse algal communities (Appendix B), with a total of 236 taxa encountered during this study. Species richness, diversity, and equitability were the highest in

Wiggington Creek (stations 18-3 and 18-4). Algal communities at 18-11 and 18-12 (Gasper River) were typical of productive limestone streams. No obvious impacts could be detected at those sites. The community was limited at 12-7 (Mud River) probably because of cooler water temperature and the presence of a dense tree canopy rather than water quality impacts. Black Lick Creek (18-19) was affected by nutrient enrichment from the Auburn WWTP and agricultural runoff. With the exception of Black Lick Creek, the streams sampled appeared to be relatively unstressed and supported diverse assemblages of typical stream algae. The occurrence of Achnanthes hauckiana, Caloneis lewisii, Navicula mutica var. cohnii, Navicula mutica var. capitata, Navicula mutica f. gibbosa, Navicula pupula var. mutata, and Nitzschia sublinearis represent new collection records for Kentucky.

Mud River

Station 12-7

The periphyton community was dominated by moderate to dense growths of Lemanea australis, a red alga, as well as by unidentified bryophytes (mosses). This was the only site in the study where Tribonema utriculosum, an uncommon filamentous chrysophyte, was collected. While species richness was the lowest observed in the study (Table 5), the apparent reduction in algal taxa was probably not the result of water quality impacts. Diatom diversity ($\bar{d}$) and equitability (e) (Table 5) were also the lowest seen in the study because of the dominance of Cocconeis species (65%), which are common moss and filamentous algal epiphytes (Lowe 1974). The reduction in diversity, equitability, and species richness was most likely the result of cooler water temperature (because of the groundwater origin 2.5 mi upstream), as well as the presence of a dense tree canopy at this site. While nutrient values here were similar to those observed at station 18-19 (Black Lick Creek), taxa associated with nutrient enrichment were not particularily abundant in the community.

Table 5: Selected Algal Data for the Mud River and Gasper River Drainages

	12-7	18-3	18-4	18-11	18-12	18-19
Species Richness	91	119	143	121	115	129
Diatom Diversity ($\bar{d}$)	3.2507	5.4719	5.2376	4.3459	3.3894	4.0756
Diatom Equitability (e)	0.2823	0.7742	0.7628	0.4406	0.3408	0.4839
Green Algal Species	5	7	11	7	7	23
Euglenoid Algal Species	1	1	1	1	2	12
Blue-green Algal Species	2	4	7	5	3	8

Wiggington Creek

Station 18-3

The algal community was characterized by moderate growths of filamentous red and blue-green algae, as well as diverse assemblages of pennate diatoms and placcoderm desmid algae. Species richness was typical for the drainage and community structure is probably typical of unimpacted streams in this region of the state. Diatom $\bar{d}$ and e were the highest observed in this study (Table 5). Species characteristic of nutrient enrichment were not particularly abundant in the community. The abundance of diatom taxa in the Wiggington Creek watershed, including many clean water forms, is reflective of diverse microhabitat availability, as well as excellent water quality. This observation is in agreement with the physicochemical data. Certain species of Cymbella, Eunotia, Frustulia, Gomphonema, and Pinnularia occurred only in Wiggington Creek.

Wiggington Creek

Station 18-4

The algal community was similar to that observed at the previous station, except that taxa associated with nutrient enrichment were more abundant in the community. For example, green algae (order Chlorococcales) and blue-green algae were more diverse here than at the upstream site (Table 5). The diatom community was dominated by *Melosira varians* (Appendix B), which is considered an obligate nitrogen heterotroph by Cholnoky (1968) and a eutrophic species by Lowe (1974). However, the second most frequently occurring diatom *Achnanthes deflexa* was considered a clean water species by Harker et al. (1979). While total phosphorus here was twice that observed at the upstream site (18-3), most likely because of agricultural activities, the algal community did not seem to be adversely affected. Diatom $\bar{d}$ and e were among the highest observed in the study (Table 5). Species richness was the highest observed in the drainage (143) because of the presence of not only typical stream taxa, but also those associated with nutrient-rich waters.

Gasper River

Station 18-11

The periphyton community was characterized by moderate growths of filamentous red, blue-green, and green algae. Species richness (Table 5) was typical for the drainage. Diatom $\bar{d}$ was considered good, but e was lower than average because of the dominance of *Cocconeis* species (38%). The community seems typical of productive limestone streams. No obvious impacts could be detected at this stream site.

Gasper River

Station 18-12

The periphyton community was similar to that observed at the previous station, except that the filamentous green alga *Cladophora glomerata* reached dominant status at this site. Green algal flagellates, including *Chlamydomonas*, were also present in the community. *Melosira varians*, a eutrophic species (Lowe 1974), accounted for 29% of the diatom community. This suggests that this site was more affected by nutrient enrichment than the upstream site (18-11), although nutrient concentrations were similar at both sites at the time of sampling. Sources of nutrient enrichment were probably limited to agricultural activities. Species richness (Table 5) was typical for the drainage, while diatom $\bar{d}$ and e were reduced, because of the dominance of *Melosira* and *Cocconeis* species.

Black Lick Creek

Station 18-19

The attached algal community consisted of moderate growths of filamentous green, blue-green, and red algae. However, the most striking feature at this site was the dominance of flagellate algae, notably *Euglena viridis*, considered to be the most tolerant alga to organic pollution by Palmer (1969). The abundance of eutrophic, planktonic species (Appendix B) was reflective of the exposed, pooled nature of the stream and suggests a greater degree of nutrient and organic enrichment here than at the other sites in this study. This was supported by the number of green, euglenoid, and blue-green algal taxa at 18-19 in comparison with the other sites (Table 5). Many of these taxa are typically found in eutrophic lakes (Palmer 1977). While species richness (129 taxa) was above average for the drainage, the number of diatom species observed here was among the lowest seen in the study. This is further indication that the stream is under stress.

While the water quality data from Black Lick Creek was similar to other sites in this study, the algal community structure at 18-19 was very different. For example, the dominant species observed here suggested higher nutrient concentrations (particularly phosphorus) than was evident in the physico-chemical data. The source of nutrient enrichment was probably the Auburn WWTP effluent and runoff from intensive agricultural practices (ie. row crops) occurring in the watershed. Diatom frustular aberrancy was noted in four species collected from Black Lick Creek. This phenomenon is associated with physiological stress (C. Reimer, pers. comm.) and is often found in streams affected by metal toxicity (DOW 1981, 1983). Sediment values for As, Cr, Pb, Ni, and Zn were the highest observed for the biological sampling sites. While none of these metals were in the U.S. EPA (1977) polluted category, potential synergistic effects of these metals may account for the observed aberrancies, which occurred only at station 18-19.

Macroinvertebrates

Except for samples from Black Lick Creek, all of the invertebrate collections (Appendix C) from the Gasper River and Mud River drainages represented diverse benthic communities that reflected partitioning of available habitats. The Black Lick Creek communities were altered in species composition by environmental stresses and/or habitat loss. A total of 48 taxa were collected during this study. Of these, 15 were observed from the Mud River station (12-7), 24 from the Wiggington Creek stations (18-3 and 18-4), 25 from the Gasper River sites (18-11 and 18-12), and 18 from the Black Lick Creek locations (18-17 and 18-19).

The occurrence of *Orconectes barrenensis* in the Gasper River at station 18-12 is noteworthy. This species is endemic to the Green River system (i.e., principally the Barren River and its tributaries) in Kentucky and probably Tennessee (Rhoades 1944). According to Rhoades (1944), this species is typically found in pools in association with *O. putnami*. Data from this study support Rhoades (1944) statements.

Mud River

Station 12-7

Large, slab-rock riffle areas provided most of the invertebrate habitats and substrates for periphyton colonization. As a result, the community was largely relegated to the scraper and collector functional groups. The community contained several taxa, such as Glossosoma (caddisfly) and Paragyractis (butterfly), that are considered intolerant of organic enrichment and other impacts that affect water quality. In addition, a viable population of Alasmidonta viridis, a freshwater mussel reflects the past and present high water quality.

Gasper River

Station 18-11 and 18-12

Most of the habitats for invertebrates were associated with slab-rock riffle areas. Consequently, the community structures reflected considerable partitioning of habitats within the scraper and collector functional groups. In general, the communities contained several taxa, such as Neophylax and Glossosoma (caddisflies), which are considered intolerant to many environmental perturbations. Most other members are considered facultative to organic enrichment, with the exception of Cheumatopsyche (caddisfly), Stenacron (mayfly), and Simulium (blackfly), which are tolerant to many environmental disturbances. The benthic communities contain full complements of feeding types for the available habitats. Those factors indicated good water quality and the absence of any sustained environmental disturbances.

Wiggington Creek

Stations 18-3 and 18-4

The invertebrate collections (Appendix C) from this drainage contained most of the feeding types associated with lotic waters. Bedrock limestone and scattered, slab rocks provided the bulk of the available habitats. As a result, scraper and collector organisms were the most diverse at both sampling sites. The remainder of the communities included several predatory odonates (dragonflies and damselflies) and megalopterans (hellgramities and fishflies).

Station 18-4 contained a viable population of Villosa iris, a small, freshwater mussel common to undisturbed headwater habitats and considered intolerant to organic enrichment and other perturbations. In general, the invertebrate communities were considered facultative to organic enrichment. However, several tolerant organisms were collected, such as Cheumatopsyche (caddisfly), Stenacron (mayfly) and Simulium (blackfly). From the analysis of the invertebrate communities, and based on available data of the environmental requirements for most of the species collected, it was evident that sustained impacts to aquatic communities in this portion of the drainage were not detectable.

Black Lick Creek

Station 18-17

The habitats for invertebrates at this location were largely related to the bank sides. However, many Odonates (dragonflies and damselflies) and Coleopterans (beetles), which are routinely collected from bank-side habitats, were absent. The bottom substrate was mostly sand and gravel, which is not as conducive to invertebrate habitation as some other types, but should have a characteristic fauna. The absence of organisms that would normally be present and the presence of other tolerant forms indicate the community is altered in species composition by environmental stresses other than the loss of critical habitats.

Black Lick Creek

Station 18-19

Most of the habitats for invertebrates at this site were related to the bank sides and a bedrock bottom. Eleven species were collected (Appendix C). A small, slab-rock riffle afforded some habitat, but it was largely exposed (i.e., dry) at the time of sampling. The community structure lacked a diverse scraper functional group which is an intergal part of most benthic communities occurring in lotic waters. Two genera of freshwater mussels, Strophitus and Lampsilis, and a collector organism, Chimarra (caddisfly), reflect acceptable water quality conditions. From the species composition and functional feeding categories it appears the loss of habitats resulting from stream channelization has masked the influences of organic enrichment upon the community structure at this location.

Fishes

Sampling for fish was conducted at five sites in the Gasper River drainage and one site in the Mud River drainage (Appendix D). A total of 22 species were collected (Appendix E). At all but one site (18-19), the low flow and clear water made seining difficult because the fish could avoid the net. Therefore, the species diversity and numbers may not be representative of the fish communities, especially at the Mud River station (12-7). However, the limited collections indicate that the communities were well balanced and healthy. The site on Black Lick Creek (18-19), less than six miles below the Auburn and CLL WWTPs was the most diverse site. The fish could not avoid the net as readily, because of the turbidity of the water. The overall community structure and the number of young-of-the-year fish of seven species indicate the Auburn WWTP impacts were not severely affecting the fish community at that location during the time of sampling.

Mud River

Station 12-7

The water at this site was extremely clear and seining was unproductive. Only three species and five individuals were collected. This sample is undoubtedly not representative of the fish community and an assessment cannot be made on this basis.

Wiggington Creek

Station 18-3

Seven species and 23 individuals were collected by seine at this site. Creek chub (Semotilus atromaculatus), a typical headwater species, and rosefin shiners (Notropis ardens) were the dominant species. Considering the size of the stream at this location, the fish community is rated as good (after Karr 1981).

Wiggington Creek

Station 18-4

Eleven species and 74 individuals were collected here. The rosefin shiner was the most common species. The stream is somewhat larger, with deeper pools than at the previous location, and the better diversity of ichthyofauna reflects that increase in size. The fish community is rated good to excellent (after Karr 1981).

Gasper River

Station 18-11

Seining at this site produced 10 species and 82 individuals. The low flow and clarity of water made sampling difficult. A large rock bass (Ambloplites rupestris) and a large longear sunfish (Lepomis megalotis) were captured and released, indicating that the stream has a potential sport fishery. The fish community is rated as good (after Karr 1981).

Gasper River

Station 18-12

The sampling problems noted before (low flow, clear water) were also present here. Only nine species and 72 individuals were collected. However, rockbass, green sunfish and bluegill were present indicating the potential for a sport fishery. The fish community is rated as good (after Karr 1981).

Black Lick Creek

Station 18-19

This site produced more species than any of the other sampled locations. However, the water here was more turbid, which made seining more productive. Thirteen species and 56 individuals were collected. Young of the year of seven species were taken, indicating that spawning is occurring in this section of stream. Even though impacts from the Auburn WWTP were evident (physicochemical data), the fish community seems able to tolerate the perturbations and is rated as good to excellent (after Karr 1981).

APPENDIX A

Site Information

Site No:	03012001
Stream:	Wet weather spring
County:	Logan
Location:	450 m north of the junction of RT 722 and the CSX Transportation railroad
Latitude:	36° 51' 51"
Longitude:	86° 45' 27"
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012002
Stream:	Wet weather spring
County:	Logan
Location:	500 m north of the junction of RT 722 and the CSX Transportation railroad
Latitude:	36° 51' 55"
Longitude:	86° 45' 34"
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012003
Stream:	Wet weather spring
County:	Logan
Location:	475 m north of the junction of RT 722 and the CSC Transportation railroad
Latitude:	36° 51' 49"
Longitude:	86° 45' 45"
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012004
Stream:	Wet weather spring
County:	Logan
Location:	Bridge on KY 68, 1.7 mi west of Auburn
Latitude:	36° 51' 04"
Longitude:	86° 45' 46"
Stream Order:	First
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012005
Stream:	UT, intermittent
County:	Logan
Location:	1/2 mi southwest of the junction of RT 722 and Duncan Chapel Rd.
Latitude:	36° 51' 33"
Longitude:	86° 46' 27"
Stream Order:	Second
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012006
Stream:	Mud River
County:	Logan
Location:	Just north of the Muddy River Church off KY 68
Latitude:	36° 50' 14"
Longitude:	86° 48' 23"
Stream Order:	First
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
MP:	70.6 (source)
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03012007
Stream:	Mud River
County:	Logan
Location:	Bridge on Stevenson Mill Rd.
Latitude:	36° 51' 29"
Longitude:	86° 49' 35"
Stream Order:	First
USGS Topo Quad:	Dennis, KY
DOW Map No.:	3-26
MP:	68.15
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Low
Pool Width:	5 - 10 m
Pool Depth:	0.1 - 0.5 m
Pool Substrate:	Slabrock, gravel, cobble
Riffle Width:	5 - 10 m
Riffle Depth:	0.1 m
Riffle Substrate:	Slabrock, cobble
Bank Height:	ND
Bank Slope:	ND
<u>Riparian Vegetation - %</u>	
Trees:	50
Shrubs:	30
Herbs:	10

Site Information

Exposed:	10
Width:	ND
Canopy over Stream - %	75 - 100
Bank Stability:	Good
Erosion:	ND
Sedimentation:	Slight
Imbeddedness:	None
Periphyton Abundance:	Moderate
Stream Habitat:	Gravel bar, justicia bed, man-made objects, various substrates
Hydraulic Structures:	Gravel bars, bridge abutment
Physical Impacts:	None
Nonpoint Sources:	Agriculture, road

ND - Not Determined

Site Information

Site No:	03018001
Stream:	UT to Wiggington Creek
County:	Logan
Location:	1/2 mi northwest of the junction of Duncan Chapel Rd and RT 722
Latitude:	36° 52' 18"
Longitude:	86° 45' 52"
Stream Order:	First
USGS Topo Quad:	Homer, KY
DOW Map No.:	4-26
MP:	Source
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018002
Stream:	UT to Wiggington Creek
County:	Logan
Location:	1/4 mi north of the junction of Duncan Chapel Rd.
and	
	RT 1039
Latitude:	36° 53' 10"
Longitude:	86° 45' 27"
Stream Order:	First
USGS Topo Quad:	Homer, KY
DOW Map No.:	4-26
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018003
Stream:	Wiggington Creek
County:	Logan
Location:	At the end of Boston Rd.
Latitude:	36° 53' 31"
Longitude:	86° 47' 01"
Stream Order:	Second
USGS Topo Quad:	Homer, Ky
DOW Map No.:	4-26
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	2 - 4 m
Pool Depth:	Up to 3 m
Pool Substrate:	Primarily sand and silt
Riffle Width:	2 m
Riffle Depth:	0.1 m
Riffle Substrate:	Gravel, cobble, boulder
Bank Height:	1 - 2 m
Bank Slope:	ND
<u>Riparian Vegetation - %</u>	
Trees:	50
Shrubs:	20
Herbs:	10
Exposed:	40

Site Information

Width:	ND
Canopy over Stream - %	75 - 100
Bank Stability:	Fair
Erosion:	Moderate
Sedimentation:	Moderate
Imbeddedness:	Slight
Periphyton Abundance:	Moderate
Stream Habitat:	Undercut banks, tree roots, gravel bars, large boulders (slab)
Hydraulic Structures:	Bar
Physical Impacts:	Ford
Nonpoint Sources:	Agricultural (cattle and row crops)

ND - Not Determined

Site Information

Site No:	03018004
Stream:	Wiggington Creek
County:	Logan
Location:	1/4 mi north of the bridge on KY 103
Latitude:	36° 54' 37"
Longitude:	86° 45' 03"
Stream Order:	Third
USGS Topo Quad:	Homer, KY
DOW Map No.:	4-26
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	5 - 10 m
Pool Depth:	Up to 1 m
Pool Substrate:	Boulders, bedrock, silt
Riffle Width:	5 - 10 m
Riffle Depth:	0.1 m
Riffle Substrate:	Boulders, bedrock, cobble
Bank Height:	Up to 3 m
Bank Slope:	ND
<u>Riparian Vegetation - %</u>	
Trees:	50
Shrubs:	30
Herbs:	10
Exposed:	10

Site Information

Width:	ND
Canopy over Stream - %	50 - 75
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Moderate
Imbeddedness:	1/4 - 1/2
Periphyton Abundance:	Moderate
Stream Habitat:	Boulders, submerged roots, man-made objects
Hydraulic Structures:	Bridge abutment
Physical Impacts:	None
Nonpoint Sources:	Cattle and agriculture, road

ND - Not Determined

Site Information

Site No:	03018005
Stream:	UT to Wiggington Creek
County:	Logan
Location:	1/2 upstream of the mouth of Wiggington Creek
Latitude:	36° 54' 42"
Longitude:	86° 44' 48"
Stream Order:	First
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018006
Stream:	Gasper River
County:	Logan
Location:	South of KY 103, off Ayers Rd.
Latitude:	36° 53' 15"
Longitude:	86° 44' 03"
Stream Order:	First
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
MP:	38.0 (source)
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018007
Stream:	UT to Gasper River
County:	Logan
Location:	Just south of KY 103, 1/2 mi east of Ayers Rd.
Latitude:	36° 53' 28"
Longitude:	86° 43' 54"
Stream Order:	First
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018008
Stream:	UT to Gasper River
County:	Logan
Location:	Just west of Ayers Rd., 1/4 mi south of KY 103
Latitude:	36° 53' 34"
Longitude:	86° 44' 26"
Stream Order:	First
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018009
Stream:	UT to Gasper River
County:	Logan
Location:	At bridge on Ayers Rd., 1/8 mi south of KY 103
Latitude:	36° 53' 40"
Longitude:	86° 44' 15"
Stream Order:	First
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018010
Stream:	Gasper River
County:	Logan
Location:	1 mi downstream of the bridge on Ayers Rd.
Latitude:	36° 54' 02"
Longitude:	86° 44' 03"
Stream Order:	Second
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
MP:	36.9
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018011
Stream:	Gasper River
County:	Logan
Location:	At bridge on Bucksville Rd.
Latitude:	36° 56' 07"
Longitude:	86° 43' 27"
Stream Order:	Third
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
MP:	32.35
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Low
Pool Width:	10 - 15 m
Pool Depth:	Up to 1.5 m
Pool Substrate:	Gravel, pebble
Riffle Width:	10 - 15 m
Riffle Depth:	0.1 - 0.2 m
Riffle Substrate:	Cobble, gravel, pebble
Bank Height:	1 - 3 m
Bank Slope:	ND
<u>Riparian Vegetation - %</u>	
Trees:	50
Shrubs:	30
Herbs:	10

Site Information

Exposed:	10
Width:	ND
Canopy over Stream - %	50 - 75
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Slight - moderate
Imbeddedness:	Slight
Periphyton Abundance:	Moderate
Stream Habitat:	Undercut banks, submerged roots, various substrates
Hydraulic Structures:	Bridge abutment
Physical Impacts:	Cattle
Nonpoint Sources:	Agriculture and road

ND - Not Determined

Site Information

Site No:	03018012
Stream:	Gasper River
County:	Logan
Location:	At KY 73 bridge
Latitude:	36° 58' 11"
Longitude:	86° 42' 02"
Stream Order:	Third
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
MP:	27.09
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Low
Pool Width:	10 - 15 m
Pool Depth:	> 1 m
Pool Substrate:	Gravel, cobble, boulders
Riffle Width:	5 - 10 m
Riffle Depth:	0.2 - 0.3 m
Riffle Substrate:	Cobble, boulder
Bank Height:	Up to 20 m
Bank Slope:	ND
Riparian Vegetation - %	
Trees:	50
Shrubs:	10
Herbs:	20

Site Information

Exposed:	20
Width:	ND
Canopy over Stream - %	Varied 25 - 100
Bank Stability:	Good
Erosion:	Slight
Sedimentation:	Slight
Imbeddedness:	None
Periphyton Abundance:	Moderate
Stream Habitat:	Boulders, undercut banks, tree roots
Hydraulic Structures:	None
Physical Impacts:	None
Nonpoint Sources:	Agriculture and road

ND - Not Determined

Site Information

Site No:	03018013
Stream:	UT, intermittent
County:	Logan
Location:	0.9 mi west of Auburn and just north of CSX Transportation railroad
Latitude:	36^{o} 51' 55"
Longitude:	86^{o} 44' 11"
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018014
Stream:	UT, intermittent
County:	Logan
Location:	Just north of CSX Transportation railroad, 0.8 mi west of Auburn
Latitude:	36° 51' 59"
Longitude:	86° 43' 34"
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018015
Stream:	Black Lick Creek
County:	Logan
Location:	At the source
Latitude:	36° 51' 37"
Longitude:	86° 42' 21"
Stream Order:	First
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
MP:	12.5
Sampling Dates:	7-22-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018016
Stream:	Blue hole, UT to Black Lick Creek
County:	Logan
Location:	Waterworks plant at Auburn
Latitude:	36° 51' 41"
Longitude:	86° 42' 32"
Stream Order:	First
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
Sampling Dates:	7-22-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018017
Stream:	Black Lick Creek
County:	Logan
Location:	Below Caldwell outfall, above Auburn WWTP
Latitude:	36° 51' 56"
Longitude:	86° 42' 29"
Stream Order:	Second
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
MP:	12.2
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	5 m
Pool Depth:	0.5 m
Pool Substrate:	Sand, man-made objects
Riffle Width:	None
Riffle Depth:	None
Riffle Substrate:	None
Bank Height:	2 m
Bank Slope:	ND
<u>Riparian Vegetation - %</u>	
Trees:	5
Shrubs:	5
Herbs:	80

Site Information

Exposed:	10
Width:	ND
Canopy over Stream - %	None
Bank Stability:	Fair
Erosion:	Slight
Sedimentation:	Slight
Imbeddedness:	None
Periphyton Abundance:	ND
Stream Habitat:	Man-made objects
Hydraulic Structures:	None
Physical Impacts:	None
Nonpoint Sources:	Urban runoff

ND - Not Determined

Site Information

Site No:	03018018
Stream:	Black Lick Creek
County:	Logan
Location:	Just north of the CSX Transportation railroad, at Auburn
Latitude:	36° 52' 06"
Longitude:	86° 42' 29"
Stream Order:	Second
USGS Topo Quad:	Auburn, KY
DOW Map No.:	3-27
MP:	11.9
Sampling Dates:	7-21-83
Type Sampling:	Physicochemical

Site Information

Site No:	03018019
Stream:	Black Lick Creek
County:	Logan
Location:	At the KY 73 bridge
Latitude:	36° 54' 03"
Longitude:	86° 40' 17"
Stream Order:	Second
USGS Topo Quad:	South Union, KY
DOW Map No.:	4-27
MP:	6.45
Sampling Dates:	7-22-83
Type Sampling:	Biological, Physicochemical
Stream Gradient:	Moderate
Pool Width:	2 - 5 m
Pool Depth:	0.5 m
Pool Substrate:	Silt and sand
Riffle Width:	2 m
Riffle Depth:	0.1 m
Riffle Substrate:	Cobble and pebble
Bank Height:	2 - 3 m
Bank Slope:	ND
Riparian Vegetation - %	
Trees:	0
Shrubs:	20
Herbs:	75

Site Information

Exposed:	5
Width:	ND
Canopy over Stream - %	None
Bank Stability:	Fair
Erosion:	Slight
Sedimentation:	Moderate
Imbeddedness:	1/4 - 1/2
Periphyton Abundance:	Moderate
Stream Habitat:	Justicia beds, gravel bars
Hydraulic Structures:	Bridge abutment
Physical Impacts:	Channelized
Nonpoint Sources:	Agriculture and road

ND - Not Determined

APPENDIX B

Algal Synoptic List for the Headwaters of the Mud and Gasper Rivers

Taxa	12-7	18-3	18-4	18-11	18-12	18-19
			Station			
Chlorophycophyta (Green Algae)						
Ankistrodesmus falcatus	X	X	-	X	-	X
Aphanocapsa repens	-	-	-	-	-	X
Carteria klebsii	-	-	-	-	-	X
Chlamydomonas sp.	-	-	X	-	X	X
Chl. globosa	-	-	-	-	-	X
Cladophora glomerata	-	-	-	-	X	X
Closterium sp.	X	X	-	-	-	-
Cl. acerosum	-	X	-	X	X	X
Cl. ehrenbergii	-	-	X	-	X	-
Cl. moniliferum	-	X	X	X	X	-
Coelastrum microporum	-	-	-	-	-	X
Coel. sphaericum	-	-	-	-	-	X
Cosmarium spp.	-	X	X	-	-	X
Cos. botrytis	-	-	-	-	-	X
Cos. pseudopyramidatum	-	-	-	-	-	X
Crucigenia apiculata	-	X	-	X	-	-
Cylindrocapsa geminella	X	X	X	X	-	X
Eudorina elegans	-	-	-	-	-	X
Mougeotia sp.	X	-	X	-	-	-
Oedogonium sp.	X	-	X	X	X	X
Oocystis sp.	-	-	-	-	-	X
Pandorina morum	-	-	-	-	-	X
Scenedesmus sp.	-	-	X	-	-	-
Sc. acutiformis	-	-	X	-	-	-
Sc. dimorphus	-	-	-	-	-	X
Sc. obliquus	-	-	X	-	-	X
Sphaerellopsis fluviatilis	-	-	-	-	-	X
Staurastrum chaetocerus	-	-	-	-	X	X
Ulothrix tenerrima	-	-	X	-	-	-
Uronema elongatum	-	-	-	-	-	X
green algal flagellates	-	-	-	X	-	X
Charophyta (stoneworts)						
Chara sp.	-	-	-	-	-	X
Chrysophycophyta						
Chrysophyseae (Golden Algae)						
Lagynion sp.	-	-	-	X	X	-
Tribonema utriculosum	X	-	-	-	-	-
Bacillariophyseae (Diatoms)						
Achnanthes sp.	X	X	X	-	X	-
Ach. affinis	X	X	X	X	X	X
Ach. clevei	-	-	-	-	X	-
Ach. deflexa	X	X	X	X	-	X
Ach. hauckiana	-	-	-	X	-	-
Ach. lanceolata	X	-	-	-	-	-
Ach. lanceolata var. dubia	X	X	X	X	X	X

Algal Synoptic List for the Headwater of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-19
Ach. linearis	X	X	X	-	X	X
Ach. minutissima	X	X	X	X	X	X
Amphipleura pellucida	-	-	X	-	-	-
Amphora ovalis var. affinis	X	X	X	X	X	X
Amp. perpusilla	X	X	X	X	X	-
Amp. submontana	X	X	X	X	X	-
Caloneis sp.	-	-	-	-	X	X
Cal. bacillum	X	X	X	X	X	X
Cal. hyalina	-	-	X	-	-	X
Cal. lewisii	-	X	-	-	-	-
Cal. ventricosa var. truncatula	X	-	X	X	X	X
Cocconeis pediculus	X	X	X	X	X	X
Coc. placentula var. euglypta	X	X	X	X	X	X
Coc. placentula var. lineata	X	X	-	X	X	X
Cyclotella atomus	X	-	-	-	-	-
Cyc. meneghiniana	X	X	X	X	X	X
Cymatopleura elliptica	-	X	-	X	X	-
Cy. solea	X	X	X	X	X	X
Cymbella spp.	X	X	-	-	X	-
Cym. affinis	-	-	X	-	-	X
Cym. amphicephala	-	-	X	-	X	-
Cym. aspera	-	X	-	-	-	-
Cym. delicatula	-	-	-	-	-	X
Cym. microcephala	-	-	-	-	X	-
Cym. minuta	X	X	X	X	X	X
Cym. minuta var. A	-	X	X	-	-	-
Cym. naviculiformis	-	X	X	-	-	-
Cym. prostrata	X	X	X	X	X	X
Cym. prostrata var. auerswaldii	-	X	X	X	X	X
Cym. sinuata	X	X	-	X	X	X
Cym. triangulum	-	-	-	-	X	-
Cym. tumida	-	-	X	-	-	-
Cym. turgidula	-	-	X	-	-	X
Cym. sp. K	-	X	X	X	X	-
Diploneis sp.	-	-	-	-	-	X
Dip. oblongella	-	X	X	-	-	X
Dip. pseudovalis	-	X	X	X	X	X
Entomoneis ornata	-	-	X	-	-	-
Eunotia sp.	-	X	-	-	X	-
E. pectinalis	-	X	X	-	-	-
Fragillaria vaucheriae	-	X	-	-	-	-
Frustulia rhomboides var. amphipleuroides	-	X	X	-	-	-
Fr. vulgaris	X	X	X	X	X	-

Algal Synoptic List for the Headwater of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-19
Gomphonema spp.	X	X	X	X	X	-
G. acuminatum	-	-	X	-	-	-
G. affine	-	-	X	-	-	-
G. angustatum	X	X	X	X	X	X
G. brasiliense	X	X	-	X	X	X
G. clevei	X	X	X	X	-	-
G. gracile	-	-	X	-	-	-
G. cf intricatum	X	-	X	-	-	-
G. parvulum	X	X	X	X	X	X
G. puiggarianum var. aequatorialis	X	X	X	X	X	X
G. sphaerophorum	-	X	X	X	-	X
G. subclavatum var. mexicanum	X	-	X	-	-	X
G. tenellum	X	-	X	X	X	X
G. truncatum	-	-	X	-	-	-
Gyrosigma scalproides	X	X	X	X	X	X
Gyr. spencerii	X	X	X	X	X	X
Hantzschia amphioxys	X	X	X	X	X	X
Melosira varians	X	X	X	X	X	X
Meridion circulare	-	X	-	X	-	-
Navicula spp.	X	X	X	X	X	X
Nav. accomoda	-	-	-	-	X	-
Nav. anglica var. subsalsa	X	-	X	-	-	X
Nav. angusta	-	-	X	X	-	-
Nav. capitata	X	X	X	X	X	X
Nav. capitata var. luneburgensis	X	X	X	X	X	-
Nav. cincta	-	-	X	-	X	-
Nav. contenta var. biceps	-	-	-	-	X	-
Nav. confervacea	-	X	-	-	-	-
Nav. cryptocephala	X	X	X	X	X	X
Nav. cryptocephala var. veneta	-	-	X	X	-	-
Nav. cuspidata	-	-	X	-	X	X
Nav. decussis	X	-	-	-	-	-
Nav. exigua var. capitata	-	X	X	X	X	X
Nav. gastrum	X	X	X	X	-	-
Nav. gottlandica	X	X	X	X	X	X
Nav. graciloides	X	X	X	X	-	-
Nav. gregaria	-	-	-	X	X	X
Nav. grimmei	-	-	X	X	X	-
Nav. gysingensis	-	-	X	-	-	-
Nav. heufleri var. leptocephala	X	X	X	X	X	-
Nav. hustedtii	-	X	X	X	X	-
Nav. lanceolata	X	X	X	X	X	X
Nav. menisculus var. upsaliensis	X	X	X	X	X	X
Nav. mutica	X	X	X	X	X	X
Nav. mutica var. binodis	X	-	-	-	-	-
Nav. mutica var. capitata	-	-	-	-	-	X

Algal Synoptic List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-19
Nav. mutica var. cohnii	X	-	-	-	-	-
Nav. mutica f. gibbosa	X	-	-	-	-	-
Nav. notha	-	X	X	X	-	-
Nav. placentula f. rostrata	-	-	-	X	X	X
Nav. protracta var. elliptica	X	-	X	X	-	-
Nav. pupula	X	X	X	X	-	X
Nav. pupula var. elliptica	-	X	X	X	X	-
Nav. pupula var. mutata	-	-	X	-	-	-
Nav. pygmaea	-	-	X	-	-	-
Nav. radiosa	X	X	X	X	-	-
Nav. radiosa var. parva	X	-	-	X	X	-
Nav. radiosa var. tenella	X	X	X	X	X	X
Nav. rhynchocephala	-	X	X	X	X	X
Nav. rhynchocephala var. germainii	-	X	X	X	X	X
Nav. salinarum var. intermedia	X	X	X	X	X	X
Nav. schroeteri var. escambia	-	X	X	-	X	-
Nav. secreta var. apiculata	-	X	-	X	X	-
Nav. subhamulata	-	X	X	-	-	-
Nav. symmetrica	-	X	X	X	X	-
Nav. tantula	-	-	X	-	-	-
Nav. tripunctata	X	X	X	X	X	X
Nav. viridula	-	-	-	-	X	-
Nav. viridula var. linearis	-	X	X	X	X	X
Nav. viridula var. rostrata	-	-	-	X	-	-
Neidium sp.	-	-	-	-	-	X
Neid. affine var. amphirhynchus	X	X	X	X	-	-
Neid. affine var. longiceps	-	-	X	X	-	-
Neid. binode	-	X	X	X	X	-
Neid. dubium	X	X	X	X	X	X
Neid. iridis var. ampliatum	-	-	X	-	-	-
Nitzschia spp.	X	X	X	X	X	X
Nit. acicularis	-	X	-	-	-	-
Nit. acula	X	X	X	X	X	X
Nit. amphibia	X	X	X	-	-	X
Nit. apiculata	-	X	X	X	X	X
Nit. clausii	-	X	-	X	-	-
Nit. denticula	-	-	X	-	X	-
Nit. dissipata	X	X	X	X	X	-
Nit. fonticola	-	-	-	-	-	X
Nit. frustulum var. perminuta	-	X	X	X	X	-
Nit. gandersheimiensis	-	-	-	-	X	X
Nit. gracilis	-	-	X	X	X	X
Nit. hungarica	-	-	-	X	X	X
Nit. intermedia	X	X	X	X	X	X
Nit. linearis	X	X	X	X	X	X
Nit. palea	X	X	X	X	X	X

Algal Synoptic List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-19
Nit. rautenbachiae	-	-	-	X	-	-
Nit. recta	X	X	X	X	X	X
Nit. romana	-	-	X	X	-	X
Nit. sigma	-	-	-	X	X	-
Nit. sigmoidea	-	X	X	X	X	-
Nit. sinuata var. tabellaria	-	-	-	-	X	-
Nit. sublinearis	X	-	X	X	-	-
Nit. tryblionella var. levidensis	-	X	X	X	X	X
Nit. tryblionella var. victoriae	-	X	X	X	X	-
Pinnularia sp.	X	X	X	X	-	-
Pin. biceps	-	-	X	-	-	-
Pin. mesogonglya	-	X	X	-	X	-
Pin. mesolepta	-	X	X	X	-	-
Pin. obscura	-	X	-	X	-	-
Pin. subcapitata var. paucistriata	-	-	-	-	-	X
Rhoicosphenia curvata	X	X	X	X	X	X
Stauroneis kriegeri	X	-	-	X	X	-
Sta. phoenicenteron	X	-	X	-	-	-
Sta. smithii	X	X	X	X	X	X
Sta. smithii var. incisa	-	-	X	-	-	-
Surirella angusta	X	X	X	X	X	X
Sur. biseriata	-	-	-	X	-	-
Sur. linearis var. helvetica	-	X	X	X	X	-
Sur. ovata	X	X	X	X	X	X
Sur. ovata var. salina	-	X	X	X	X	X
Sur. stalagma	-	X	-	X	X	X
Sur. tenera var. nervosa	-	X	-	X	X	X
Synedra radians	X	-	X	-	-	X
Syn. rumpens var. fragillarioides	-	X	-	-	-	-
Syn. ulna	X	X	X	X	X	X
Euglenophycophyta (Euglenoid Algae)						
Ascoglena vaginicola	-	-	-	-	-	X
Characium ambiguum	-	-	X	-	-	-
C. falcatum	-	-	-	-	-	X
Euglena spp.	-	-	-	X	-	X
E. minuta	-	-	-	-	-	X
E. viridis	-	-	-	-	-	X
Lepocinclis sp.	-	-	-	-	-	X
Phacotus lenticularis	-	-	-	-	-	X
Phacus sp.	-	-	-	-	-	X
P. curvicauda	-	X	-	-	-	X
Trachelomonas sp.	-	-	-	-	-	X
T. hispida	-	-	-	-	X	X
T. volvocina	X	-	-	-	X	X
Rhodophycophyta (Red Algae)						
Audouinella violacea	X	X	-	X	X	-

Algal Synoptic List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-19
<u>Lemanea</u> <u>australis</u>	X	X	X	X	-	X
Cyanochloronta (Blue-green Algae)						
<u>Agmenellum</u> <u>quadruplicatum</u>	-	-	X	X	X	X
<u>Anabaina</u> <u>oscillarioides</u>	-	X	X	X	X	X
<u>Calothrix</u> <u>parientina</u>	-	-	-	-	-	X
<u>Coccochloris</u> <u>aeruginosa</u>	-	-	-	-	-	X
<u>Dactylococcopsis</u> <u>rhaphidioides</u>	-	-	-	-	-	X
<u>Gomphosphaeria</u> <u>lacustris</u>	-	-	-	X	-	-
<u>Microcoleus</u> <u>lyngbyaceous</u>	-	-	X	-	-	X
<u>M.</u> <u>vaginatus</u>	-	-	X	-	-	-
<u>Oscillatoria</u> <u>lutea</u>	X	X	X	-	-	X
<u>Schizothrix</u> <u>calcicola</u>	-	X	X	X	X	X
<u>S.</u> <u>friesii</u>	X	X	X	X	-	-
Total Taxa	90	119	143	122	115	127

Total Taxa Observed in Study: 232

Diatom Species Proportional Count for Station 12-7, Mud River

Taxa	Relative Abundance
Cocconeis placentula var. euglypta	50.8%
Cocconeis pediculus	10.2%
Amphora perpusilla	5.7%
Cocconeis placentula var. lineata	4.2%
Achnanthes lanceolata var. dubia	3.1%
Navicula radiosa var. tenella	2.3%
Navicula tripunctata	1.9%
Cymbella sinuata	1.5%
Gomphonema tenellum	1.3%
Navicula capitata var. luneburgensis	1.3%
Nitzschia linearis	1.3%
Navicula menisculus var. upsaliensis	1.1%
Amphora submontana	1.0%
Gomphonema brasiliensis	1.0%
Gomphonema clevei	1.0%
Amphora ovalis var. affinis	0.8%
Navicula lanceolata	0.8%
Rhoicosphenia curvata	0.8%
Synedra ulna	0.8%
Achnanthes affinis	0.6%
Gomphonema parvulum	0.6%
Hantzschia amphioxys	0.6%
Navicula gastrum	0.6%
Navicula pupula var. elliptica	0.6%
Nitzschia intermedia	0.6%
Nitzschia sublinearis	0.6%
Synedra radians	0.6%
Gomphonema angustatum	0.4%
Gyrosigma scalproides	0.4%
Navicula mutica	0.4%
Achnanthes linearis	0.2%
Cymatopleura solea	0.2%
Frustulia vulgaris	0.2%
Gomphonema sp.	0.2%
Gomphonema puiggarianum var. aequatorialis	0.2%
Gomphonema subclavatum var. mexicanum	0.2%
Navicula capitata	0.2%
Navicula protracta var. elliptica	0.2%
Navicula radiosa var. parva	0.2%
Nitzschia sp.	0.2%
Nitzschia acula	0.2%
Nitzschia amphibia	0.2%
Nitzschia palea	0.2%
Pinnularia sp.	0.2%
Stauroneis kriegeri	0.2%

Diatom Species Proportional Count
for Station 12-7, Mud River

Taxa	Relative Abundance
Stauroneis phoenicenteron	0.2%
Surirella angusta	0.2%
Surirella ovata	0.2%
Diversity ($\bar{d}$)	3.2507
Equitability (e)	0.2823

Diatom Species Proportional Count
for Station 18-3, Wiggington Creek

Taxa	Relative Abundance
Cocconeis placentula var. euglypta	16.4%
Diploneis oblongella	4.7%
Navicula tripunctata	4.7%
Rhoicosphenia curvata	4.1%
Achnanthes lanceolata var. dubia	3.7%
Nitzschia acula	3.4%
Navicula rhynchocephala var. germainii	3.1%
Nitzschia linearis	3.1%
Navicula lanceolata	2.9%
Surirella tenera var. nervosa	2.9%
Gyrosigma scalproides	2.8%
Navicula salinarum var. intermedia	2.3%
Melosira varians	2.1%
Surirella ovata var. salina	2.1%
Navicula cryptocephala	1.9%
Cymatopleura solea	1.8%
Cymbella prostrata	1.8%
Navicula radiosa var. tenella	1.6%
Nitzschia dissipata	1.6%
Navicula menisculus var. upsaliensis	1.5%
Cyclotella meneghiniana	1.3%
Navicula symmetrica	1.3%
Surirella ovata	1.3%
Gomphonema brasiliense	1.1%
Navicula exigua var. capitata	1.1%
Nitzschia recta	1.1%
Amphora submontana	1.0%
Gyrosigma spencerii	1.0%
Navicula capitata	1.0%
Cocconeis pediculus	0.8%
Cymbella minuta	0.8%
Cymbella sp. K	0.8%
Frustulia vulgaris	0.8%
Navicula capitata var. luneburgensis	0.8%
Surirella angusta	0.8%
Diploneis pseudovalis	0.6%
Frustulia rhomboides var. amphipleuroides	0.6%
Navicula pupula	0.6%
Neidium dubium	0.6%
Nitzschia apiculata	0.6%
Cocconeis placentula var. lineata	0.5%
Gomphonema clevei	0.5%
Navicula hustedtii	0.5%
Navicula notha	0.5%
Navicula schroeteri var. escambia	0.5%
Nitzschia palea	0.5%
Synedra ulna	0.5%

Diatom Species Proportional Count
for Station 18-3, Wiggington Creek

Taxa	Relative Abundance
Achnanthes deflexa	0.3%
Achnanthes minutissima	0.3%
Amphora perpusilla	0.3%
Cymbella naviculiformis	0.3%
Fragillaria vaucheriae	0.3%
Gomphonema sp.	0.3%
Gomphonema puiggarianum var. aequatorialis	0.3%
Hantzschia amphioxys	0.3%
Navicula cryptocephala var. veneta	0.3%
Navicula gottlandica	0.3%
Navicula graciloides	0.3%
Navicula pupula var. elliptica	0.3%
Navicula radiosa	0.3%
Neidium binode	0.3%
Nitzschia intermedia	0.3%
Nitzschia sigmoidea	0.3%
Pinnularia sp.	0.3%
Pinnularia obscura	0.3%
Surirella linearis var. helvetica	0.3%
Achnanthes sp.	0.2%
Achnanthes affinis	0.2%
Achnanthes linearis	0.2%
Amphora ovalis var. affinis	0.2%
Caloneis bacillum	0.2%
Cymatopleura elliptica	0.2%
Cymbella sinuata	0.2%
Eunotia sp.	0.2%
Eunotia pectinalis	0.2%
Gomphonema sphaerophorum	0.2%
Navicula sp.	0.2%
Navicula mutica	0.2%
Navicula rhynchocephala	0.2%
Navicula subhamulata	0.2%
Nitzschia sp.	0.2%
Nitzschia amphibia	0.2%
Nitzschia clausii	0.2%
Nitzschia frustulum var. perminuta	0.2%
Nitzschia tryblionella var. levidensis	0.2%
Stauroneis smithii	0.2%
Diversity ($\bar{d}$)	5.4719
Equitability (e)	0.7742

Diatom Species Proportional Count
for Station 18-4, Wiggington Creek

Taxa	Relative Abundance
Melosira varians	11.1%
Achnanthes deflexa	9.9%
Cocconeis pediculus	7.6%
Gomphonema sphaerophorum	5.2%
Cymbella affinis	4.9%
Navicula salinarum var. intermedia	4.6%
Navicula lanceolata	4.0%
Navicula rhynchocephala var. germainii	4.0%
Navicula cryptocephala	3.8%
Gomphonema tenellum	2.4%
Navicula menisculus var. upsaliensis	2.4%
Nitzschia intermedia	2.3%
Cymbella turgidula	2.1%
Cymbella minuta	2.0%
Achnanthes linearis	1.8%
Achnanthes minutissima	1.5%
Gyrosigma scalproides	1.4%
Navicula capitata var. luneburgensis	1.4%
Navicula grimmei	1.4%
Navicula pupula	1.4%
Cocconeis placentula var. euglypta	1.1%
Gomphonema truncatum	1.1%
Cymatopleura solea	0.9%
Navicula cryptocephala var. veneta	0.9%
Navicula gottlandica	0.9%
Nitzschia apiculata	0.9%
Amphipleura pellucida	0.8%
Gomphonema parvulum	0.8%
Gomphonema subclavatum var. mexicanum	0.8%
Navicula hustedtii	0.8%
Navicula radiosa var. tenella	0.8%
Navicula tripunctata	0.8%
Nitzschia linearis	0.8%
Caloneis bacillum	0.6%
Navicula capitata	0.6%
Nitzschia acula	0.6%
Nitzschia romana	0.6%
Synedra ulna	0.6%
Achnanthes lanceolata var. dubia	0.5%
Caloneis ventricosa var. truncatula	0.5%
Cymbella prostrata	0.5%
Cymbella prostrata var. auerswaldii	0.5%
Gomphonema acuminatum	0.5%
Gomphonema puiggarianum var. aequatorialis	0.5%
Navicula anglica var. subsalsa	0.5%
Navicula symmetrica	0.5%
Nitzschia gracilis	0.5%

Diatom Species Proportional Count
for Station 18-4, Wiggington Creek

Taxa	Relative Abundance
Nitzschia recta	0.5%
Achnanthes sp.	0.3%
Amphora submontana	0.3%
Gyrosigma spencerii	0.3%
Navicula sp.	0.3%
Navicula exigua var. capitata	0.3%
Navicula gastrum	0.3%
Navicula notha	0.3%
Navicula pupula var. elliptica	0.3%
Navicula rhynchocephala	0.3%
Nitzschia sp.	0.3%
Nitzschia amphibia	0.3%
Nitzschia dissipata	0.3%
Nitzschia sublinearis	0.3%
Surirella ovata	0.3%
Surirella ovata var. salina	0.3%
Achnanthes affinis	0.2%
Cyclotella meneghiniana	0.2%
Cymbella tumida	0.2%
Gomphonema sp.	0.2%
Navicula angusta	0.2%
Navicula cuspidata	0.2%
Navicula graciloides	0.2%
Neidium binode	0.2%
Nitzschia denticula	0.2%
Nitzschia palea	0.2%
Surirella linearis var. helvetica	0.2%
Diversity ($\bar{d}$)	5.2376
Equitability (e)	0.7628

Diatom Species Proportional Count for Station 18-11, Gasper River

Taxa	Relative Abundance
Cocconeis placentula var. euglypta	34.9%
Navicula tripunctata	8.3%
Cymatopleura solea	5.2%
Cocconeis pediculus	3.5%
Navicula radiosa var. tenella	3.4%
Nitzschia acula	3.4%
Rhoicosphenia curvata	3.4%
Gyrosigma scalproides	2.2%
Achnanthes lanceolata var. dubia	2.0%
Nitzschia apiculata	2.0%
Nitzschia linearis	2.0%
Cyclotella meneghiniana	1.8%
Melosira varians	1.7%
Navicula salinarum var. intermedia	1.7%
Navicula secreta var. apiculata	1.5%
Nitzschia recta	1.5%
Navicula capitata var. luneburgensis	1.3%
Amphora perpusilla	1.2%
Surirella linearis var. helvetica	1.2%
Navicula gottlandica	1.0%
Navicula lanceolata	1.0%
Surirella ovata	1.0%
Navicula menisculus var. upsaliensis	0.8%
Gomphonema puiggarianum var. aequatorialis	0.7%
Navicula grimmei	0.7%
Navicula rhynchocephala var. germainii	0.7%
Achnanthes affinis	0.5%
Gomphonema clevei	0.5%
Gomphonema tenellum	0.5%
Gyrosigma spencerii	0.5%
Navicula hustedtii	0.5%
Nitzschia sigmoidea	0.5%
Stauroneis smithii	0.5%
Surirella tenera var. nervosa	0.5%
Gomphonema sp.	0.3%
Gomphonema angustatum	0.3%
Hantzschia amphioxys	0.3%
Navicula mutica	0.3%
Navicula protracta var. elliptica	0.3%
Navicula radiosa var. parva	0.3%
Navicula rhynchocephala	0.3%
Navicula symmetrica	0.3%
Nitzschia dissipata	0.3%
Nitzschia gracilis	0.3%
Nitzschia sublinearis	0.3%
Surirella ovata var. salina	0.3%
Achnanthes deflexa	0.2%

Diatom Species Proportional Count
for Station 18-11, Gasper River

Taxa	Relative Abundance
Cymatopleura elliptica	0.2%
Cymbella prostrata var. auerswaldii	0.2%
Cymbella sinuata	0.2%
Cymbella sp. K	0.2%
Frustulia vulgaris	0.2%
Navicula sp.	0.2%
Navicula angusta	0.2%
Navicula capitata	0.2%
Navicula cryptocephala	0.2%
Navicula cryptocephala var. veneta	0.2%
Navicula notha	0.2%
Navicula radiosa	0.2%
Navicula viridula var. linearis	0.2%
Navicula viridula var. rostrata	0.2%
Nitzschia sp.	0.2%
Nitzschia frustulum var. perminuta	0.2%
Nitzschia romana	0.2%
Nitzschia sigma	0.2%
Nitzschia tryblionella var. victoriae	0.2%
Pinnularia obscura	0.2%
Synedra ulna	0.2%
Diversity ($\bar{d}$)	4.3459
Equitability (e)	0.4406

Diatom Species Proportional Count
for Station 18-12, Gasper River

Taxa	Relative Abundance
Melosira varians	29.3%
Cocconeis pediculus	29.1%
Cocconeis placentula var. euglypta	7.7%
Cymatopleura solea	6.4%
Rhoicosphenia curvata	4.5%
Gyrosigma scalproides	3.2%
Navicula tripunctata	1.7%
Navicula salinarum var. intermedia	1.5%
Nitzschia linearis	1.5%
Navicula menisculus var. upsaliensis	1.1%
Surirella linearis var. helvetica	1.1%
Navicula radiosa var. tenella	0.9%
Navicula symmetrica	0.9%
Surirella ovata	0.9%
Navicula rhynchocephala var. germainii	0.8%
Nitzschia dissipata	0.8%
Surirella angusta	0.8%
Navicula secreta var. apiculata	0.6%
Nitzschia acula	0.6%
Nitzschia recta	0.6%
Surirella ovata var. salina	0.6%
Gomphonema tenellum	0.4%
Gyrosigma spencerii	0.4%
Nitzschia hungarica	0.4%
Nitzschia sigmoidea	0.4%
Stauroneis smithii	0.4%
Achnanthes affinis	0.2%
Amphora perpusilla	0.2%
Cocconeis placentula var. lineata	0.2%
Cymbella minuta	0.2%
Cymbella prostrata	0.2%
Cymbella sinuata	0.2%
Frustulia vulgaris	0.2%
Gomphonema angustatum	0.2%
Gomphonema brasiliense	0.2%
Gomphonema parvulum	0.2%
Navicula capitata	0.2%
Navicula cryptocephala	0.2%
Navicula hustedtii	0.2%
Navicula lanceolata	0.2%
Navicula rhynchocephala	0.2%
Navicula viridula var. linearis	0.2%
Nitzschia apiculata	0.2%
Nitzschia gracilis	0.2%
Diversity ($\bar{d}$)	3.3894
Equitability (e)	0.3408

Diatom Species Proportional Count
for Station 18-19, Black Lick Creek

Taxa	Relative Abundance
Cocconeis placentula var. euglypta	29.0%
Gomphonema tenellum	13.3%
Gomphonema subclavatum var. mexicanum	8.4%
Cocconeis pediculus	8.0%
Nitzschia amphibia	5.2%
Diploneis pseudovalis	4.6%
Achnanthes minutissima	3.0%
Cymbella minuta	3.0%
Nitzschia intermedia	3.0%
Achnanthes deflexa	2.8%
Caloneis hyalina	1.3%
Cocconeis placentula var. lineata	1.1%
Gomphonema sphaerophorum	1.1%
Caloneis bacillum	0.9%
Caloneis ventricosa var. truncatula	0.9%
Cyclotella meneghiniana	0.9%
Gomphonema parvulum	0.9%
Navicula lanceolata	0.9%
Navicula rhynchocephala	0.9%
Synedra ulna	0.9%
Achnanthes lanceolata var. dubia	0.6%
Navicula cryptocephala	0.6%
Navicula gottlandica	0.6%
Navicula menisculus var. upsaliensis	0.6%
Nitzschia acula	0.6%
Nitzschia gracilis	0.6%
Nitzschia linearis	0.6%
Nitzschia romana	0.6%
Amphora ovalis var. affinis	0.4%
Cymbella turgidula	0.4%
Navicula rhynchocephala	0.4%
Nitzschia spp.	0.4%
Surirella angusta	0.4%
Surirella tenera var. nervosa	0.4%
Cymbella sinuata	0.2%
Diploneis oblongella	0.2%
Gomphonema angustatum	0.2%
Melosira varians	0.2%
Navicula capitata	0.2%
Navicula cuspidata	0.2%
Navicula pupula	0.2%
Navicula radiosa var. tenella	0.2%
Nitzschia apiculata	0.2%
Nitzschia gandersheimiensis	0.2%
Nitzschia hungarica	0.2%
Nitzschia recta	0.2%
Rhoicosphenia curvata	0.2%

Diatom Species Proportional Count
for Station 18-19, Black Lick Creek

Taxa	Relative Abundance
Stauroneis smithii	0.2%
Surirella ovata	0.2%
Surirella ovata var. *salina*	0.2%
Synedra radians	0.2%
Diversity ($\bar{d}$)	4.0756
Equitability (e)	0.4839

APPENDIX C

Macroinvertebrate Synoptic Species List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-17	18-19
Haplotaxidae							
Naididae							
Dero sp.	-	-	-	-	-	X	-
Basommatophora							
Pleuroceridae							
Elimia spp.	-	X	X	-	X	-	X
Pleurocera spp.	X	-	-	X	-	X	X
Heterodonta							
Corbiculidae							
Corbicula fluminea	-	-	-	X	-	-	-
Sphaeriidae							
Sphaerium simile	X	-	-	X	X	-	X
Schizodonta							
Unionidae							
Alasmidonta viridis	X	-	-	-	-	-	-
Lampsilis radiata luteola	-	-	-	-	-	-	X
Strophitus undulatus undulatus	-	-	-	-	-	-	X
Villosa iris	-	-	X	-	-	-	-
Isopoda							
Asellidae							
Lirceus fontinalis	-	-	-	-	-	X	-
Amphipoda							
Gammaridae							
Gammarus sp.	-	-	-	-	-	X	-
Decapoda							
Cambaridae							
Cambarus graysoni	-	X	-	-	-	-	-
C. tenebrosus	X	-	-	-	X	-	-
Orconectes barrenensis	-	-	-	-	X	-	-
O. putnami	X	X	X	X	X	-	X
Ephemeroptera							
Baetidae							
Baetis sp.	-	-	-	X	X	X	-
Heptageniidae							
Heptagenia sp.	-	-	-	X	X	-	-
Stenacron interpunctatum	X	X	X	X	-	-	-
Stenonema femoratum	-	-	X	-	X	-	-
S. modestum	X	-	-	X	-	-	-
S. pulchellum	-	X	-	-	-	-	-
Leptophlebiidae							
Leptophlebia sp.	-	-	-	-	-	X	-
Oligoneuriidae							
Isonychia sp.	-	X	-	-	-	-	X

Macroinvertebrate Synoptic Species List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-17	18-19
Odonata							
Calopterygidae							
Calopteryx sp.	-	X	-	-	-	-	-
Aeschnidae							
Boyeria vinosa	X	X	X	X	X	-	-
Macromiidae							
Macromia sp.	-	X	-	-	-	-	-
Hemiptera							
Belostomatidae							
Belostoma sp.	-	-	-	-	-	-	X
Gerridae							
Trepobates sp.	-	-	X	-	-	-	-
Coleoptera							
Elmidae							
Optioservus ovalis	-	X	X	X	X	-	X
Stenelmis crenata	-	-	-	X	-	-	-
Stenelmis sp.	-	-	-	X	-	-	-
Dryopidae							
Helichus sp.	-	X	-	-	-	-	-
Dytiscidae							
Laccophilus sp.	-	-	-	-	-	X	-
Haliplidae							
Peltodytes sp.	-	X	-	-	-	-	-
Psephenidae							
Psephenus herricki	X	X	X	-	-	-	-
Megaloptera							
Corydalidae							
Corydalus cornutus	-	-	X	-	X	-	-
Sialidae							
Sialis sp.	-	-	X	-	-	-	-
Diptera							
Empididae							
Hemerodromia sp.	X	-	-	X	-	-	-
Simuliidae							
Simulium sp.	X	X	-	X	-	-	-
Tipulidae							
Tipula sp.	-	X	-	-	X	-	-
Trichoptera							
Glossosomatidae							
Glossosoma sp.	X	X	-	X	-	-	-
Hydropsychidae							
Cheumatopsyche sp.	X	X	-	X	X	X	-
Hydropsyche frisoni	-	-	-	-	X	-	-
Symphitopsyche sp.	X	X	-	X	X	X	X

Macroinvertebrate Synoptic Species List for the Headwaters of the Mud and Gasper Rivers

Taxa	Station 12-7	18-3	18-4	18-11	18-12	18-17	18-19
Limnephilidae							
Neophylax sp.	-	-	-	X	-	-	-
Pycnopsyche sp.	-	-	X	-	-	-	-
Philopotomidae							
Chimarra sp.	-	-	-	-	-	-	X
Lepidoptera							
Pyralidae							
Parargyractis sp.	X	-	-	-	-	-	-
Total Number of Taxa by site	15	18	12	18	15	9	11

Total Number of Taxa Observed = 48

Macroinvertebrate Qualitative Data for the Mud River at Station 12-7

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Pleurocera sp. 1	4
P. sp. 2	3
Heterodonta	
Sphaeriidae	
Sphaerium simile	2
Schizodonta	
Unionidae	
Alasmidonta viridis	7
Decapoda	
Cambaridae	
Cambarus tenebrosus	3
Orconectes putnami	3
Ephemeroptera	
Heptageniidae	
Stenacron interpunctatum	8
Stenonema modestum	9
Odonata	
Aeschnidae	
Boyeria vinosa	3
Coleoptera	
Psephenidae	
Psephenus herricki	9
Diptera	
Empididae	
Hemerodromia sp.	2
Simuliidae	
Simulium sp.	8
Trichoptera	
Glossosomatidae	
Glossosoma sp.	14
Hydropsychidae	
Cheumatopsyche sp.	13
Symphitopsyche sp.	9
Lepidoptera	
Pyralidae	
Parargyractis sp.	10

Macroinvertebrate Qualitative Data
for the Gasper River at Station 18-3

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Elimia sp. 1	5
E. sp. 2	4
E. sp. 3	6
Decapoda	
Cambaridae	
Cambarus graysoni	2
Orconectes putnami	5
Ephemeroptera	
Heptageniidae	
Stenacron interpunctatum	9
Stenonema pulchellum	6
Oligoneuriidae	
Isonychia sp.	13
Odonata	
Calopterygidae	
Calopteryx sp.	1
Aeschnidae	
Boyeria vinosa	2
Macromiidae	
Macromia sp.	1
Coleoptera	
Elmidae	
Optioservus ovalis	31
Dryopidae	
Helichus sp.	2
Haliplidae	
Peltodytes sp.	2
Psephenidae	
Psephenus herricki	2
Diptera	
Simuliidae	
Simulium sp.	7
Tipulidae	
Tipula sp.	2
Trichoptera	
Glossosomatidae	
Glossosoma sp.	6
Hydropsychidae	
Cheumatopsyche sp.	12
Symphitopsyche sp.	33

Macroinvertebrate Qualitative Data
from Wiggington Creek at Station 18-4

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Elimia sp. 1	4
E. sp. 2	4
E. sp. 3	7
Schizodonta	
Unionidae	
Villosa iris	2
Decapoda	
Cambaridae	
Orconectes putnami	2
Ephemeroptera	
Heptageniidae	
Stenacron interpunctatum	10
Stenonema femoratum	6
Odonata	
Aeschnidae	
Boyeria vinosa	1
Hemiptera	
Gerridae	
Trepobates sp.	1
Coleoptera	
Elmidae	
Optioservus ovalis	1
Psephenidae	
Psephenus herricki	2
Megaloptera	
Corydalidae	
Corydalus cornutus	1
Sialidae	
Sialis sp.	1
Trichoptera	
Hydropsychidae	
Symphitopsyche sp.	10
Limnephilidae	
Pycnopsyche sp.	1

Macroinvertebrate Qualitative Data
for the Gasper River at Station 18-11

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Pleurocera sp. 1	4
P. sp. 2	7
P. sp. 3	5
Heterodonta	
Corbiculidae	
Corbicula fluminea	4
Sphaeriidae	
Sphaerium simile	4
Decapoda	
Cambaridae	
Orconectes putnami	18
Ephemeroptera	
Baetidae	
Baetis sp.	17
Heptageniidae	
Heptagenia sp.	17
Stenacron interpunctatum	17
Stenonema modestum	9
Odonata	
Aeschnidae	
Boyeria vinosa	4
Coleoptera	
Elmidae	
Optioservus ovalis	15
Stenelmis crenata	7
Stenelmis sp.	8
Diptera	
Empididae	
Hemerodromia sp.	4
Simuliidae	
Simulium sp.	13
Trichoptera	
Glossosomatidae	
Glossosoma sp.	12
Hydropsychidae	
Cheumatopsyche sp.	9
Symphitopsyche sp.	27
Limnephilidae	
Neophylax sp.	9

Macroinvertebrate Qualitative Data
for the Gasper River at Station 18-12

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Elimia sp. 1	4
E. sp. 2	8
E. sp. 3	3
Heterodonta	
Sphaeriidae	
Sphaerium simile	17
Decapoda	
Cambaridae	
Cambarus tenebrosus	1
Orconectes barrenensis	5
O. putnami	11
Ephemeroptera	
Baetidae	
Baetis sp.	8
Heptageniidae	
Heptagenia sp.	2
Stenonema femoratum	6
Odonata	
Aeschnidae	
Boyeria vinosa	1
Coleoptera	
Elmidae	
Optioservus ovalis	4
Stenelmis crenata	6
Megaloptera	
Corydalidae	
Corydalus cornutus	2
Diptera	
Tipulidae	
Tipula sp.	2
Trichoptera	
Hydropsychidae	
Cheumatopsyche sp.	12
Hydropsyche frisoni	2
Symphitopsyche sp.	9

Macroinvertebrate Qualitative Data
for Black Lick Creek at Station 18-17

Taxa	Number of Organisms
Haplotaxidae	
Naididae	
Dero sp.	5
Basommatophora	
Pleuroceridae	
Pleurocera sp. 1	7
P. sp. 2.	4
Isopoda	
Asellidae	
Lirceus fontinalis	7
Amphipoda	
Gammaridae	
Gammarus sp.	5
Ephemeroptera	
Baetidae	
Baetis sp.	2
Leptophlebiidae	
Leptophlebia sp.	2
Coleoptera	
Dytiscidae	
Laccophilus sp.	7
Trichoptera	
Hydropsychidae	
Cheumatopsyche sp.	4
Symphitopsyche sp.	5

Macroinvertebrate Qualitative Data
for Black Lick Creek at Station 18-19

Taxa	Number of Organisms
Basommatophora	
Pleuroceridae	
Elimia sp.	22
Pleurocera sp.	4
Heterodonta	
Sphaeriidae	
Sphaerium simile	1
Schizodonta	
Unionidae	
Lampsilis radiata luteola	2
Strophitus undulatus undulatus	2
Decapoda	
Cambaridae	
Orconectes putnami	1
Ephemeroptera	
Oligoneuriidae	
Isonychia sp.	4
Hemiptera	
Belostomatidae	
Belostoma sp.	1
Coleoptera	
Elmidae	
Optioservus ovalis	2
Trichoptera	
Hydropsychidae	
Symphitopsyche sp.	5
Philopotamidae	
Chimarra sp.	4

APPENDIX D

Fish Synoptic Species List for the Headwaters of the Mud and Gasper Rivers

Species	Stations 18-3	18-4	18-11	18-12	18-19	12-7
Cyprinidae						
Campostoma anomalum stoneroller	-	4	-	-	-	-
Notropis ardens rosefin shiner	7	42	55	45	8	-
Notropis chrysocephalus striped shiner	-	1	-	3	-	-
Notropis rubellus rosyface shiner	-	-	-	1	-	-
Pimephales notatus bluntnose minnow	-	15	4	13	3	-
Semotilus atromaculatus creek chub	10	-	1	-	1	3
Catostomidae						
Catostomus commersoni white sucker	-	1	-	-	-	-
Erimyzon oblongus creek chubsucker	-	-	-	-	1	-
Moxostoma sp. redhorse sucker	-	-	-	-	-	1
Centrarchidae						
Ambloplites rupestris rock bass	-	-	1	1	2	-
Lepomis cyanellus green sunfish	-	-	-	2	3	-
Lepomis macrochirus bluegill	2	2	-	3	-	-
Lepomis megalotis longear sunfish	-	3	1	-	4	-
Micropterus dolomieui smallmouth bass	-	-	-	-	4	-

Fish Synoptic Species List for the Headwaters of the Mud and Gasper Rivers

	18-3	18-4	18-11	18-12	18-19	12-7
Micropterus punctulatus spotted bass	-	-	-	-	2	-
Percidae						
Etheostoma blennioides greenside darter	-	1	3	2	3	-
Etheostoma caeruleum rainbow darter	1	-	10	-	3	-
Etheostoma flabellare fantail darter	-	1	-	-	-	-
Etheostoma rafinesquei Kentucky snubnose darter	1	-	2	-	18	-
Etheostoma squamiceps spottail darter	1	-	2	-	4	-
Etheostoma stigmaeum speckled darter	-	3	-	-	-	-
Cottidae						
Cottus carolinae banded sculpin	1	1	3	2	-	1
Total Species	7	11	10	9	13	3
Total Individuals	23	74	82	72	56	5

Total Number of Species= 22

Index of Biotic Integrity for the Upper Mud and Gasper River Systems

		Number of Individuals						Proprotion of Individuals (%)							
Station	Stream Size	Total Species	Total Individ-uals	Darter Species	Sunfish Species	Sucker Species	Intol-erant Species	Omini-vores	Insecti-vorous Cyprinids	Green Sunfish	Top Carni-vores	Hybrids	Diseased etc.	Index	Class
Wiggington Cr.															
18-3	Head	0/7	0/23	+/3	-/1	-/0	+/4	+/0	+/74	+/0	+/8	+/0	+	48	G
18-4	Head	+/11	+/74	+/3	0/2	0/1	+/4	+/22	+/57	+/0	+/7	+/0	+	56	E-G
Gasper River															
18-11	Mid	0/10	+/82	+/4	0/2	-/0	+/5	+/5	+/68	+/0	0/2.4	+/0	+	50	G
18-12	Mid	0/9	+/72	-/1	+/3	-/0	+/4	+/22	+/64	+/2.4	+/8.3	+/0	+	50	G
Black Lick Cr.															
18-19	Head	+/13	+/56	+/4	+/5	0/1	+/6	+/7	0/16	0/5	+/14	+/0	+	54	E-G
Mud River															
12-7	Head	-/3	-/5	-/0	-/0	0/1	0/1	+/20	+/60	+/0	-/0	+/0	+	32	P-F

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

APPENDIX E

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