from North Carolina, through Georgia, Alabama, Mississippi, Arkansas, and into Texas (Table I). This belt evolved from a node of production in the Delmarva Peninsula and presently accounts for more than 50 per cent of the broilers grown in the United States. These same states occupy the first six positions on the list of leading broiler growing states.

Table I
Ten Leading States in United States Broiler Production, 1969

State	Total
1. Georgia	374,271,143
2. Arkansas	368,078,464
3. Alabama	334,952,131
4. North Carolina	252,003,506
5. Mississippi	176,261,489
6. Texas	156,150,513
7. Maryland	151,189,410
8. Delaware	112,850,951
9. California	68,089,158
10. Maine	59,906,919
Total	2,053,758,647

Source: United States Bureau of the Census, *United States Census of Agriculture:* 1969, Vol. 1 (Washington: Government Printing Office, 1972).

Reasons for the concentration of broiler production in the South are varied, but two factors appear to be outstanding. First, the South has been in a period of economic flux during the greatest growth of the broiler industry. Dependence on a "cotton economy" has changed to a diversified economy where cattle, vegetables, and soybeans have joined cotton, corn, and tobacco as major crops. Many farmers have sought a diversified combination of farm activities while others seek a selected type of agricultural pursuit which will allow them to take non-farm jobs. Broilers fit almost ideally into such an arrangement. Nearly all broiler farms are at least partially mechanized; consequently, the farmer is required to devote but a small portion of his time to caring for his flock.

Another factor in the regionalization of the industry is that the mild climate in the South allows farmers to build uninsulated houses, an initial savings of $2,000 to $4,000 when compared with the cost of fully insulated houses in more northerly locations. Considering the relatively low annual income for broiler growers, this amount may have been a major factor favoring the regional concentration. Less expensive labor and materials for the same quality house in the South is an additional concentrating factor.

Cullman County History

The broiler industry in Cullman County began in the late 1920's as a sideline of a few cotton farmers. Chickens were sold by the head, usually to meat packing companies. It was the responsibility of the purchasing organization to collect the chickens from the farms. Farmers commonly sold a few broilers each week from the same flock. Growers would sometimes replace broilers as they were sold and thus would have chickens of several different ages in the same flock.

The 1930's and early 1940's brought little change in the basic format for raising broilers in Cullman County. The latter part of the 1930's saw some changes in the industry's financial structure in the form of credit extension to growers by feed dealers. Previous forms of credit had been based on a personal relationship between the farmer and the merchant, with no contractual agreement that used the farmer's broilers as collateral to secure the debt. As the size of flocks increased. it became common for growers to delay payment for feed until the broilers were sold. In rare cases the feed dealer required a formal agreement, but throughout this period most growers had only to sign for the feed and pay when the chickens were marketed.

The war years brought increased demands for broilers, partially because of rationing of beef and other red meats. Furthermore, despite government price ceilings, the average selling price of broilers increased from 17.0 cents per pound in 1939 to 33.8 cents in 1945. This increase largely accounts for the doubling of total broiler output in Cullman County between 1940 and 1945 (Table II).

Table II
Cullman County Broiler Production, 1940-1964[a]

Year	Number of broilers produced	Value	National rank
1940	432,483	Not available	Unranked
1945	928,780	Not available	Unranked
1949	1,011,410	$ 739,201	74
1954	5,582,298	3,426,558	22
1959	20,455,824	10,220,295	7
1964	43,767,914	21,500,000[b]	4
1969	116,262,663	55,000,000[b]	1

[a]Totals include both broilers and other meat-type chickens.
[b]Estimated.

Source: United States Bureau of the Census, *Census of Agriculture* for the years cited.

Price restrictions on broilers were removed at the end of World War II. The average farm price per pound for Cullman County broilers immediately increased to 38 cents, the highest figure in the history of the industry. These unusually high prices stimulated broiler house construction in the county to peak outputs. Quality of construction improved as more houses were built, with poorly constructed pole houses being replaced by high quality wood structures and houses made of concrete blocks.

After 1946 Cullman County's broiler production received another boost as a result of the start of vertical integration in the nation's broiler industry. Vertical integration involves the control of more than one step in the production process by a single company. It is an operational concept utilized in many types of agricultural production, including the broiler industry. When vertical integration of the broiler industry in Cullman County began, the character of the industry changed immediately. The 1946-1951 period saw nearly all independent growers shift to contract growing with one of several integrators which had established offices in the county during this period.

During the first few years after integration began the broiler industry went through a transitional phase as the integrators came into direct competition with local feed and seed dealers. Integrators would agree to buy finished birds at market prices, from which they would subtract costs of feed and chicks which they had supplied to the farmer on a credit basis. Through their market connections and their ability to obtain feed at low prices as a result of large scale purchases, the integrators were able to provide farmers with feed at prices substantially lower than those charged by local feed dealers. Personal loyalties, friendships, and credit ties allowed the local dealers to survive for a while, but most of them were soon forced to go out of business or to specialize in new lines of products.

In a very short period during the late 1940's and early 1950's, several companies opened or purchased their own hatcheries and feed mills. More and more of the individual functions of the industry were taken over by single organizations until the complete operation, from production of eggs for hatcheries, to marketing of the finished product, was controlled by the integrator. In rare instances the broiler

companies, chiefly those owned by local individuals, also owned the farm and houses where broilers were grown. Large organizations, by contrast, left farm and house ownership to the individual farmer.

The process of vertical integration seems, at first, to be contradictory to the independent nature of the southern farmer. It should be emphasized, however, that for a farmer to grow chickens independently he must be capable of financing land, buildings, and equipment for the initial portion of the operation and must have adequate short-term working capital for feed, fuel, litter, chicks, and medicine. The average farm value for the county in 1969 was $23,222, an increase of nearly $10,000 over the 1964 figure of $13,594. Obviously, most farmers could not afford to invest $5,000 to $10,000 in a chicken house without being assured of adequate returns on his investment. The contracts of all integrators operating in Cullman County guarantee the grower of a minimum of one cent per pound for mature broilers, regardless of the market price at the time the chickens are sold. Above a minimum market price the farmer is compensated by the amount of meat produced per pound of feed and by the exact price received by the integrator when the dressed broiler is sold. Consequently, by the contractural arrangement of growing broilers the farmer could profit in relation to the market price of the chickens but, regardless of the price, he would always be moderately compensated for his efforts.

Integration, then, was well received in Cullman County, with the greatest growth of the industry being made after integrators took complete control of broiler production. The county has gained national prominence in the broiler industry only in the last 10 to 15 years. Following a very modest growth in the 1940's, production accelereated rapidly during the 1950's. Annual output increased by more than 19 million broilers for the decade. The most astonishing growth, however, was between the years 1959 and 1969 when the total broiler output grew from 20,400,000 to nearly 116,260,000 annually. This is an increase of nearly ten million broilers each year or a total increase of almost 100 million for the ten year period.

There is a correlation between the growing of broilers and the size of farms within the county. The average farm size in Cullman County is only 75.2 acres, while the state average is 188.3. In fact, the average farm size in the top eight producing counties of the state is slightly over 100 acres, considerably below most other counties of the state. It is possible that because of the small size of farms in these top counties there was a need for a more intensive form of farming or, perhaps the higher intensity and greater per-acre returns received has retarded farm consolidation. It is also possible that residents of these counties may have been more receptive to the idea of trying new means of farming since it was impossible for them to produce other crops in the quantities necessary to achieve a satisfactory income.

It is noteworthy, also, that the farm tenancy rate for Cullman County is 3.9 per cent while the tenancy rate for the state is 10 per cent. There are almost no tenant farms in the county which have broiler houses. Integrators will only rarely enter into a contractual agreement if the broilers are to be cared for by someone other than the owner. In this respect the broiler industry is analogous to the dairy industry because integrators feel a large part of the success of the operation depends on the personal care rendered by the owner. Thus, integrators are likely to choose an area of low tenancy over an equally qualified region where the tenancy rate is higher.

Economic Importance

The importance of broilers in the economy of Cullman County is readily apparent to even the casual observer. The many broiler houses throughout the county provide a source of livelihood for a large percentage of the county's population. The 1969 Census of Agriculture lists the total income from all farm products sold in the county as $80,620,000. Of this total, poultry and poultry products accounted for $70,710,188 or more than four-fifths of the aggregate farm income. Of the monies received for all poultry products, approximately $55,000,000 came from the sale of broilers alone. Broilers are by far the most important single factor in the economy of Cullman County.

The success of early independent broiler growers contributed to the development of Cullman County's broiler concentration. When integrators came into the county, farmers saw in the broiler industry an opportunity to have a guaranteed income with no outlay of working capital, all with little time taken away from other farming activities. With an expanding national economy, little effort was required for the farmer to secure the financial assistance necessary to build one or two houses. The interplay of these factors, small farms, low tenancy rate, early grower success, complete vertical integration, and an expanding national economy, is largely responsible for providing conditions necessary for the county to attain its presently held position as the nation's leading broiler producing county.

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AN ECOLOGICAL SURVEY OF THE WEST FORK OF THE OBEY RIVER, TENNESSEE WITH EMPHASIS ON THE EFFECTS OF ACID MINE DRAINAGE

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Abstract

A one-year study of the West Fork of the Obey River in Overton County, Tennessee, was undertaken to survey the water quality, benthic macroinvertebrate population, and fish population. A secondary objective was to determine the effects of acid mine drainage from a small intermittent tributary stream, Cub Creek.

Water quality immediately below the zone of pol-

lution was only slightly affected. A precipitate resulting from the reaction of sulfuric acid and iron salts with carbonates covered the bottom below the source of pollution, thereby reducing the total numbers and taxonomic diversity of the benthic macroinvertebrate and fish populations. Cub Creek had a localized, detrimental effect on the water quality, benthos, and fish populations in the West Fork.

Thirteen water quality parameters were monitored. Twenty-five invertebrate families and 29 species of fishes were identified.

Introduction

A one-year study of the West Fork of the Obey River, hereafter referred to as the West Fork, was conducted to obtain results which could be useful in four broad areas. First, to define the natural conditions of the West Fork in relation to water chemistry, benthic macroinvertebrates, and fish populations. Second, to determine the effect of intermittent acid mine drainage on the water quality and aquatic life in the West Fork. Third, to compare the results with the very severely polluted East Fork of the Obey River (Nichols and Bulow, 1973). Finally, to provide data which could be compared with conditions in the impounded Dale Hollow Reservoir.

The importance of the West Fork is closely associated with the fishery of Dale Hollow Reservoir. Spawning runs of suckers (Catostomidae), white bass (*Morone chrysops*), and walleye (*Stizostedion vitreum*) occur in the West Fork each spring. The annual spawning run of the white bass provides good fishing and is an important economic and recreational resource of the area.

Description

The Obey River is part of the Cumberland River drainage. The West Fork of the Obey River is located in Overton and Pickett Counties, Tennessee. The West Fork flows north to join the East Fork of the Obey River in Pickett County where the Obey is impounded to form part of Dale Hollow Reservoir.

The West Fork is approximately 28.5 miles in length. It drains an area of 115 square miles, 34 of which do not show surface drainage (U.S. Department of Interior, 1969). The West Fork lies entirely on the eastern edge of the Eastern Highland Rim. This Rim is covered with a caprock composed almost entirely of limestone (Swingle, *et. al.,* 1966).

The Northern Cumberland Plateau is located to the east of the Eastern Highland Rim and varies greatly in geologic formation. Pennsylvanian caprock, 400 to 500 ft. thick, composed of sandstone, shale, siltstone, and minor amounts of coal, cover the Plateau. The West Fork could be considered the western boundary to the Wilder Coal Field (Luther, 1959). A small amount of coal mining has taken place on the western escarpment of the Plateau. To our knowledge, the only known acid drainage pollution of the West Fork comes from these abandoned strip mines.

For the purpose of this study, the West Fork can be divided into three sections: The 12½ miles of headwaters, the 8 miles of the study area, and the remaining 8 miles to the confluence with the East Fork of the Obey River.

The study area, which began at the bridge on State Highway 85 and terminated at the bridge on State Highway 52, had 14 major tributary branches and streams. The largest of these, Puncheon Camp Creek, flows northeast through the community of Allred. At minimum flow, water was present here only in pools. All the tributaries in the study area were generally characterized by this lack of flow during the summer and fall months. The majority of the surrounding countryside was wooded hills. The average stream gradient is 27 feet per mile. The stream width varied from 10 to 60 feet and averaged 30 feet. The average pool depth was three feet and the average riffle depth six inches. Fishing pressure was very light in the study area.

The West Fork originates in Overton County near the small communities of Anderson and Columbia Hill, at an altitude of approximately 1400 feet. About seven and a half miles downstream, at Three Forks, the river is approximately 900 feet above sea level. This location was considered part of the headwaters by Shoup, Peyton, and Gentry (1941). In February 1970, this site was visited twice. The stream was approximately 12 feet wide with a maximum depth of three feet. The water temperature ranged from 8° to 10° C.

To determine the influence of acid mine drainage from Cub Creek, seven sample stations were chosen (Figure 1). Station 1 (Highway 85) was the unpolluted control, Station 2 (Cub Creek) and 2A (Spring) were used to check the polluted water before it entered the West Fork, and Stations 3 (below Cub Creek) through 6 (Highway 52) were used to gauge the conditions at increasing distances from the source.

Sample Station 1 (Highway 85) was approximately five miles downstream from the area known as Three Forks.

Sample Station 2 (Cub Creek) was located one-tenth mile downstream in Cub Creek, a small northwest flowing tributary. Cub Creek is approximately three miles long, and receives one major stream, Scott Branch. Scott Branch is about two miles in

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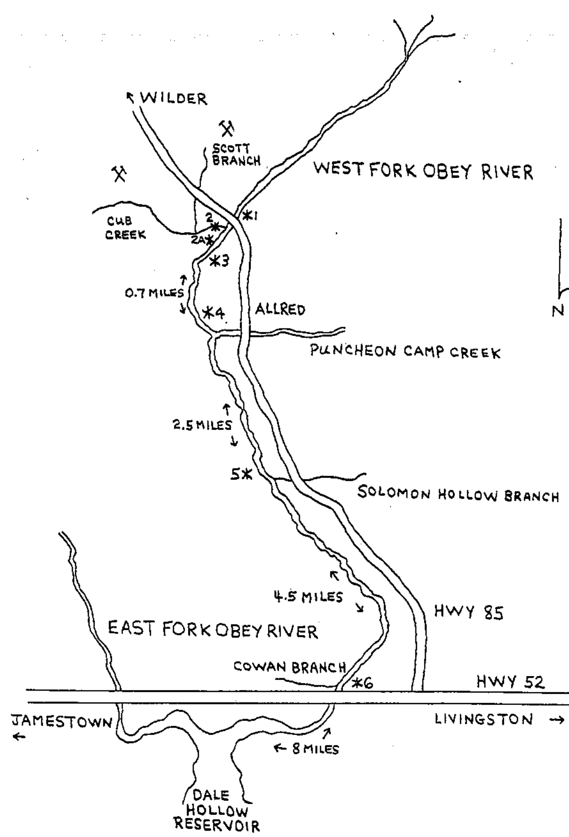

Figure 1. Diagrammatic Map of the West Fork of the Obey River, Tennessee, Indicating Active and Inactive Mines and Sample Station Locations.

Table 1. Annual Minimum, Maximum, and Mean Values of the Water Quality Parameters Evaluated on the West Fork Obey River, Tennessee, 1970[a]

	Hwy 85	Cub Creek	Spring	Below Cub Creek	Allred	Solomon Hollow	Hwy 52
pH	7.3	4.2	4.2	6.3	6.5	7.0	7.8
	8.5	4.5	6.0	8.2	8.5	8.5	8.5
	8.1	4.4	5.0	7.0	7.4	8.0	8.2
Free Acidity	0.0	34.2	0.0	0.0	0.0	0.0	0.0
	0.0	427.5	56.9	0.0	0.0	0.0	0.0
	0.0	299.8	12.4	0.0	0.0	0.0	0.0
Total Acidity	5.6	91.1	34.2	7.5	5.6	5.6	5.6
	11.3	626.9	148.1	42.7	14.2	11.3	11.3
	8.3	299.8	82.2	17.1	9.9	6.9	7.8
M. O. Alkalinity	76.9	0.0	0.0	59.8	68.4	76.9	90.0
	136.8	0.0	38.4	127.4	120.0	153.9	153.9
	118.2	0.0	13.6	89.2	97.3	109.4	119.0
Iron	0.0	4.5	0.0	0.0	0.0	0.0	0.0
	0.4	85.0	5.0	5.0	2.5	2.5	1.5
	0.1	21.1	1.0	1.0	0.7	0.4	0.2
Sulfate	15.0	220.0	280.0	41.0	42.0	3.0	17.0
	38.0	1000.0	650.0	83.0	88.0	60.0	49.0
	23.2	664.0	432.0	63.0	64.8	44.0	36.4
Manganese	0.0	1.9	0.0	0.1	0.2	0.0	0.0
	0.2	10.0	3.8	0.3	0.5	0.4	0.3
	0.1	4.6	2.0	0.3	0.3	0.1	0.2
Total Hardness	94.0	115.0	188.1	100.0	102.6	100.0	102.6
	145.0	376.2	420.0	175.0	171.0	171.0	171.0
	128.5	236.8	344.2	135.7	141.8	141.8	138.6
Calcium Hardness	70.0	55.0	225.0	75.0	70.0	60.0	80.0
	130.0	230.0	300.0	150.0	140.0	130.0	135.0
	100.9	132.5	236.7	111.8	112.0	111.0	109.0
Magnesium Hardness	15.0	60.0	72.0	10.0	28.9	20.0	15.0
	50.0	100.0	120.0	50.0	40.0	43.9	53.9
	34.1	80.0	87.1	32.8	32.5	34.9	31.3
Dissolved Oxygen	7.0	6.0	8.0	8.0	8.0	8.0	8.0
	12.0	12.0	11.0	12.0	11.0	11.0	12.0
	9.8	9.7	9.7	9.6	9.4	9.6	9.6
Color	10.0	0.0	10.0	0.0	0.0	0.0	0.0
	50.0	215.0	110.0	70.0	73.0	55.0	40.0
	28.6	95.0	42.0	40.9	29.3	26.7	15.4
Turbidity	5.0	0.0	13.0	10.0	0.0	4.0	0.0
	25.0	80.0	40.0	25.0	24.0	20.0	18.0
	12.9	29.3	22.6	17.3	11.8	10.4	6.3

[a] Values are expressed in parts per million except for color (APHA Platinum -Cobalt Standard), turbidity (Jackson Turbidity Units) and pH. Values are a summary of bimonthly samples.

length and flows northwest into Cub Creek. Cub Creek is dry an estimated five months per year.

Sample Station 2A (spring) was a continually flowing spring which is located adjacent to Cub Creek and empties into the West Fork. Several other small springs which empty into the mouth vicinity of Cub Creek were not used in the study.

Sample Station 3 (below Cub Creek) was located in the West Fork immediately below the suspected pollution sources.

Sample Station 4 (Allred) was located seven-tenths of a mile below Cub Creek, adjacent to Highway 85, just south of Allred.

Sample Station 5 (Solomon Hollow) was located approximately two and one-half miles downstream from the Allred community. A small, intermittent stream flowed eastward out of Solomon Hollow and entered the West Fork at this point.

Sample Station 6 (Highway 52) was located four and one-half miles downstream from Solomon Hollow and seven and eight-tenths miles upstream from the confluence with the East Fork of the Obey River. Cowan Branch flows westerly into the West Fork at this station and Nettlecarrier Creek is located three-tenths of a mile upstream.

A stream flow gauging station, #3-4150, was maintained by the United States Geologic Survey at the bridge on Highway 52. It operated at 684.28 feet above sea level, unadjusted. From October 1942 to September 1968, the average discharge was 161 cfs (U.S. Department of Interior, 1969). The maximum and minimum discharge for 1968 was 5,200 cfs on March 12 and 3.8 cfs on September 3, 4, 29, and 30.

Highest water temperatures ranged from 22° C in Cub Creek to 27° C at Station 5. The lowest water temperature recorded was 44° C in Cub Creek. The stream bottom was composed of rubble and gravel except the Station 5 area which was almost entire bedrock.

Materials and Methods

Water Quality

Samples were taken bimonthly from February 1970 through January 1971, except in December 1970, when only one sample was taken.

The parameters tested were pH, dissolved oxygen, free acidity, total acidity, methyl orange alkalinity, total hardness, calcium hardness, magnesium hardness, iron, sulfate, manganese, color, and turbidity. These parameters were tested using standard Hach Chemical Company analysis kits. The accuracy of the drop-count method of titration was determined to be ± 2% (Hach Chemical Co., 1969). Acid waters are always very erratic in carbon dioxide content (Amer. Publ. Heal. Assoc., *et. al.*, 1965). This was found to be true in this study and no data are presented.

Benthic Macroinvertebrates

Two sampling methods were used in the collecting of invertebrates, the Surber sampler and multiple-plate sampler. The Surber square-foot sampler (Surber, 1969) was used once a month in May and July 1970, and twice a month in August and September 1970. Two samples were taken per sample station, one in the center of the stream and the other midway between the center and a bank.

The multiple-plate samplers, described by Hester and Dendy (1962), were placed in the West Fork on March 28, 1970. They were checked once a month in April, June and July, and twice a month in May, August and September. Samplers were replaced when lost due to strong currents of vandalism.

Organisms were transported to the laboratory, sorted, preserved, identified, and counted.

Fish

Fish were collected using electrofishing gear and sodium cyanide (Tatum, 1968). Fish were preserved in 10% formalin and transported to the laboratory for identification. Scientific and common names used in this study agree with those of Bailey *et. al.* (1970).

Results and Discussion

Water Quality

Certain water quality characteristics generally considered to be typical of acid mine drainage are discussed by Nichols and Bulow (1973). These include low pH, acidity greater than alkalinity, high iron, high sulfate, and significant amounts of aluminum, manganese, calcium, and magnesium (Hill, 1968). These characteristics were found in Cub Creek. Sulfur and iron, which are exposed during coal mining operations, are converted into ferrous sulfate and sulfuric acid. Ferrous sulfate can then be converted to basic ferric sulfate or ferric hydroxides with additional free sulfuric acid created. Precipitation of the slightly soluble iron hydrates creates the characteristic yellow, orange or red deposits of acid streams. Natural stream alkalinity gradually neutralizes the sulfuric acid of mine drainage (Porges, Van Den Berg and Ballinger, 1966). The acid water from Cub Creek, on entering the West Fork, underwent the process of neutralization. Precipitates formed during this neutralization are believed to be responsible for the coating of the bottom of Cub Creek and Stations 3 and 4 below Cub Creek.

Results from the entire year of sampling indicate that values obtained from Stations 1, 5, and 6 are representative of the unpolluted West Fork (Table 1). Station 5 (three and one quarter miles below Cub Creek) showed no indication, with the possible exception of iron, of being affected. Values from Station 3 (below Cub Creek) and Station 4 (Allred) indicated effects of acid drainage from Cub Creek.

It can be assumed that the West Fork above Station 1 is not affected by acid drainage since preliminary sampling five miles above this station showed no indication of such pollution. Values obtained there, at Three Forks, were similar to those obtained at Stations 1 and 6 during this study. Shoup, *et. al.* (1941) and Shoup (1950) recorded similar values at Three Forks.

Benthic Macroinvertebrates

A benthic macroinvertebrate study was conducted on the West Fork to survey the natural fauna, and to evaluate the effects of acid mine drainage on the natural fauna. Five sample stations were used. Station 5, at Solomon Hollow, was omitted because of a bottom composed almost entirely of bedrock. This was done to standardize the bottom types of each station checked for invertebrates.

The stream at Station 6 showed no effects of the pollution and maintained a diverse population (Table 2). This station and Station 1 were characteristic of the natural benthic populations. The stream bottom at Stations 3 and 4 was covered with a precipitate and had benthic populations reduced in number and diversity. These stations illustrated the effect of localized acid mine precipitation in the West Fork. Cub Creek had a drastically affected population due to the poor water quality and bottom precipitate.

Twenty-five taxonomic categories, composed of one class, 23 families, and one subfamily, were recovered from the plate and Surber samples. Members of two other families were observed.

The number of these taxonomic groups represented at Stations 1, 2, 3, 4, and 6 were 19, 1, 9, 8, and 21. The number of organisms per square foot at Stations

Table 2. Mean number of Benthic Macroinvertebrates per square foot collected from the West Fork Obey River, Tennessee, April 1970 through September 1970

TAXON		Hwy 85	Cub Creek	Below Cub Creek	Allred	Hwy 52
CLASS OLIGOCHAETA		0.06	0.00	0.00	0.00	0.11
	Total	0.06	0.00	0.00	0.00	0.11
ORDER AMPHIPODA						
Family Gammaridae		0.00	0.00	0.00	0.00	0.17
	Total	0.00	0.00	0.00	0.00	0.17
ORDER DECAPODA						
Sub-Family Cámbarinae		0.06	0.00	0.00	0.00	0.06
	Total	0.06	0.00	0.00	0.00	0.06
ORDER PLECOPTERA		0.00	0.00	0.06	0.05	0.00
Family Perlidae		0.00	0.00	0.00	0.00	0.00
Neophasganophora capitata		0.28	0.00	0.25	0.22	0.11
Neoperla clymene		0.17	0.00	0.00	0.00	0.06
Family Perlodidae		0.00	0.00	0.00	0.00	0.00
Isoperla sp.		0.00	0.00	0.06	0.00	0.00
Family Nemouridae		0.00	0.00	0.00	0.00	0.00
Nemoura sp.		0.00	0.00	0.00	0.05	0.00
	Total	0.45	0.00	0.37	0.32	0.17
ORDER EPHEMEROPTERA		0.22	0.00	0.19	0.22	0.44
Family Baetidae		0.28	0.00	0.19	0.22	0.11
Améletus sp.		0.50	0.00	0.62	0.27	0.28
Ephemerella sp.		0.33	0.00	0.06	0.00	0.72
Paraleptophlebia sp.		0.00	0.00	0.00	0.00	0.44
Siphlonurus sp.		0.00	0.00	0.00	0.00	0.11
Family Heptageniidae		0.44	0.00	0.25	0.11	0.39
Stenonema sp.		6.72	0.00	0.38	0.16	3.72
Heptagenia sp.		0.83	0.00	0.69	0.05	0.28
Family Ephemeridae		0.00	0.00	0.00	0.00	0.00
Ephemera sp.		1.44	0.00	0.06	0.00	0.06
	Total	10.76	0.00	2.44	1.03	6.55
ORDER ODONATA		0.00	0.00	0.00	0.00	0.06
Family Coenagrionidae		0.06	0.00	0.00	0.00	0.06
Lestes sp.		0.00	0.00	0.00	0.00	0.11
Family Libellulidae		0.00	0.00	0.00	0.00	0.06
	Total	0.06	0.00	0.00	0.00	0.29
ORDER HEMIPTERA						
Family Notonectidae		0.06	0.00	0.00	0.00	0.00
	Total	0.06	0.00	0.00	0.00	0.00
ORDER NEUROPTERA						
Family Corydalidae						
Corydalus cornutus		0.00	0.00	0.00	0.00	0.22
Chauliodes sp.		0.28	0.00	0.00	0.00	0.06
Family Sialidae						
Sialis sp.		0.11	0.00	0.06	0.00	0.00
	Total	0.39	0.00	0.06	0.00	0.28
ORDER TRICHOPTERA						
Family Rhyacophilidae						
Rhyacophila sp.		0.22	0.00	0.00	0.00	0.00
Glossosoma sp.		0.06	0.00	0.00	0.00	0.06
Family Hydropsychidae						
Hydropsyche sp.		0.00	0.00	0.00	0.00	0.11
	Total	0.28	0.00	0.00	0.00	0.17
ORDER COLEOPTERA						
Family Psephenidae						
Psephenus herricki		0.33	0.00	0.00	0.05	0.06
Family Elmidae		0.67	0.00	0.25	0.00	0.28
Family Dryopidae		0.17	0.00	0.06	0.00	0.17
Family Gyrinidae						
Dineutus sp.		0.00	0.00	0.00	0.00	0.06
Family Dytiscidae		0.00	0.00	0.00	0.05	0.00
	Total	1.17	0.00	0.31	0.10	0.57
ORDER DIPTERA		0.06	0.00	0.06	0.00	0.11
Family Tipulidae		0.06	0.00	0.00	0.00	0.00
Family Tabanidae						
Tabanus sp.		0.06	0.00	0.00	0.00	0.00
Chrysops sp.		0.11	0.00	0.00	0.00	0.00
Family Chironomidae		0.11	0.00	0.00	0.00	0.06
Chironomus sp.		0.50	38.40	0.00	0.05	0.06
Pentaneura sp.		0.33	0.00	0.13	0.05	0.28
	Total	1.23	38.40	0.19	0.10	0.51
CLASS GASTROPODA						
Family Pleuroceridae		3.22	0.00	0.00	0.05	4.55
	Total	3.22	0.00	0.00	0.05	4.55
Total mean number of organisms		17.80	38.40	3.37	1.60	13.93
Total sq. ft. of Plate Samples		8.00	3.50	8.00	8.50	8.00
Total sq. ft. of Surber Samples		10.00	4.00	8.00	10.00	10.00

Table 3. Fish population composition and estimated number per surface acre, West Fork Obey River, Tennessee

TAXON		Hwy 85[a]	Below Cub Creek	Allred	Solomon Hollow[b]	Hwy 52
Family Lepisosteidae						
Lepisosteus osseus		0.0	0.0	0.0	0.0	4.0
	Total	0.0	0.0	0.0	0.0	4.0
Family Cyprinidae						
Campostoma anomalum		328.0	128.0	1089.0	198.0	108.0
Hybopsis amblops		0.0	0.0	163.0	6.0	0.0
Hybopsis dissimilis		0.0	0.0	0.0	0.0	17.0
Notropis ardens		175.0	173.0	230.0	87.0	108.0
Notropis chrysocephalus		0.0	0.0	30.0	0.0	0.0
Notropis cornutus		7.0	0.0	0.0	6.0	0.0
Notropis galacturus		0.0	15.0	37.0	302.0	367.0
Notropis telescopus		0.0	173.0	770.0	35.0	83.0
Pimephales notatus		730.0	15.0	67.0	17.0	0.0
	Total	1240.0	504.0	2386.0	651.0	683.0
Family Catostomidae						
Hypentelium nigricans		58.0	15.0	37.0	52.0	75.0
Moxostoma erythrurum		365.0	7.0	207.0	0.0	25.0
	Total	423.0	22.0	244.0	52.0	100.0
Family Ictaluridae						
Noturus flavus		15.0	7.0	0.0	46.0	58.0
	Total	15.0	7.0	0.0	46.0	58.0
Family Cyprinodontidae						
Fundulus catenatus		0.0	7.0	0.0	0.0	0.0
	Total	0.0	7.0	0.0	0.0	0.0
Family Centrarchidae						
Ambloplites rupestris		80.0	45.0	67.0	52.0	46.0
Lepomis gulosus		0.0	0.0	0.0	0.0	75.0
Lepomis megalotis		44.0	0.0	0.0	41.0	387.0
Micropterus dolomieui		15.0	15.0	0.0	35.0	43.0
Micropterus punctulatus		0.0	0.0	0.0	0.0	100.0
	Total	139.0	60.0	67.0	128.0	650.0
Family Percidae						
Etheostoma blennioides		29.0	0.0	15.0	23.0	79.0
Etheostoma caeruleum		139.0	53.0	7.0	23.0	92.0
Etheostoma cinereum		0.0	0.0	0.0	0.0	4.0
Etheostoma flabellare		73.0	0.0	0.0	0.0	4.0
Etheostoma jessiae		22.0	0.0	0.0	0.0	29.0
Etheostoma obeyense		36.0	0.0	0.0	17.0	4.0
Etheostoma rufilineatum		44.0	0.0	0.0	0.0	13.0
Etheostoma simoterum		102.0	0.0	15.0	0.0	4.0
Percina caprodes		7.0	0.0	0.0	52.0	287.0
	Total	452.0	53.0	37.0	115.0	516.0
Family Cottidae						
Cottus carolinae		66.0	0.0	0.0	29.0	0.0
	Total	66.0	0.0	0.0	29.0	0.0
Total Estimated Population		2335.0	653.0	2734.0	1021.0	2011.0

[a]Highway 85, Below Cub Creek, and Allred were sampled on September 22, 1970.

[b]Solomon Hollow and Highway 52 were sampled on July 6, 1970.

1, 2, 3, 4, and 6 were 17.8, 38.4, 3.4, 1.6, and 13.9.

The above results were calculated from the number of organisms collected by both plate and Surber samplers. Both sampling methods produced approximately the same number of organisms per square foot, but the Surber sampler picked up more kinds of organisms.

The acid mine drainage in Cub Creek rendered it unfit for the varied invertebrate life native to the West Fork drainage. Katz (1969) summarized the occurrence of benthos in acid water. In waters with a pH below 3.5, members of the families Chironomidae and Ceratopogonidae, and genus *Sialis* are common. In water with a pH of 3.5 to 4.5, Trichoptera and Odonata begin to appear, but the Chironomidae are still dominant. At pH's above 4.5, diverse fauna will begin to appear.

In Cub Creek, only *Chironomus* sp. was collected. These were collected in July from the water remaining in isolated pools. They were extremely abundant with from 90 to 100 organisms per square foot. Dinsmore (1968) found two kinds of Chironomidae in acid mine drainage with a pH of 3.1 to 3.8. One kind was found in large numbers. Reppert (1964) found a pure culture of *Chironomus* sp. in a small, 0.1 acre lake polluted by a shaft coal mine. He found the bottom to be completely covered with precipitated ferric hydroxide. Katz (1969) reported of 16,675 *Chironomus plumosus* per square meter that were collected from an area with a medium pH of 2.8. Nichols and Bulow (1973) found only *Sialis* and *Chironomus* in the polluted section of the East Fork of the Obey River, with *Chironomus* as dense as 106 organisms per square foot at one station.

Acid mine drainage from Cub Creek had relatively little effect on the water chemistry of the West Fork due to neutralization and dilution. Available literature contained no examples of harmful effects to benthos due to the water quality comparable to that present at Stations 3 and 4.

Bell and Nebeker (1966) used ten species of aquatic organisms to test the toxicity of low pH. Three genera used in their study were also collected from the West Fork. They found that *Hydropsyche betteni, Stenonema rubrum,* and *Ephemerella subvaria* were able to survive at a pH considerably lower than that which occurred at Stations 3 and 4.

If water quality was not detrimental to the benthic population at Stations 3 and 4, then the reduced population must have been caused by the flocculation. There is a great deal of literature containing examples of the harmful effects of siltation on benthos.

Although precipitation of metallic salts was greatest at Station 3 on the West Fork, the number of invertebrates was lowest at Station 4. The number of taxa remained approximately the same at these stations. A possible explanation for this is the natural downstream drift of stream invertebrates (Waters, 1961). The higher number of invertebrates at Station 3 was probably due to this drift of organisms from the unpolluted sections.

Fish

The fish population composition and estimated number per surface acre for each station are listed in Table 3. Eight families were represented, with 29 species collected. These results are in sharp contrast to those found in the East Fork where no fish were collected in the severely polluted section (Nichols and Bulow, 1973).

Questions have often been raised concerning the accuracy of a total fish population estimation by random sampling in rivers and streams. This method of sampling implies an even space distribution of the population, but this is not always the case since serious errors in population estimates can be caused by nonrandom movement of fish (Cleary and Greenback, 1954).

The use of fish toxicants is considered an adequate method for counting the entire population in a definite portion of water because all or nearly all the fish in the sample area are taken. The sample is representative of the total population to the extent that the sample area is representative of the entire body of water (Cleary and Greenback, 1954).

Shoup *et. al.* (1941) collected fish from the West Fork and tributaries in 1939. They found a total of 24 species, 17 of which were also collected during this study. The following species collected by Shoup *et. al.* were not collected during this study: *Notropis spilopterus,* the spotfin shiner; *Notropis volucellus,* the mimic shiner; *Notropis micropteryx,* the shortfin shiner; *Semotilus atromaculatus,* the creek chub; *Moxostoma duquesnii,* the black redhorse; *Etheostoma spectabile,* the orange throat darter; and an unidentified darter. Species collected in 1970, but not in 1939 included: *Lepisosteus osseus, Notropis chrysocephalus, Lepomis gulosus, Micropterus punctulatus, Cottus carolinae,* and all Percidae except *Etheostoma blennioides* and *Etheostoma obeyense.*

The principal damage done to the fish population by acid mine drainage in the West Fork is through deterioration of the stream bottom. Bottom deposits smother benthic organisms and disrupt food chains. Bottom deposits also destroy spawning grounds for certain fish species. Fish eggs can be covered over and smothered. Finally, although compounds containing sulfate, iron, aluminum, and manganese are precipitated, as long as they remain on the stream bottom, they are subject to re-solution and ingestion by fish or other aquatic life (Ellis, 1937).

Below the pollution zone, at Stations 3 and 4, the bottom deposits reduced the darter population both in total numbers and number of species. A definite reduction in the total number of all fish was noted at Station 3.

Conclusions

Cub Creek, associated springs, and tributaries were polluted by acid mine drainage. Cub Creek was the most severely polluted. In comparison to the West Fork, the acid waters of Cub Creek, Scott Branch, and the springs had a lower pH, little or no alkalinity, and higher readings of free acidity, total acidity, sulfates, iron, manganese, silica, and hardness.

Due to the acid mine drainage entering the West Fork via Cub Creek, a slight decrease in alkalinity and slight increases in total acidity, iron, and sulfates were recorded below the zone of pollution. The changes in water quality were slight because of dilution and neutralization.

The precipitation of various compounds due to the reaction of metallic salts with naturally occurring carbonates had a localized detrimental effect. The benthic macroinvertebrate population was uniformly reduced in total species and numbers due to the precipitate below Cub Creek. Fish were less affected, but showed a reduction in the number of species and total numbers immediately below Cub Creek. The darters were particularly sensitive to this disturbed bottom.

Natural productivity of the West Fork does not appear to be significantly reduced by acid mine drainage, although some damage is done to a small section.

The West Fork is important to the productivity of the upper end of Dale Hollow Reservoir and will be of greater importance should acid pollution from the East Fork of the Obey River become worse. Every effort should be made to prevent further pollution of the West Fork.

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THE TENNESSEE WATER POLLUTION LAW: AN OPINION

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Abstract

In 1971 the Tennessee legislature passed a wholly new state-wide water pollution control law. One of the draftsmen of the law provides an interpretive outline of the new statute. Included is an explanation of one of the law's major innovations known as the public trust doctrine. Also given is an opinion of the statute, in which the author discusses the efficiency, constitutionality and future of the Act.

Introduction

In nearly eight thousand words of statutory language, the *Tennessee Water Quality Control Act of 1971** is

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**Tennessee Code Annotated* §§ 70-324 to 342 (Supp. 1971).

a legislative attempt to provide a modern regulatory framework for controlling water pollution in Tennessee. The new law is the subject of this article. This discussion is divided into three parts. First, the law is summarized. Next, the Act's major innovation, called the public trust doctrine, is explained. Finally, the author will give opinions about the new Act.

Summary of the Law

A section-by-section analysis of the Act is beyond the scope of this article. Such a treatment of the Act can be found in the legal literature (Maloney, 1972). Instead, a summary of the law is presented here in broad outline form. The administration of the law involves two separate bodies, the Water Quality Control Board and the Public Health Department's Division of Water Quality Control. These two entities work together but have very difficult functions, as seen in the following:

The Public Trust Doctrine

Before writing the Act, the draftsmen carefully studied the water pollution laws of the other forty-nine states. Their purpose was to distill from that body of legislation features which were considered most efficient in controlling pollution. One of those features, called the public trust doctrine, has recently been suggested as a device for protecting the environment (Sax, 1970). The draftsmen sought to incorporate the trust doctrine into Tennessee statutory law. To accomplish this, they began the new Act with a strong policy declaration. This declaration was calculated to make clear to the public, and the courts, the purpose of the law. It reads:

> *Declaration of Policy and Purpose.* Recognizing that the *waters* of the State of Tennessee are the property of the State and *are held in public trust for the use of the people of the State,* it is declared to be the public policy of the State of Tennessee that the people of Tennessee as beneficiaries of this trust have a right to unpolluted waters. In the exercise of its public trust over the waters of the State, the government of the State of Tennessee, has an obligation to take all prudent steps to secure, protect and preserve this right. (emphasis added).
>
> It is further declared that the purpose of this law is to abate existing pollution of the waters of Tennessee, to reclaim polluted waters, to prevent the future pollution of the waters, and to plan for the future use of the waters so that the water resources of Tennessee might be used and enjoyed to the fullest extent consistent with the maintenance of unpolluted waters. (*Tennessee Code Annotated* §§ 70-325 (Supp. 1971)).

The need for this policy statement has its origins in a failure of our legal system. Although scientific authorities have long recognized that the pollution and purification of water is a dynamic rather than static process, the law has not incorporated these scientific realities into our legal system. As one legal scholar explains:

> "Scientists see the hydrologic cycle as a continually changing entity, whereas the legal process has tried to fractionalize this ever-continuing cycle into correlative rights and duties applicable to specific persons who control a body of water for only a short time period of the total cycle." (Maloney, 1972)

As seen in the Act's policy declaration, the public trust doctrine imposes a duty on both state authorities and private citizens to protect the *res* (Lat. "thing"), of the trust for all citizens. No longer is the law focused merely on riparian owners. Rather, it looks further in order to benefit the total citizenry of the state because everyone is a beneficiary of the trust. In short, the doctrine applies traditional trust concepts to a new setting. The government is a *trustee* of the waters (*res*) for the benefit of the trust *beneficiaries,* namely, the people of Tennessee, whether alive or yet unborn.

The trust doctrine has been upheld in other states, at least when used to protect navigable waters. While the Tennessee courts have never passed on the constitutionality of the public trust doctrine, the draftsmen were encouraged by several longstanding cases in which the Tennessee courts recognized a high state interest in protecting navigable streams. The draftsmen were hopeful that the concept will be properly upheld as applicable to *all* waters. However, the doctrine is expected to have a dramatic influence in protecting Tennessee waters even if its application is restricted to navigable streams. (Maloney, 1971).

Aside from educating the courts to the reality of the hydrologic cycle, the doctrine is expected to have pragmatic effects too. For example, since each citizen is a beneficiary of the *res,* the courts should no longer be able to deny the citizen a forum on the ground that he lacks sufficient standing to sue (Maloney 1972). Anticipating the public's response to this new pathway to litigation, the draftsmen included in the Act a procedure whereby a citizen can, at least, officially complain about environmental deterioration which surrounds him. (Tenn. Code Ann. § 70-340 (Supp. 1971)).

Opinion of the Act

A. Constitutionality

The *Water Quality Control Act of 1971* has yet to withstand the acid-test of constitutional attack. However, one polluter did initiate a constitutional challenge but recently abandoned the matter. (*In re Coey Tanning Co.,* Davidson County Chancery Court, Case A-1352, March 3, 1972). The case raised a constitutional issue which is likely to appear again. The defendant company claimed that the Act was an unconstitutional grant of judicial power to an executive department because, it maintained, the Board performed judicial duties such as hearing evidence, determining guilt and assessing damages.

It would appear, however, that the company's contentions were unfounded. First, the clear trend today is to place these regulatory matters in the hands of a governmental agency rather than burdening the courts