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The BRECKINRIDGE PROJECT

Initial Effort

REPORT VII

ENVIRONMENTAL, SOCIOECONOMIC, HEALTH AND SAFETY

VOLUME 2
ENVIRONMENTAL BASELINE REPORT

MASTER

ASHLAND SYNTHETIC FUELS, INC.
AIRCO ENERGY COMPANY, INC.

PREPARED FOR
UNITED STATES DEPARTMENT OF ENERGY
UNDER COOPERATIVE AGREEMENT
NO. DE-FC05-80OR20717

DISCLAIMER

The information and data contained in this report are the result of an economic evaluation and a preliminary design effort and because of the nature of this work no guarantees or warranties of performance, workmanship, or otherwise are made, either expressed or by implication.

INITIAL EFFORT REPORTS REFERENCE

<u>Report I</u> - Executive Summary

<u>Report II</u> - Breckinridge Project Design Basis

<u>Report III</u> - Specifications
Volume 1 - Specifications A through J
Volume 2 - Specifications K through W

<u>Report IV</u> - Process Units
Volume 1 - Plants 26, 27 and 1
Volume 2 - Plants 2, 3 and 4
Volume 3 - Plants 5, 6 and 17
Volume 4 - Plant 7
Volume 5 - Plants 8, 9 and 10
Volume 6 - Plant 12
Volume 7 - Plants 15 and 18

<u>Report V</u> - Utilities and Offsites Units
Volume 1 - Plants 19, 20, 21, 22, 23 and 30
Volume 2 - Plants 31, 32, 33 and 34
Volume 3 - Plant 35
Volume 4 - Plants 36, 37, 38, 39, 40, 41, 42 and 44

<u>Report VI</u> - Project Management Plan

<u>Report VII</u> - Environmental, Socioeconomic, Safety and Health
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Introduction

1.0 INTRODUCTION

Ashland Synthetic Fuels, Inc. (ASFI) and Airco Energy Company, Inc. (AECI) have recently formed the Breckinridge Project and are currently conducting a process and economic feasibility study of a commercial scale facility to produce synthetic liquid fuels from coal. The coal conversion process to be used is the H-Coal® Process, which currently is in the pilot plant testing stage under the auspices of the U.S. Department of Energy at the H-Coal® Pilot Plant Project near Catlettsburg, Kentucky. The preliminary plans for the commercial plant are for a 18,140 metric ton/day (24,000 ton/day) nominal coal assumption capacity utilizing the abundant high sulfur Western Kentucky coals. The Western Kentucky area offers a source of the coal along with adequate water, power, labor, transportation and other factors critical to the succesful siting of a plant. Various studies by Federal and State governments, as well as private industry, have reached similar conclusions regarding the suitability of such plant sites in Western Kentucky. Of the many individual sites evaluated, a site in Breckinridge County, Kentucky, approximately 4 kilometers (2.5 miles) west of the town of Stephensport, has been identified as the plant location. Actions have been taken to obtain options to insure that this site will be available when needed.

ASFI and AECI have initiated baseline environmental studies of the proposed site to characterize the existing environment. These will help determine the constraints placed on the location and design of the facilities within the plant due to the need to mitigate any adverse impacts of the plant. These baselines studies will enable ASFI and AECI to plan and proceed in accordance with the other requirements of the National Environmental Policy Act (NEPA) and other Federal and State environmental protection statutes.

This report contains an overview of the regional setting and results of the baseline environmental studies. These studies included collection of data on ambient air and water quality, sound, aquatic and terrestrial biology and geology. Data on historical and archaeological features are contained in a separate report. This report contains the following chapters; introduction, review of significant findings, ambient air quality monitoring, sound, aquatic ecology, vegetation, wildlife, geology, soils, surface water, and ground water.

Review of
Significant Findings

2.0 REVIEW OF SIGNIFICANT FINDINGS

Although data collection for certain disciplines has not been completed yet, the significant findings contained in this draft report have been summarized. Discussions are divided into air quality, sound, aquatic ecology, vegetation, wildlife, geology, soils, surface water and groundwater.

Air quality data from two quarters (six months) indicate the area has virtually no air quality related problems. All criteria pollutants show attainment by wide margins. Only one day with a maximum hourly average concentration above the 0.12 ppm standard occurred. The standard is attained when the expected number of days per calender year with maximum hourly average concentrations above 0.12 ppm is equal to or less than one, as determined by Appendix H of 40 CFR 50. Therefore, the area presently attains the ozone standard. Two trace element concentrations, nickel and beryllium, were higher than generally reported in the literature. Nickel values were higher for the August to October quarter. However, nickel values were within the range of ambient data for the SRC-I project. Similarly beryllium values which are high are also within the range report for the SRC-I project. It is our belief that the values for these parameters are normal background in this area and may be derived from weathered shale in the region. Further study is required to pinpoint the causes of these background levels.

Sound data at the site was measured once for six locations. Ambient sound values are low and are typical of rural areas.

Aquatic ecology program consisted of quarterly sampling for one year. Plankton, peryphyton, macrophytes, macroinvertebrates, mussels, adult and larval fishes were sampled. Also fish and mussel tissue was analyzed for selected organic compound and trace elements. No federally threatened or endangered species were collected during these surveys.

Ohio River plankton communities showed greater taxonomic richness and generally higher densities than those plankton communities observed in Town Creek and Bull Creek. The plankton communities representing these significantly different ecological areas were typical for their respective habitates.

Periphyton were collected from the Ohio River, Bull and Town Creeks. Little suitable habitat exist for periphyton in the Ohio River which limits their ecological importance, although a diverse community does exist. The periphyton are ecologically important in both creeks and are quite diverse.

Macrophytes surveys were conducted in three areas Ohio River, Bull and Town Creeks. However, macrophytes existed only in the embayment areas of both creeks where suitable habitat exist. Limited distribution and low diversity of macrophytes at the site is normal for these types of habitat.

Benthic macroinvertebrates collected from the Ohio River showed similar taxonomic composition and overall densities compared to other lower Ohio River studies. The most significant findings at the Ashland site were the distribution of taxonomic and functional groups relative to macroinvertebrate densities. Densities were generally higher and taxonomic diversity and functional feeding groups less complex near the Kentucky side of the river. Benthic communities showed the converse to this relationship near the Indiana side of the river. The mid-channel benthic macroinvertebrate communities generally showed reduced diversity and abundance of organisms although isolated exceptions to this relationship occasionally occurred. Town Creek and Bull Creek consistently had a more rich and diverse benthic fauna than the Ohio River.

The freshwater mussel resource was found to be very sparse along the Kentucky side of the Ohio River below the Bull Creek outlet. Mussels here represented only a scattered distribution and were comprised of relatively common Ohio River species. Freshwater mussels were not captured from Town Creek or Bull Creek.

When compared to other Ohio River pools studied by the Kentucky Fisheries Division, the Cannelton Pool and its backwater areas provides an outstanding sport fishery for largemouth bass and panfish. Larval fish (ichthyoplankton) densities were quite high in the embayment areas of Bull and Town Creeks which indicates their importants to the fisheries of the Ohio River.

Tissue analyses of fish and mussels revealed low amounts of most organic and inorganic constitutents. Copper appeared to be the only trace metal that was higher than found in fish tissue of other studies. Most constituents were found in greater amounts in mussels than in fish, and at times a few trace metals approached the levels found in the sediments. Thus, as found in several other studies, the levels of constituents in the biological compinent of the ecosystem were higher than in the water but usually less than in the sediments.

Vegetation and wildlife quarterly sampling is not complete. However, collections to date indicate a moderately productive area in the waste disposal areas and bottomland along Town Creek. No federally threatened or endangered species have been collected. However, specific sampling to document the presence or absence of the Indiana Bat has not been conducted.

The geology of the proposed plant site and waste disposal areas is typical of the Ohio River Valley. The plant is located on the alluvial deposits of the Ohio River. The proposed waste disposal areas are in the upper portions of Bull and Town Creeks. These areas are surrounded by Mississippian age formations of limestone and shale or sandstone and shale. The Rough Creek Fault Zone is the closest structural feature to the site and lies 50 km to the south.

A soil investigation program was conducted at the plant site and southern waste disposal area. Data from this program is presented inpart in this report. However, the full report is under separate cover. The plant site is covered by deep deposits of alluvial soils which are loamy. Residual soils characterize the waste disposal areas. Approximately 70 percent of the soils on the plant site are classified as prime farmland. Only a minor portion of the soils in the water disposal areas are classified as prime farmland.

Surface water and sediment were sampled quarterly from two stations on the Ohio River, and one station each on Bull and Town Creeks. The surface waters of the site were generally of good quality. However, this portion of the Ohio River is classified as "effluent limited". Constituents which exceeded standards in these water bodies include manganese, iron, mercury and fecal coliforms. Almost no diurnal variations on the Ohio River for pH, dissolved oxygen, conductivity occurred during the four quarterly samplings.

Sediments contained much higher levels of chemical constituents than did surface water. Although most organic and inorganic materials were present in low amounts, the trace metals cobalt, chromium, copper, nickel, and zinc were higher than many values reported in the literature. Most metal levels were lower in the creek sediments as compared to river sediments.

The major ground water aquifer on site is the Ohio River alluvial plain. Bedrock aquifers also exist in the sandstones and limestone around the waste disposal areas and result in springs and seeps which recharge Bull and Town Creeks. Ground water in the alluvial aquifer on site flows towards the Ohio River but is affected locally by Town Creek. The bedrock aquifers follow the regional trend towards the west. Ground water quality is generally good with occasional high values for manganese, iron and fecal coliforms bacteria. The latter is probably due to animal wastes in the re-change zone.

Ambient Air
Quality Monitoring

3.0 AMBIENT AIR QUALITY MONITORING

3.1 SUMMARY

Ashland Synthetic Fuels, Inc. and the Airco Energy Company, Inc. have joined together to build a coal to oil conversion plant in Kentucky. It will be located near the coalfields in Western Kentucky.

Baseline ambient air quality monitoring at the proposed site is required to satisfy the State and Federal requirements of the Prevention of Significant Deterioration (PSD) regulations under the Clean Air Act and the environmental impact assessment requirements of the National Environmental Policy Act. This report describes the monitoring plan being used to obtain representative air quality baseline data at the proposed site.

The proposed plant site lies in Breckinridge County, Kentucky, along the Ohio River and is presently primarily used for agriculture with some wooded lands. The climate and meteorology at the site are described in terms of the observations made at the Evansville, Indiana, National Weather Service Station. Existing air quality is characterized on the basis of existing monitoring data available for nearby areas since no such data is presently available for this remote rural site. On the whole, air quality at the site is uniformly good, with no ambient air quality standards likely to be exceeded.

Increments of air quality under the PSD program have been consumed in the area due to applications to construct by two major sources approximately 9.7 km (6 mi) to the west; however, both sources are to be well controlled and only a small fraction of the increments have been allocated to these sources. Sufficient increments are available in the area of the proposed coal liquefaction plant so that no maximum allowable increments are or will be exceeded by the plant construction.

The air quality monitoring will be by U. S. EPA Reference or Equivalent Methods for the criteria pollutants. Continuous analyzers will be used for sulfur dioxide, carbon monoxide, nitrogen dioxide and ozone, while particulate concentrations will be measured using the integrated sampling technique specified by the applicable EPA Method. Ambient concentrations of other air pollutants such as polyaromatic hydrocarbons, sulfates, trace metals and total reduced sulfur will also be determined in order that existing air quality may be fully characterized. Meteorological parameters are to be measured as well. The air quality and meteorological observations will be made in accordance with "Ambient Monitoring Guidelines for PSD", EPA-450/2-78-019, 1978.

The monitoring site location and instrument exposure have been selected so as to satisfy the criteria contained in the above U.S. EPA guidelines. All instrumentation will be operated and calibrated within the requirements of the guidelines, including daily zero and span checks on all analyzers. A description of the equipment and routine operating procedures has been provided in this report.

Quality assurance procedures to be used will be as defined by regulations under 40 CFR 58, Appendix B, "Quality Assurance Requirements for PSD Air Monitoring". Precision and accuracy statistics will be generated as provided for in the regulations and independent audits will be performed quarterly so as to assure generation of valid data.

Data will be reduced manually and quarterly reports containing all valid data generated over the previous monitoring period will be compiled and made available to the regulatory agencies. Summaries of the data, together with comparisons to the ambient standards and the required quality assurance data will also be included. The monitoring program commenced on July 1, 1980 and will continue for a period of one calendar year. The effort will provide baseline air quality data that can be used in complying with the air quality requirements of the applicable State and Federal laws and regulations.

3.2 INTRODUCTION

Ashland Synthetic Fuels, Inc. (ASFI) and Airco Energy Company, Inc. (AECI) have recently formed the Breckinridge Project and are currently conducting a process and economic feasibility study of a commercial scale facility to produce synthetic liquid fuels from coal. The basic conversion process to be used is the H-Coal Process®, which currently is in the pilot plant testing stage under the auspices of the U. S. Department of Energy at the H-Coal Pilot Plant Project near Catlettsburg, Kentucky. The preliminary plans for the commercial plant are for a 24,000 tpd nominal coal consumption capacity utilizing the abundant high sulfur Western Kentucky coals. The Western Kentucky area offers a source of the coal along with adequate water, power, labor, transportation and other factors critical to the successful siting of a plant. Various studies by Federal and State governments, as well as private industry, have reached similar conclusions regarding the suitability of such plant sites in Western Kentucky. Of the many individual sites evaluated, a site in Breckinridge County, Kentucky, approximately 2-1/2 miles west of the town of Stephensport, has been identified as the plant location. Actions have been taken to obtain options to insure that this site will be available when needed. ASFI and AECI are in the process of initiating ambient air quality monitoring as part of the baseline environmental studies of the proposed site to characterize the existing environment.

3.2.1 Purpose and Objectives

The Clean Air Act Amendments of 1977 (the Act) codified into law, and considerably expanded the Prevention of Significant Deterioration (PSD) of Air Quality Program initiated by the U.S. EPA in December 1974 as a result of legal action brought against it by the Sierra Club. Part C of the Act provides for a comprehensive preconstruction review and permit program to ensure that all air pollution sources with emissions of criteria pollutants in excess of 100 tons per year in certain specified categories, Table 3.1, comply with the control technology and incremental and ambient air quality requirements of the Act. The purpose is to minimize preventable degredation of air quality in areas where the air is cleaner than the level represented by the National Ambient Air Quality Standards (NAAQS). The currently effective U.S. EPA regulations governing the PSD program are contained in 40 CFR 52.21 and parallel requirements are contained in the Kentucky State Implementation Plan (SIP), Appendix I, 401 KAR Chapters 50 and 51.

These regulations require that each applicant for a PSD permit conduct one year of air quality monitoring for each criteria pollutant for which the source would be classified as major under the PSD regulations. The present regulatory monitoring provisions have been successfully challenged in the U.S. Court of Appeals for the District of Columbia, and remanded to EPA for reconsideration. New regulations were adopted on August 7, 1980 which was after the monitoring plan was approved. The EPA has obtained a stay from the Court to allow an orderly transition through continued enforcement of the existing regulations in the interim. ASFI constantly monitors changes to these regulations and plans to adopt revisions to the monitoring network as required.

The purpose of the air quality monitoring network under the PSD program

Table 3.1

28 SOURCE TYPES WITH POTENTIAL EMISSIONS OF 100 TONS PER YEAR, AND ALLOWABLE EMISSIONS GREATER THAN 50 TONS PER YEAR, AS FOLLOWS:

1. FOSSIL FUEL-FIRED STEAM ELECTRIC PLANTS OF MORE THAN 250 MILLION BRITISH THERMAL UNITS PER HOUR HEAT INPUT
2. COAL CLEANING PLANTS (WITH THERMAL UNITS)
3. KRAFT PULP MILLS
4. PORTLAND CEMENT PLANTS
5. PRIMARY ZINC SMELTERS
6. IRON AND STEEL MILL PLANTS
7. PRIMARY ALUMINUM ORE REDUCTION PLANTS
8. PRIMARY COPPER SMELTERS
9. MUNICIPAL INCINERATORS CAPABLE OF CHARGING MORE THAN 250 TONS OF REFUSE PER DAY
10. HYDROFLUORIC ACID PLANTS
11. SULFURIC ACID PLANTS
12. NITRIC ACID PLANTS
13. PETROLEUM REFINERIES
14. LIME PLANTS
15. PHOSPHATE ROCK PROCESSING PLANTS
16. COKE OVEN BATTERIES
17. SULFUR RECOVERY PLANTS
18. CARBON BLACK PLANTS (FURNACE PROCESS)
19. PRIMARY LEAD SMELTERS
20. FUEL CONVERSION PLANTS
21. SINTERING PLANTS
22. SECONDARY METAL PRODUCTION PLANTS
23. CHEMICAL PROCESS PLANTS
24. FOSSIL FUEL BOILERS (OR COMBINATIONS THEREOF) TOTALING MORE THAN 250 MILLION BRITISH THERMAL UNITS PER HOUR HEAT INPUT
25. PETROLEUM STORAGE AND TRANSFER UNITS WITH A TOTAL STORAGE CAPACITY EXCEEDING 300 THOUSAND BARRELS
26. TACONITE ORE PROCESSING PLANTS
27. GLASS FIBER PROCESSING PLANTS
28. CHARCOAL PRODUCTION PLANTS

is two-fold. The first is to establish the baseline air quality in the area if no PSD increment consuming sources have been permitted previously in the region. Maximum allowable increments have been established for particulate and sulfur dioxide by law. The second objective is to determine if allowable increments or the National Ambient Air Quality Standards (NAAQS) are being exceeded in the area. Since there has already been increment consumption in the site area due to the permitting of the Willamette Industries paper mill expansion at Hawesville and more is expected due to the reservation of the increments for the proposed Kentucky Utilities Power Plant in Hancock County, the purpose of the ASFI/AECI air quality monitoring will be to determine how much increment remains and whether ambient standards will be exceeded in the area of the plant site. An additional purpose will be the determination of the baseline air quality for criteria pollutants for which the increment scheme does not exist (CO, O_3, NO_x, Pb) and for non-criteria pollutants such as polyaromatic hydrocarbons, trace metals, reduced sulfur compounds and sulfates, which are air pollutants and which may require an air quality impact analysis under regulations to be promulgated in the future. The data will also be used to satisfy various governmental policies concerning environmental impact assessment under NEPA.

3.2.2 Ambient Air Monitoring Program

The preconstruction ambient air monitoring program at the proposed plant site will be implemented by a nationally known environmental consulting company under contract to ASFI/AECI. The essential elements of the monitoring plan will be:

a) Selection of the pollutants to be monitored

b) Design of the monitoring system network, including site selection

c) Installation and operation of the network

d) Quality assurance, and

e) Data processing and reporting.

The criteria pollutants for which ambient monitoring will be conducted are sulfur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2) and lead (Pb). All monitoring for criteria pollutants will be by continuous methods except TSP and Pb, which will be by integrated sampling methods. Total reduced sulfur (TRS) will also be monitored continuously.

In addition to monitoring the criteria air pollutants, on-site meteorological data will also be collected. Instrumentation will be provided to monitor wind speed, wind direction and temperature at the standard 10 meter tower height. These data will be useful in subsequent dispersion analyses and in determining sources of any abnormal air pollution concentrations.

Analyses of the TSP samples will be performed for Pb, various polyaromatic hydrocarbons (PAH's) and trace elements. Also, microscopic analyses will be performed to characterize the particulate for those days on which high loadings occur. The U.S. Department of Energy has recommended that samples be analyzed for the species listed in "Environmental Monitoring Handbook for Coal Conversion Facilities", ORNL-5319, prepared by the Oak Ridge National Laboratory. These species are:

Polyaromatic Hydrocarbons

2-Methyl naphthalene
Fluoranthene

2-Methyl fluoranthene
Pyrene
Benzo (c) phenanthrene
Chrysene
5-Methyl chrysene
Benzo (b) fluoranthene
Benzo (j) fluoranthene
Benzo (a) pyrene
o-Phenylene pyrene
Dibenz (a,c) anthracene
Dibenz (a,h) anthracene
Benzo (g,h,i) perylene
Dibenzothiophene

<u>Trace Elements</u>

Arsenic
Beryllium
Cadmium
Chromium
Cobalt
Iron
Mercury
Lead
Manganese
Nickel
Titanium
Vanadium
Zinc

<u>Others</u>

Sulfates

All ambient and meteorological monitoring will be done in accordance with the methods and procedures specified in "Ambient Monitoring Guidelines for Prevention of Significant Deterioration", EPA-450/2-78-019, May 1978. Air quality monitoring will be by approved methods considered to be the reference or equivalent methods under 40 CFR 50. For meteorological data, the equipment will be equivalent to National Weather Service specifications as required by the above referenced guideline. The quality assurance procedures will be as specified in 40 CFR 58, Appendix B, "Quality Assurance Requirements for Prevention of Significant Deterioration (PSD) Air Monitoring."

Operations are to be conducted such that data recovery exceeds 80% for air quality parameters and 90% for meteorological parameters, as required by the Federal guidelines. The data will be reduced to provide summary results as well as hard copy of the raw data. Additionally, it will be encoded in SAROAD format on magnetic tape for transmission to the permit reviewing authority. Considerable flexibility has been built into the overall program so as to allow reasonable changes to be made to the ongoing monitoring effort if necessitated by the changing PSD regulations.

3.3 STUDY AREA CHARACTERISTICS

3.3.1 Climate

The climate in the vicinity of the proposed source is essentially continental in character, being within the paths of storms in the belt of the westerly winds. It is therefore characterized by moderately cold winters and warm summers. Precipitation occurs with the systems which generally move from west to east. Warm moist air predominates during the summer months and the relative humidity remains consistently high (U.S. Department of Commerce, 1959).

The nearest first order National Weather Service climatological station is the Dress Regional Airport, Evansville, Indiana, which is 83 km (52 mi) northwest of the site. The normal mean monthly temperature at the Airport ranges from a low of 1°C (33°F) in January to a high of 26°C (78°F) in July (U.S. Department of Commerce, 1976). Temperatures at the proposed site are expected to show a similar variation.

Wind speeds and directions observed at the airport are shown in the wind rose in Figure 3.1. The predominant wind direction is south to southwest (23% of the time) and north to northwest (21% of the time). The proposed site is expected to show a similar pattern, although the presence of the nearby Ohio River valley may result in some localized channelization of surface winds.

Annual precipitation at Evansville averages 106.4 cm (41.6 in), with March experiencing the highest mean precipitation of 11.9 cm (4.7 in) and October the lowest of 6.4 cm, or 2.5 in (U.S. Department of Commerce, 1976). Precipitation in the form of snow or sleet can occur from October through April. Mean annual snowfall amounts to 32.8 cm (12.9 in), with the highest mean

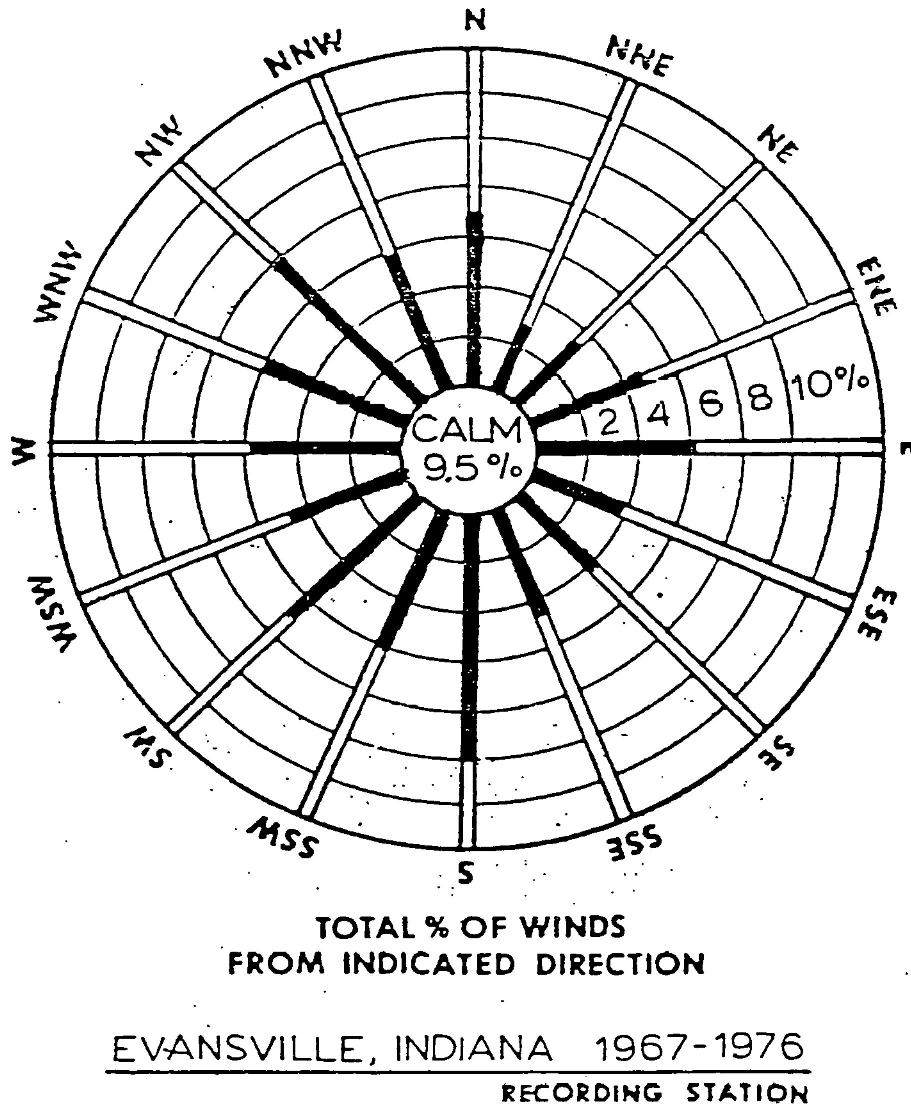


Figure 3.1 - Wind Rose for Evansville
Source: National Weather Service

monthly snowfall of 8.1 cm (3.2 in) occurring in January and February (U.S. Department of Commerce, 1976). The average number of days with measurable precipitation varies between 110 to 115 per year for the area of the proposed plant (Atlas of Kentucky, University Press of Kentucky, 1977).

Extended stagnation periods occur at the location of the plant. Figure 3.2 shows the number of stagnation days which occurred in connection with stagnation periods of four days or more during a thirty year period (Kentucky Revised SIP, 1979, after Korshover). The number of such days in the vicinity of the site are estimated to be 190 over the period 1936 to 1965, or an average of 6 stagnation days per year.

Heavy fogs are rare in Kentucky. Light morning fog in the Ohio River valley is a more common occurrence through the autumn and spring months. The average number of days with heavy fog varies between 8 and 17 during the year, with the majority occurring during the months of September through March inclusive (Kentucky Revised SIP, 1979).

Maximum mixing depths in the atmosphere vary during the day and by season. Average values from data by Holzworth[1], assembled in the Kentucky Revised SIP, 1979, for Paducah and Louisville are as follows in meters:

	Winter	Spring	Summer	Fall
Paducah	1050	1720	1810	1430
Louisville	950	1680	1760	1380

The proposed site is expected to be intermediate of these values.

[1] Holzworth, G.C., 1964, Estimates of Mean Mixing Depths in Contiguous United States. Monthly Weather Review, May.

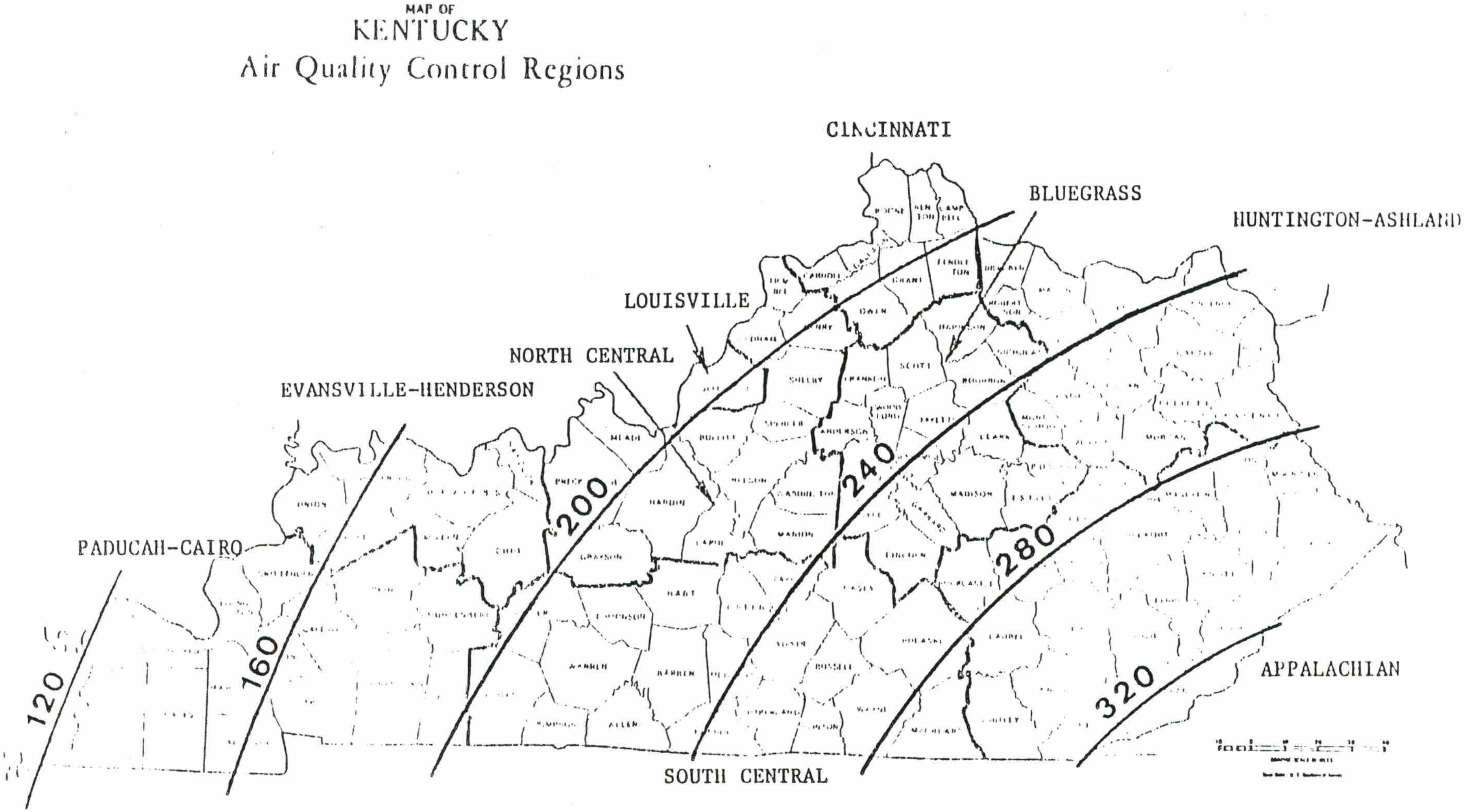


FIGURE 3.2 NUMBER OF STAGNATION DAYS, 1936-1965 (AFTER KORSHOVER)

Holzworth[2] has also defined episode days of limited dispersion as days during periods in which the mixing layer did not exceed 1500 m (4900 ft) and the wind in the mixing layer did not exceed 4 m/sec (9 mph) for at least two days (five consecutive radiosonde observations). Over a five year period, he found somewhat less than 50 such days over Western Kentucky. The number in the vicinity of the site is expected to be comparable.

3.3.2 Topography

The 1600 acre proposed site is located in northwestern Kentucky on the banks of the Ohio River at Mile 706. The Ohio River forms the border with the State of Indiana to the north and west. Part of a rural setting, the site is located in Breckinridge County, which is predominately agricultural, and borders Perry County, Indiana (Figure 3.3).

The nearest communities to the site are the hamlet of Stephensport, Kentucky, located about 5.6 km (3½ mi) northeast of the site and Cloverport, Kentucky which is 9.7 km (6 mi) to the southwest. The City of Owensboro, in Daviess County, is approximately 45 km (28 mi) to the west while Louisville, Kentucky, lies approximately 80 km (50 mi) to the northeast.

The site lies entirely in Breckinridge County, with the Ohio River looping around it to the west and north approximately. The topography of the site is flat, ranging from 122 to 131 m (400 to 430 ft) above mean sea level along the Ohio River, and rising gradually to over 210 m (700 ft) towards the southeast

[2] Holzworth, G.C., 1970, Meteorological Potential for Urban Air Pollution in the Contiguous United States. Presented at the Second International Clean Air Congress, Washington, D.C.

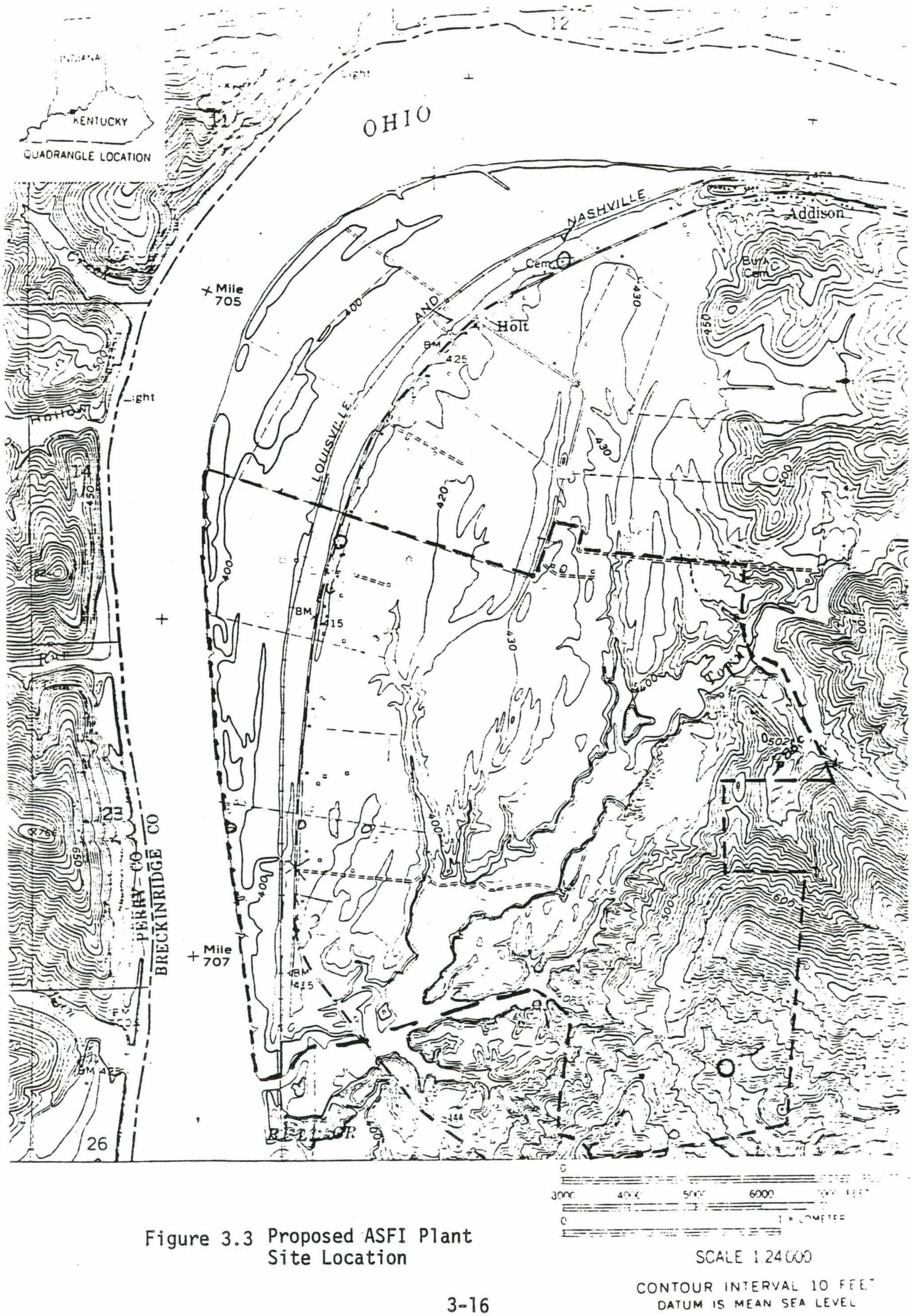


Figure 3.3 Proposed ASFI Plant Site Location

corner of the site. The Ohio River is at 116.7 m (383 ft) above mean sea level. The land across the Ohio River in Perry County, Indiana, to the west of the site rises steeply from the river to elevations of over 210 m (700 ft). It is part of the Hoosier National Forest. The land to the east and south of the site in Breckinridge County, Kentucky, also increases in elevation to over 244 m (800 ft).

Drainage from the area is to the Ohio River and Town Creek, which flows southeast through the site and into the Ohio River at the southern boundary of the site. A number of small agricultural ponds dot the site area as well. In summary, the basic site topography is flat bottomland, resulting from originally being part of the Ohio River uncontrolled floodplain, with uplands away from the river. The Ohio River is now controlled by the Cannellton Locks and Dam, approximately 26 km (16 mi) downstream.

3.3.3 Land Use

The predominant activity at the project site is agriculture. Approximately two-thirds of the site acreage consists of farm fields and farm ponds with some of this in use as road and railway rights of way. The remainder of the site is wooded upland, particularly towards the southeast corner of the site.

The major crops grown in the area are corn, soybeans, wheat and tobacco. This is consistent with the agricultural patterns in this part of the State where low-lands support agriculture and uplands are in timber. The change in use from agricultural to industrial activity would not cause a displacement of any significant population since the site had previously been acquired by ASARCO for a smelter operation. All the dwellings, mostly along Kentucky 144, had previously been vacated when the inhabitants sold their property to the previous industrial owner. There will, therefore, be no significant change in terms of displacement of people from conditions that have existed for over a decade.

The nearest major industrial activity is in Hancock County to the west. An existing paper mill and a proposed power plant lie approximately 9.5 km (6 mi) to the west at Skillman Bottoms along the Ohio River. Breckinridge County itself has only one major source, a rock quarry, approximately 16 km (10 mi) to the southwest of the plant site. There are no other major industrial facilities in the vicinity of this remote, rural site.

3.3.4 Current Air Quality Status

The proposed project site lies in the North Central Air Quality Control Region (AQCR), an intrastate airshed which has few localized air pollution problems and relatively good ambient air quality. This is evidenced from the low priority designations assigned the AQCR in 1971 for the various criteria pollutants pursuant to 40 CFR 51, Section 3 (Ky. Revised SIP, 1979). Since the Commonwealth has largely abandoned the "example region" concept in developing the current implementation plan and gone to the more exact county by county system, the priority designations are largely academic and only reflect conditions at the time of designation, viz, 1971.

Owing to the absence of any significant source in Breckinridge County, and the lack of the potential for air pollution in the largely rural area, there are no air quality monitoring sites operated by the Kentucky Division of Air Pollution Control in this county. There is, therefore, no past air quality monitoring data available from governmental agencies. Kentucky Utilities Company (KU), a public utility has had an air quality monitoring program for PSD purposes in the general area since July 1, 1979, but the data collected to date is currently unavailable to ASFI/AECI and the State. The monitoring is only for total suspended particulates (TSP), sulfur dioxide (SO_2), and ozone (O_3) and by itself inadequate for PSD purposes because of the court decision in Alabama Power et al. v. Costle.

Breckinridge County is either attainment or cannot be classified due to lack of data for all of the criteria pollutants, 401 KAR 51.010. It is, therefore, wholly a Class II area for purposes of PSD review, Section 162(b) of the Act. The nearest Class I area is Mammoth Cave National Park, approximately 80 km (50 mi) to the south of the proposed site. Moderate growth of new emission sources is allowed in PSD Class II areas whereas growth affecting Class I (pristine) areas is more severely restricted.

Based on ambient monitoring and/or modeling data from 1975 to 1977, the attainment status designations in 40 CFR 81.300 show that all counties in Kentucky and Indiana adjacent to Breckinridge County are either attainment or not classifiable. This includes Hancock, Ohio, Grayson, Hardin, and Meade Counties in Kentucky and Perry County in Indiana. Non-attainment areas for the pollutants specified and their distances from the project site are as follows:

Owensboro in Daviess County, Kentucky - 48 km (30 mi) west (TSP,SO_2)

Muhlenberg County, Kentucky - 64 km (40 mi) south (TSP, SO_2)

Shepherdsville in Bullitt County, Kentucky - 40 km (25 mi) east (TSP)

Jefferson County, Kentucky - 48 km (30 mi) northeast (TSP, SO_2, CO, O_3)

All the non-attainment areas in Indiana are even farther to the west and north and, therefore, outside the area of impact of the proposed plant.

The latest annual air quality report available for the Commonwealth of Kentucky is for 1978. Based on that data for the counties adjacent to Breckinridge, it is possible to obtain some characterization of the background levels which may exist at the monitoring site. Table 3.2 lists the statistics for the monitoring stations nearest the site in each Kentucky county bordering Breckinridge County. Table 3.3 presents the Kentucky ambient air quality standards and Table 3.4 the applicable maximum allowable increments under the PSD program.

The maximum recorded ambient concentrations for SO_2, NO_2, Pb and TSP are respectively 16.7, 38.8, 36 and 87 percent of the corresponding ambient standards. No statistics for ozone or carbon monoxide are available for contiguous counties but Owensboro, the nearest urban area, is attainment for both pollutants, although the ozone levels are 99% of the NAAQS. Levels of these transportation related pollutants are expected to be well below the standards at the remote site chosen for the ASFI/AECI plant.

Sulfur dioxide air quality modeling for all existing sources within 60 km (37 mi) of the KU Power Plant site was performed by KU in their permit application, dated July 26, 1978. (Preconstruction Review and Preliminary Determination by Roger Cook, Kentucky Division of Air Pollution Control, October 12, 1979). A listing of these sources is contained in Table 3.5. Figure 3.4 is the isopleths of the predicted annual mean SO_2 concentrations ($\mu g/m^3$) for all major existing sources in the vicinity of the KU Hancock County site. This location is only 9.6 km (6 mi) west of the ASFI/AECI Breckinridge County site. The modeling indicates that the entire proposed site area lies between

Table 3.2 Air Quality Statistics for Contiguous Areas.

Sulfur Dioxide Statistics
(in micrograms per cubic meter)

Site Address and No.	Reporting Period	No. Obs.	24-hour Maximum	3-hour Maximum	Annual Mean
Hawesville Meth. Ch., Hancock County (4127)	1/78 - 12/78	54	31.2		5.9
U.S. 62, Beaver Dam, Ohio County (4207)	1/78 - 12/78	375	68.1	201.7	14.2
City Swim Pool, N. Elizabethtown, Hardin County (7138)	1/78 - 11/78	46	41.7	--	8.6

Table 3.2 (Continued)

Nitrogen Dioxide Statistics
(in micrograms per cubic meter)

Site Address and No.	Reporting Period	No. Obs.	Annual Mean
Hawesville Methodist Church, Hancock County (4127)	1/78 - 12/78	52	26.3
City Swim Pool, North Elizabethtown, Hardin County (7138)	2/78 - 11/78	43	33.8

Lead Statistics
(in micrograms per cubic meter)

Site Address and No.	Reporting Period	No. Obs.	Quarterly Maximum
Hawesville Methodist Church, Hancock County (4127)	1/78 - 12/78	11	0.42
Beaver Dam, U.S. 62, Ohio County (4207)	1/78 - 12/78	11	0.32
City Swim Pool, North Elizabethtown Hardin County (7138)	1/78 - 12/78	8	0.46
Fire Dept., Elm St., West Point Hardin County (7234)	7/78 - 12/78	6	0.54

Table 3.2 (Continued)

Total Suspended Particulates Statistics
(in micrograms per cubic meter)

Site Address and No.	Reporting Period	No. of Observations	24 Hour			Annual
			Max	2nd Max	Times >150	Geom. Mean
Hawesville Methodist Church, Hancock County (4127)	1/78 - 12/78	57	163	131	1	67
U.S. 62, Beaver Dam, Ohio County (4207)	1/78 - 12/78	52	135	123	0	58
Leitchfield, E. Main Street, Fire Station, Grayson County (7141)	1/78 - 11/78	40	124	110	0	46
N. Elizabethtown, City Swim Pool, Hardin County (7138)	1/78 - 11/78	45	138	96	0	53
West Point Fire Dept. Elm Street, Hardin County (7234)	7/78 - 12/78	28	131	111	0	--

Table 3.3 AMBIENT AIR QUALITY STANDARDS

The following air contaminant concentrations shall apply at any single point location:

CONTAMINANT	PRIMARY STANDARD	SECONDARY STANDARD
Sulfur Oxides (Sulfur Dioxide) - μg/m³		
Annual Arithmetic Mean, not to exceed	80 (0.03 ppm)	---
Maximum Twenty-Four-Hour Average	365 (0.14 ppm)†	---
Maximum Three-Hour Average	---	1300 (0.50 ppm)†
Particulate Matter - μg/m³		
Annual Geometric Mean, not to exceed	75	60‡
Maximum Twenty-Four-Hour Average	260†	150†
Carbon Monoxide - mg/m³		
Maximum Eight-Hour Average	10 (9 ppm)†	Same as primary
Maximum One-Hour Average	40 (35 ppm)†	Same as primary
Ozone - μg/m³		
Maximum Average	235 (0.12 ppm)⊖	Same as primary
Hydrocarbons - μg/m³◊		
(measured as CH_4 and corrected for Methane)		
Maximum Three-Hour Morning Average (6-9 A.M.)	160 (0.24 ppm)†	Same as primary
Nitrogen Dioxide - μg/m³		
Annual Arithmetic Mean, not to exceed	100 (0.05 ppm)	Same as primary
Lead - μg/m³		
Maximum Arithmetic Mean averaged over a calendar quarter	1.5	Same as primary
Hydrogen Sulfide - μg/m³		
Maximum One-Hour Average	---	14 (0.01 ppm)†
Gaseous Fluorides - (expressed as HF) - μg/m³		
Annual Arithmetic Mean, not to exceed	400 (0.5 ppm)	---
Maximum One-Month Average	---	0.50 (0.60 ppb)†
Maximum One-Week Average	---	0.80 (0.97 ppb)†
Maximum Twenty-Four-Hour Average	800 (1.0 ppm)†	2.86 (3.50 ppb)†
Maximum Twelve-Hour Average	---	3.68 (4.50 ppb)†
Total Fluorides - ppm		
Dry weight basis (as fluoride ion) in and on forage for consumption by grazing ruminants		
The following concentrations are not to be exceeded:		
Average concentration of monthly samples over growing season (not to exceed 6 consecutive months)	---	40 ppm (w/w)
Two-Month Average	---	60 ppm (w/w)
One-Month Average	---	80 ppm (w/w)
Odors		At any time when 1 volume unit of ambient air is mixed with 7 volume units of odorless air, the mixture must have no detectable odor.

Footnotes:

† This average is not to be exceeded more than once per year.

‡ This secondary annual standard is to be used as a guide in assessing implementation plans to achieve the [illegible] four (24) hour standard.

⊖ The standard is attained when the expected number of days per calendar year with maximum hourly [illegible] concentrations above 0.12 ppm (235 μg/m³) is equal to or less than 1, as determined by Appendix H of 40 CFR 50.

◊ This standard is to be used as a guide in devising implementation plans to achieve photochemical oxidant stand[illegible]

Source: Kentucky State Implementation Plan, Appendix I, 401 KAR 53:010.

Table 3.4 Maximum Allowable Concentration Increments for SO_2 and TSP Under the PSD Regulations[a]

Pollutant	Maximum Allowable Concentration Increments ($\mu g/m^3$) Class I	Class II	Class III
Sulfur Dioxide (SO_2)			
Annual Arithmetic Mean	2	20	40
24-Hour Maximum[b]	5	91	182
3-Hour Maximum[b]	25	512	700
Total Suspended Particulates (TSP)			
Annual Geometric Mean	5	19	37
24-Hour Maximum[b]	10	37	75

[a]"EPA Regulations on Approval and Promulgation of Implementation Plans". 40 CFR 52.21, as amended by 42 FR 57459, November 3, 1977 pursuant to the 1977 Clean Air Act Amendments.

[b]May be exceeded once per year for that time period.

Table 3.5 INVENTORY OF EMISSION SOURCES WITHIN A 50-KILOMETER RADIUS OF THE PROPOSED HANCOCK POWER PLANT

SOURCE NAME	COUNTY	UTM COORDINATES (km)	TOTAL POLLUTANT EMISSION RATES ($\geq$ 100 tons/year) TSP	SO_x	NO_x	HC	CO
Mulzer Crushed Stone	Crawford	556.7 E 4,220.5 N	518				
United Wood Products	DuBois	520.0 E 4,230.0 N				124	
Mulzer Crushed Stone	Perry	541.0 E 4,209.3 N	475				
Tell City Chair Co.	Perry	520.1 E 4,199.1 N	125			388	
General Electric	Perry	520.9 E 4,201.3 N					118
Dale-Wood Mfg.	Spencer	500.7 E 4,223.7 N				205	176
Rockport Sanitary Pottery Inc.	Spencer	495.2 E 4,194.0 N	467				
White Stone Co.	Breckenridge	543.0 E 4,179.9 N	988				
Kentucky Stone Co.	Breckenridge	561.2 E 4,194.0 N	159				
W. R. Grace Co.	Daviess	495.9 E 4,184.6 N				1,084.6	
Glenmore Distilling Co.	Daviess	492.1 E 4,181.1 N	•	379.2		1,031.2	
Owensboro Brick and Tile	Daviess	487.3 E	1,917.5	103.8	39.471.0	516.0	2,919.6

Table 3.5 Continued.

SOURCE NAME	COUNTY	UTM COORDINATES (km)	TOTAL POLLUTANT EMISSION RATES (≥ 100 tons/year) TSP	SO_x	NO_x	HC	CO
O.M.U. Station 1	Daviess	492.0 E 4,181.0 N		853.3	112.0		
O.M.U. Elmer Smith	Daviess	494.7 E 4,183.0 N	1,756.7	72,103.1	15,780.6	157.9	526.1
Fleischmann Distilling	Daviess	487.6 E 4,181.6 N		529.6		1,195.8	
Murphy-Miller Co.	Daviess	492.0 E 4,180.0 N				107.4	
Field Packing Co.	Daviess	488.2 E 4,181.1 N	1,242.8	1,243.4	147.8		
Owensboro Grain Co.	Daviess	491.2 E 4,180.8 N	583.5				
Chevron USA	Daviess	491.9 E 4,180.9 N				271.4	
Medley Distilling Co.	Daviess	487.8 E 4,181.0 N		710.6		1,018.5	
Southern States Coop Inc.	Daviess	494.2 E 4,182.5 N				246.7	
Green Coal Co.	Daviess	500.3 E 4,162.5 N	680				
Western Kraft Paper Group	Hancock	527.0 E 4,193.0 N			174.0		
Big Rivers Electric	Hancock	518.3 E 4,201.5 N	1,505.0	97,700.0	13,284.0	221.0	737.0
National Southwire Aluminum	Hancock	518.7 E 4,199.2 N	958.0				
Western Kraft Paper Group	Hancock	527.6 E 4,193.9 N	163.0	306.0			

Table 3.5 Continued.

SOURCE NAME	COUNTY	UTM COORDINATES (km)	TOTAL POLLUTANT EMISSION RATES (≥ 100 tons/year)				
			TSP	SO_x	NO_x	HC	CO
Hancock Co. Ready Mix	Hancock	519.3 E 4,208.8 N	105.0				
Martin Marietta Aluminum	Hancock	509.9 E 4,199.8 N	891.0		253.0	756.0	
Olin Corp.	Meade	577.1 E 4,206.0 N	131.0	7,325.0	2,008.2	9,112.8	187.4
Flinkote Co.	Meade	562.1 E 4,217.9 N	677.0				
State Contracting and Stone Co.	Ohio	524.7 E 4,174.9 N	613.0				
Dunaway Timber Co.	Ohio	525.5 E 4,164.7 N					254.0
State Contracting and Stone Co.	Ohio	516.1 E 4,152.5 N	625.0				
Rockport Power Plant[a]	Spencer	497.0 E 4,195.0 N	2,620.0	131,821.0	b	b	b
Martin Marietta Aluminum[a]	Hancock	513.8 E 4,200.5 N	387.1	31.8	267.8	576.2	53.4
Tell City Chair[a]	Perry	520.1 E 4,199.1 N	0.35				

Note: All values in tons per year.

[a]Point sources granted construction permits since January 6, 1975, or having permit applications submitted prior to August 1, 1978. Controlled emissions listed.

[b]Data not available.

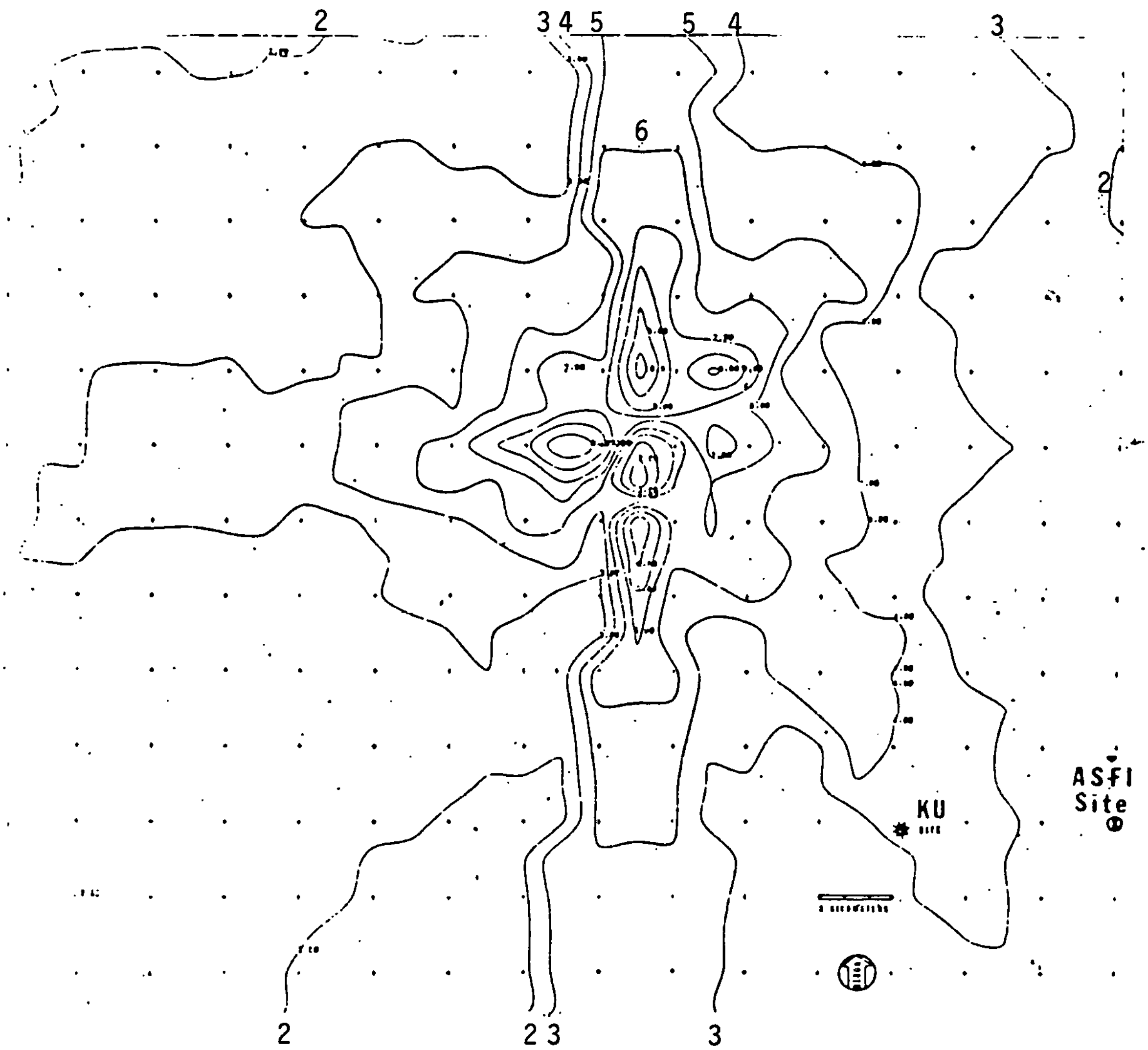


Figure 3.4 Isopleths of predicted annual mean SO_2 Concentrations ($\mu g/m^3$) from major existing point sources in the vicinity of the ASFI plant site.

Source: Preconstruction Review and Preliminary Determination, Kentucky Utilities Co., Hancock Power Plant, KY Division of Air Pollution Control, Oct. 12, 1979.

the 2 and 3 $\mu g/m^3$ annual SO_2 mean isopleths resulting from existing major sources prior to any construction of PSD increment consuming sources. The nearest State operated monitor at Hawesville shows an annual SO_2 mean of 5.9 $\mu g/m^3$ for 1978 (Table 3.2). The maximum concentrations due to modeling of all new PSD sources to the west amounts to less than 5 $\mu g/m^3$ for the SO_2 annual mean. The SO_2 air quality in the site vicinity is, therefore, fairly uniform and between 5 and 15 $\mu g/m^3$ for the annual SO_2 mean. This compares very favorably with the SO_2 NAAQS of 85 $\mu g/m^3$, annual average.

For particulate matter, the Willamette Industries permit application ("Preconstruction and Final Determination", by Sam Bruntz, Kentucky Division of Air Pollution, April 30, 1980) contains 1979 air quality monitoring data for particulate matter. Although both monitoring locations near the paper mill were affected by the existing mill operations, the following statistics for TSP in $\mu g/m^3$, were generated:

	Site 1	Site 2
Highest Concentration	126	138
Second Highest Concentration	115	127
Annual Geometric Mean	36	56

These show compliance with the 75 $\mu g/m^3$ annual and 150 $\mu g/m^3$ daily average standards. Maximum annual and daily increment consumption have been 3.1 and 9.4 $\mu g/m^3$ respectively, due to other PSD sources (Ibid). The location of the Willamette Industries paper mill is on the eastern edge of considerable industrial activity and also affected by the towns of Hawesville, Kentucky and Tell City, Indiana. The TSP levels at the remote Breckinridge County site cannot, therefore, be directly interpolated from the above data. It is sufficient to indicate, however, that the TSP levels 9.6 km (6 mi) further t(

the east and in a remote forested and agricultural area are likely to be considerably lower. It is likely that values somewhat lower than the above mentioned Willamette Site 1 would exist at the Breckinridge County plant site.

In summary, the ambient air quality at the ASFI/AECI plant site is generally good with no ambient standard exceedances having been recorded nearby. Increment consumption for SO_2 and TSP up to the present have been very small and no increments are being exceeded near the plant site. The remoteness of the site from any large major source results in fairly uniform air quality over the entire site area. Transportation related air pollutants such as CO, NO_2, O_3, and Pb are also not expected to show elevated levels due to the lack of any significant traffic or populated areas in the vicinity of the proposed plant site.

3.4 MONITORING NETWORK

3.4.1 Site Selection

The purposes of the ambient monitoring have been previously discussed in Section 3.2 as being the determination of any exceedance of PSD air quality increments or the ambient standards together with baseline determination for other pollutants at or near the proposed plant site.

The only existing major source in the impact area of the proposed plant site is the existing Willamette Industries paper mill near Hawesville, 6 mi (9.6 km) to the west. The proposed KU Power Plant and the paper mill expansion, which are both subject to PSD requirements, are also at this same location.

Ambient air quality modeling was performed by the Kentucky Utilities Company and Willamette Industries in support of the respective PSD permit applications. Particulate preconstruction monitoring was also conducted by Willamette Industries at two sites for a one year period ending on January 18, 1980. The results, as summarized in Section 3.3, indicate that the air quality at the Breckinridge County site is fairly uniform and unaffected by the existing major sources or by those now being built approximately 9.6 km to the west. The existing air quality at the site, therefore, based on the above mentioned air quality analyses and data, as well as existing land use, properly classifies the site as a remote rural area for monitoring purposes under the EPA PSD monitoring guidelines, EPA-450/2-78-019 (p. 14).

Table 3 of the same EPA guideline document lists typical network sizes, site locations and monitoring frequency and duration for a number of source categories. In general, one site is considered sufficient for remote areas (Ibid, p. 10). ASFI/AECI, based on the recommendation of the consultant, therefore, proposes to establish one monitoring site for the air quality and meteorological monitoring network.

The guidelines further go on to state (Ibid, pp. 15-16) that on-site monitoring is generally satisfactory for remote areas although the area of maximum impact is the preferred location. Air quality modeling by the EPA CRSTER model using the stack parameters shown in Table 3.6 was performed for the proposed ASFI/AECI plant. 1973, 1974, 1977 and 1978 meteorological data for the Dress Regional Airport at Evansville, Indiana was available and, therefore, used. Since the exact stack locations are not yet known, all the stacks were collocated, even though this gives a higher value than if the stacks were distributed. The results indicate that the maximum ground level concentrations due to the plant occur at the points in Indiana along the ridges bordering on the Ohio River. The general direction of these receptors is 240 to 300 degrees from the north and approximately 1.5 km from the stack location. Each of these receptors is on steeply sloping land which is inaccessable for monitoring purposes. Being generally forested, with no electric power nor roads existing in this section of the Hoosier National Forest, the area is further cut off from the plant site due to the nearest Ohio River crossing being downstream at Hawesville. The EPA monitoring guidelines, however, provide for flexibility in remote and inaccessable areas by allowing concessions in the site location. Alternate sites are considered appropriate if the purposes of the ambient monitoring are not lost in the process (Ibid, p. 15). Consideration of these factors in selecting the monitoring site are discussed next.

Table 3.6 STACK PARAMETERS AND EMISSION RATES FOR A 60,000 B/D EXXON DONOR SOLVENT PLANT (ON-SITE ELECTRICTY GENERATION) WITH EMISSIONS CONTROLLED

Location	Description of Unit	Flow Rate (all stacks) (m^3/s)	Temp. (C^o).	Stacks	Stack Height (m)	Diameter (m)	Velocity (m/s)	Emissions (all stacks) (g/s) Particulates	SO_2	NO_2
1	Coal drier	56	75	3	20	1.9	20	3.0	17	5.4
2	Liquefaction Furnace	195	350	2	25	3.15	25	0.64	76	22
3	Solvent hydrogenation feed preheat furnace	14	75	2	25	1.34	10	0.10	10	3.0
4	Hydrogen reformer furnace	123	250	4	25	2.5	25	0.96	110	32
5	Sulfur plant tail gas incinerator	41	120	2	65	2.28	30	—	4.1	0.46
6	Utility boiler	48	220	1	20	2.46	10	0.10	11	3.4
7	Power plant	394	220	1	50	4.48	25	4.7	130	92

No violations of ambient air quality increments for TSP and SO_2 are expected in the area. Table 3.7 has been compiled from the modeling results for the Kentucky Utilities Company and the Willamette Industries permit applications (Preconstruction Review and Final Determination, Appendix C, by Sam Bruntz, Kentucky Division of Air Pollution, dated April 30, 1980) as well as the CRSTER modeling for the proposed plant. It shows that none of the increments allowable will in fact be exceeded. Therefore, the necessity to monitor at the point of maximum increment consumption is not critical. All incremental consumptions can be documented by modeling.

With regards to the NAAQS, the known background and monitored values in the plant vicinity are only a small fraction of the SO_2, CO, and NO_x standards. The modeling shows that the actual emissions from the plant would cause none of these ambient standards to be threatened. Only ozone and TSP concentrations appear to be of concern in determining the location of the site since the nearest monitors have recorded values up to 99 and 87 percent of the respective NAAQS. Since ozone is an area-wide problem, the monitoring site location may be anywhere within the property area for obtaining background concentrations of this pollutant at the plant site.

Particulate matter is the only pollutant which would be crucial in determining monitoring site location. The CRSTER air quality modeling shows that the maximum 24-hour and annual TSP concentrations would occur along the hills in Indiana across the Ohio River. The most appropriate monitoring site would, therefore, be at those receptors. The monitoring station cannot, however, be located on the steep cliffs nor in the floodplain or river areas due to lack of access and utilities. Site selection is further complicated by the Louisville and Nashville Railroad and Kentucky Highway 144 being at the edge of the

Table 3.7 Maximum Increment Consumption Due to Previously Permitted PSD Sources Compared to the Impact of the Proposed ASFI/AECI Plant.

Sources Modeled	Orientation of Maximum Receptor To Applicant	Pollutant	Averaging Time	Increment Consumed	Allowable Consumption
Martin Marietta, Lewisport, KY	9.13 km, 290°	SO_2	Annual	4.4 $\mu g/m^3$	20 $\mu g/m^3$
Indiana & Michigan, Rockport, IN					
Kentucky Utilities Hawesville, KY	23.5 km, 288°	TSP	Annual	3.1 $\mu g/m^3$	19 $\mu g/m^3$
Western Kraft Paper Group Hawesville, KY					
Kentucky Utilities	10.7 km, 273°	SO_2	24-hours	29.79 $\mu g/m^3$	91 $\mu g/m^3$
Willamette Industries	8.1 km, 287°		3-hours	42.69 $\mu g/m^3$	512 $\mu g/m^3$
Willamette Industries	16.35 km, 281°	TSP	24-hours	9.40 $\mu g/m^3$	29 $\mu g/m^3$
ASFI (Proposed) Addison, KY	1.5 km, 300° 1.5 km, 240°	TSP	Annual 24-hours	1.28 $\mu g/m^3$ 19.79 $\mu g/m^3$	Not Known At Present
	7.0 km, 360° 7.0 km, 350° 1.5 km, 220°	SO_2	Annual 24-hours 3-hours	2.37 $\mu g/m^3$ 37.00 $\mu g/m^3$ 182.40 $\mu g/m^3$	Not Known At Present

floodplain. The only potentially valid monitoring sites, therefore lie to the east of Kentucky Highway 144, with a separation from the roadway so as to avoid interference as required by the monitoring guidelines (Ibid, pp. 17-26).

Based on guidance received from the Division of Air Pollution Control, the best site location would be one in the general direction of the annual TSP maximum. The results of the CRSTER modeling for that pollutant were as given below:

Met. Data Year	Annual Mean Maximum ($\mu g/m^3$)	Direction (degrees)	Distance (km)
1973	1.28	300	1.5
1974	1.16	260	1.5
1977	1.42	240	1.5
1978	1.34	240	1.5

The best location for the monitoring site, therefore, lies between the directions 240 to 300 degrees in relation to the stack and just east of Kentucky Highway 144. The exact description of the site and its layout are contained in the following section of this report.

3.4.2 Site Location and Description

On the basis of the analysis in Section 3.4.1 of this section, a survey of potential monitoring sites was made. The site finally selected as meeting all the criteria is shown in Figure 3.5. The Universal Transverse Mercator (UTM) coordinates of the proposed station are 4193.93 N, 536.09 E. This location is in the 260° direction from the tenative stack location and 0.5 km (0.3 mi) from it.

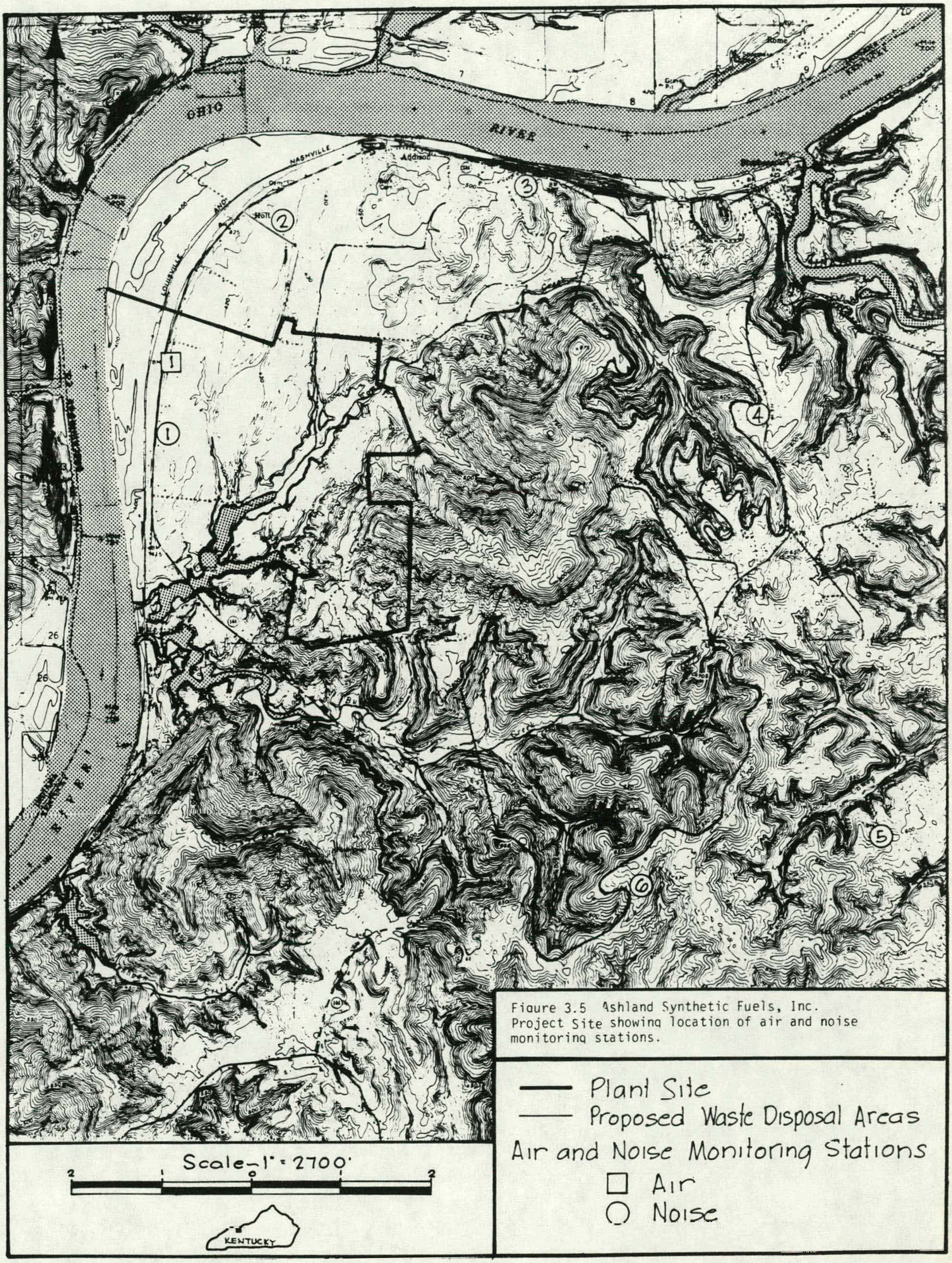


Figure 3.5 Ashland Synthetic Fuels, Inc.
Project Site showing location of air and noise monitoring stations.

The equipment trailer will be located approximately 55 m (175 ft) east of Kentucky Highway 144 at the edge of a paved parking area associated with a nearby abandoned house. The 4.3 m (15 ft) high house is the nearest structure but will not constitute an obstruction as it will be lower than the analyzer probe and only 0.3 m (1 ft) above the high volume sampler inlet. The house lies to the southwest at a distance of 20 m (65 ft) from the proposed trailer site. There is a small garage approximately 3 m (10 ft) high at the southern end of the house and approximately 24 m (75 ft) from the site. Two small trees, approximately 5 m (16 ft) tall, stand beyond the garage to the south. These will be approximately 30 m (90 ft) from the trailer, and, therefore, will not screen the particulate samplers.

The intake for the SO_2, NO_2, CO, O_3, and TRS analyzers will be located 5 m (16 ft) above ground level, and 2 m (6 ft) above the equipment trailer. The high volume particulate samplers will be located on top of the trailer and approximately 4.5 m (14 ft) above ground level. The wind and temperature sensors will be on the 10 m (32 ft) tower which will be at the north end of the equipment shelter. It will be located at least 24 m (75 ft) from the nearby house so as to satisfy the criteria for open level terrain.

The monitoring layout will provide good exposure for all sensors and minimize potential interference due to the separation from the nearby structures and roadway. The modeling indicates that the highest pollutant concentrations will occur with winds from the northeast to southeast and the layout will present full exposure in this situation. Furthermore, the presence of the nearest industrial sources to the west would presumably result in highest man-made pollutant levels being associated with winds from the west to northwest. The monitoring site layout will provide full exposure for this situation also. The land to the east, north, and south of the monitoring site is cultivated. The presence of agricultural activity will be recorded in the site diary by the local operator and, therefore, together with the wind and particulate characterization data, provide documentation for identifying invalid data. The traffic on Kentucky Highway 144 is minimal and the highway is paved. When added to the separation from the road and the elevation of the analyzer and sampler inlets, this should result in minimal roadway interference with the air quality measurements.

Site preparation and equipment mobilization will commence after approval for using this location has been granted by the Kentucky Division of Air Pollution Control. It is believed that the site will provide representative ambient air quality baseline data for the area of the proposed plant.

3.5 SYSTEM DESIGN AND SPECIFICATIONS

3.5.1 Air Quality Instrumentation

The monitoring unit will consist of a 8' x 14' x 8' mobile office trailer with white aluminum exterior and wood-paneled interior. It will be provided with electric heat and air-conditioning. The trailer will be insulated on six sides to provide a stable environment for the instrumentation. The monitoring instrumentation will be installed in the unit and tested prior to moving it to the site.

Once on site, the trailer will be protected against wind and frost-heave by anchoring to concrete footers or railroad ties buried vertically in the ground. These will also support the unit and provide a level and stable platform for the instruments.

The specific air quality instrumentation to be used will be EPA approved reference or equivalent methods. The make, model number and principle of operation will be as shown in Table 3.8. All the analyzers and other equipment will be inside the trailer except for the two TSP high volume samplers. These latter instruments will be mounted on the trailer roof. The entire installation will be protected against theft and vandalism by an 8' tall chain link security fence with a locked gate. The trailer itself will also be locked.

3.5.2 Meteorological Instrumentation

The meteorological instrumentation will be mounted on a standard 10-meter tower manufactured by the Climet Instruments Company. The wind speed sensor

Table 3.8 Air Quality Monitoring Instrument Description

Pollutant	Manufacturer	Model No.	Year of Manufacture	Principle of Operation
SO_2	Meloy	SA-185-2	1975, modified '78	Flame Photometric spectroscopy
TRS	Meloy	SA-185-2	1975, modified '78	Flame Photometric spectroscopy
CO	Beckman	866	1979	Nondispersive Infrared spectroscopy
O_3	Dasibi	1003AH	1978	Nondispersive Light Absorption spectroscopy
NO_2	Columbia Scientific	1600	1979	Chemiluminescent analyzer
TSP	General Metal Works	2000	1978	High volume integrated sampler

will be a Teledyne Geotech Model 1564B which is a low threshold photo-chopper design and the wind direction sensor, a Teledyne Geotech Model 1565B, which is of the potentiometer type. The temperature will be measured by Teledyne Geotech Model 145851 unit, which is a thermistor in aspirated shield type device. The specifications of the sensors are as follows:

Sensor	Threshold Speed	Accuracy
Wind Speed	0.27 m/sec (0.6 mph)	0.1 m/sec (0.15 mph)
Wind Direction	0.34 m/sec (0.75 mph)	3
Temperature	N/A	0.15 °C (0.30 °F)

3.6 SYSTEM OPERATION AND MAINTENANCE

3.6.1 Routine Operations and Instrument Repair

The monitoring equipment will be assembled in the trailer and initially operated/calibrated off site. Once all instruments are tested and found to function properly, the trailer will be transported to the site and anchored in place. The meteorological tower will be secured by guy wires and attached to the trailer by a bracket. Power and telephone will be installed and the equipment mounted in place. Initial calibrations will be performed after checkout of the equipment as described under Section 3.6.2 of this Section and the monitoring program commenced. The Kentucky Division of Air Pollution Control will be kept informed and notified prior to commencement of operations.

The TSP colocated samplers will be operated from midnight to midnight every three days, in phase with the schedule used by the Kentucky Division of Air Pollution Control for its nearest monitor in Hawesville. The remaining analyzers are all continuous and will, therefore, be operated continuously.

A person who lives near the site will be hired to perform the routine tasks. This person will visit the site every three days to change the high volume sampler filters and to check the status of all the instruments. The daily automatic zero and span functions will be checked as well as other items such as the chart papers, recorder functions, analyzer operations, etc. A checklist of these items will be provided to the site operator and if any item on the list is out of tolerance, the Dames & Moore office will be immediately contacted by telephone. If the problem cannot be solved over the telephone, Dames & Moore will immediately dispatch an instrument technician to the site. In most cases, the technician stationed at Evansville, Indiana, will be dispatched to minimize downtime.

Quarterly calibrations as well as instrument repair, maintanence and recalibrations will be performed by the instrument technician. Occurrence of out-of-tolerance span signals will be noted by the local operator from span control charts maintained with each analyzer. These will immediately result in a site visit by the instrument technician for necessary adjustments and recalibrations. Use of this operating routine has been proven to result in acquisition of high quality data at other projects. A site diary, analyzer logs and calibration logs will be maintained in the trailer to keep track of pertinent data. An inventory of spare analyzer parts will also be kept in the trailer to allow quick repairs and thereby minimize downtime.

3.6.2 Calibration

The calibration of the SO_2 and TRS analyzers will be done with a Monitor Labs Model 8500 R permeation calibration device. The calibrator will be used for multipoint calibrations quarterly or as required and for the daily automatic zero/span checks. Calibrator output concentration will be determined by two methods during the course of the monitoring. Initially the onsite calibrator output will be determined by comparison with a similar calibrator which has been previously calibrated using the pararosaniline method, 36 FR 8181, 1971. During later calibrations, the onsite calibration output will be determined by precision calibration of the flow, temperature and constant weight loss of the permeation device.

The onsite ozone monitor (Model 1003AH) will use the ultraviolet adsorption technique for the detection of ozone. This technique is itself a good reference technique for calibration of ozone analyzers. The calibration of the onsite analyzer will, therefore, be verified by comparison with a Dashibi Model 1003PC ultraviolet adsorption ozone analyzer. In addition, the Model 1003AH has an internal ozone generator which will be calibrated using the Model 1003PC reference instrument. The known concentration of ozone generated in the reference instrument will then be introduced into the onsite ozone analyzer to verify its calibration.

The NO_2 analyzer will be calibrated using the gas phase titration technique, which is a reference technique. The Monitor Labs Model 8500R calibrator will be used to perform multipoint as well as the daily automatic span/zero checks.

Multipoint calibration of the Beckmann CO analyzer will be accomplished by use of a standard bottle of CO in air and a precision blender. Daily span checks will be from a separate bottle of CO in air. The concentrations of the CO in the standard bottles are referenced by the supplier.

The filter conditioning for the TSP high volume samplers will be in a desiccated chamber, and the filters will be weighed on a Torbal analytical balance. The flow rates will be initially referenced by a Roots meter, which is a standard reference. Further field calibrations will be made using restrictor plates and a water monometer. The samplers will be equipped with clock timers and variable voltage transformers.

Chemical analyses for polyaromatic hydrocarbons (PAH's), trace elements and sulfates will be performed on the TSP samples subsequent to the gravimetric analysis for particulates. Each month, all of the filters for a designated high volume sampler will be combined into a composite sample for the analyses. The results will be reported as the average concentration per unit volume of air sampled during the month.

The analytical method for PAH will utilize High Performance Liquid Chromatography with fluorescence and ultraviolet detection. This is an unpublished method being developed by the U.S. EPA. A copy of the method is available on request.

Trace elements will be analyzed by flameless atomic absorption (US EPA, 1974). The sulfate will be determined using a method described by the US EPA (1974).

The meteorological equipment will be calibrated using a Dencor wind speed calibrator, a Climet precision resistor box and digital and mercury thermometers. Recalibrations will be performed every six months as required by the EPA guidelines.

One additional laboratory analysis will be a particulate characterization for all TSP samples which exceed 113 $\mu g/m^3$. Due to the presence of agricultural activity around the monitoring site, there is a potential for emission of natural fugitive soil in the area. Wind erosion from farm fields can also affect some samples. Analysis of the particulate samples by microscopy will identify what fractions of the sample were due to the natural soils and the wind direction data will help identify the source. This information will prove useful in validating the accuracy of samples for consideration in determining the maximum TSP concentrations for PSD purposes. An additional purpose would be to separate man-made or industrial particulate loadings from naturally occurring soils due to the growing realization within the U.S. EPA that the latter is considerably less harmful to health and welfare. The revised criteria document for particulate matter, due in December 1980, is likely to address the issue and the data collected could be useful for future impact assessment.

3.7 QUALITY ASSURANCE PROGRAM

In order to produce PSD monitoring data acceptable to the Division of Air Pollution and the United States Environmental Protection Agency, various activities to obtain quality assurance of the data will be necessary. These can broadly be separated into two categories:

(1) activities to demonstrate that measurements are made within acceptable control conditions, i.e., quality control actions, and

(2) assessment of the monitoring data for precision and accuracy, namely, the quality assurance procedures.

Each is described below together with the independent audit program.

3.7.1 Quality Control

These will be different for the continuous methods and the integrated sampling method (TSP sampling) and, therefore, are discussed separately.

For continuous methods, the following actions will be taken to demonstrate within control conditions:

(1) Reference or equivalent method requirement - All continuous monitors will be EPA designated Reference or Equivalent Methods, as described in Section 3.5.1.

(2) Calibration requirement - All continuous analyzers will be calibrated by gaseous calibration standards traceable to Standard Reference Materials (SRM) of the National Bureau of Standards. The specific details are contained in Section 3.6.

Analyzers will be calibrated during installation and recalibrated whenever any one of the following conditions occur:

- control limit is exceeded for the span check
- after repair of any malfunctioning analyzer, and
- after replacement of any major component of an analyzer.

Zero plus a minimum of five calibration points equally spaced over the analyzer range will be used to generate a calibration curve.

(3) Span check requirements - A daily automatic span check will be made on each analyzer with concentrations between 0.08 and 0.10 ppm for SO_2, NO_2, O_3, and TRS analyzers and between 8 and 10 ppm for the CO analyzer.

If the control limits of ±0.025 ppm for SO_2, NO_2, O_3, and TRS analyzers and ±2 ppm for the CO analyzer are exceeded, the analyzer will be removed from ambient monitoring, checks made to determine cause and corrective action taken before return of the monitor to monitoring duty. On returning to use, the zero plus five point calibration over the analyzer range will be performed. The span check will also be used to assess the precision of the monitoring data.

For the reference method TSP high volume sampler, the following quality control actions will be taken:

(1) Sampling flow rate check - Initial flow rate readings will be observed for each sampler and if the flow rate is over ±15% of the established average initial flow rate, recalibration using five flow restrictor plates and a water monometer will be performed in accordance with the reference method.

(2) Exposed filter reweighing - A sample of randomly selected exposed filters will be reweighed. Agreement between original

and repeat weighings must be ±5.0 mg or less. If any reweighed exposed filter differs more than 5.0 mg from its original weight, the entire lot of filters will be reweighed.

(3) Recalculation of sample concentration - A sample of randomly selected calculated TSP values (in $\mu g/m^3$) will be recalculated. If the original calculation does not agree with the repeat calculation, all the calculations in the lot will be checked and corrected as necessary.

3.7.2 Quality Assurance Procedures

Precision of each analyzer or sampler will be calculated and reported quarterly. For the continuous analyzers, the precision will be computed from routine biweekly span checks made by the operator during normal operations. For the high volume TSP sampler, the precision will be calculated from the results of the collocated sampler. All calculation and reporting procedures specified in "Ambient Monitoring Guidelines for Prevention of Significant Deterioration", EPA-450/2-78-019, May 1978, will be used during the program.

The accuracy of the analyzers will be assessed once per quarter. This will be accomplished by use of the independent calibration audit of the analyzers performed by the Division of Air Pollution Control using different reference standards than those used for routine primary calibrations. This audit is performed by Air Pollution Control personnel. Calculation procedures will be in accordance with the above referenced PSD monitoring guideline.

3.7.3 Quality Assurance for Meteorological Data

All new equipment is to be used for the meteorological monitoring. Field checkout and calibration procedures recommended by the manufacturer, Teledyne Analytical Instruments, will be used.

An independent meteorological audit will be performed to provide an onsite evaluation of the network installation, inspection, maintenance, and data spot checks. Further, data audits will be made for those days for which TSP data are audited. This is expected to be at least four randomly chosen days per month. The results will be reported quarterly.

3.8 APPROVAL OF MONITORING PLAN BY KENTUCKY DEPARTMENT OF NATURAL RESOURCES AND EPA

The following letter was received approving the ambient air quality monitoring plan.

JACKIE SWIGART
Secretary

JOHN Y. BROWN, JR.
Governor

COMMONWEALTH OF KENTUCKY
DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
BUREAU OF ENVIRONMENTAL PROTECTION
DIVISION OF AIR POLLUTION CONTROL
WEST FRANKFORT OFFICE COMPLEX
1050 U.S. 127 BYPASS SOUTH
FRANKFORT, KENTUCKY 40601

July 24, 1980

7/31/80 DEL 1901-001-21
Copies to:

Mr. Jay J. Hill
Ashland Synthetic Fuels, Inc.
P.O. Box 391
Ashland, Kentucky 41101

RE: Proposed Breckinridge County
Coal Liquifaction Plant

Dear Mr. Hill:

The Engineering Branch of this Division has completed its review of Ambient Air Quality Monitoring Plan submitted on June 17, 1980, and has concluded that the plan meets all of the criteria contained in the "Ambient Monitoring Guidelines for Prevention of Significant Deterioration", EPA-450/2-78-019, May 1978 with respect to the site location and pollutants monitored.

Mr. Bill Sudduth of the Technical Services Branch of this Division is reviewing the Quality Assurance portion of the plan and it is expected that approval or disapproval of that portion will be forthcoming from that Branch.

If you have any questions on this matter, please do not hesitate to call me at (502) 564-6844.

Sincerely,

for Samuel M. Murphy, Chief
Chemical Section
Engineering and Permits Branch

SMM:DJG:sm

3.9 DATA PROCESSING AND REPORTS

Continuous monitoring data on strip charts will be accumulated and processed fortnightly. The chart data will be digitized by use of a custom built digitizer which consists of a stylus, the movement of which in manually tracing the recorder strip chart is converted to digital data. These data are then automatically processed by a preprogramed minicomputer. Depending on the pollutant being monitored, the output can be manipulated by the computer to produce the time averages necessary for comparison with the particular ambient standard.

Quarterly reports will be prepared that will include all valid data generated during the quarter. These data will also be summarized for comparison with air quality standards and climatological data. The quarterly reports will include the quarterly accuracy, precision, and data recovery statistics.

The hourly averaged data will also be recorded on magnetic tape in SAROAD format for submittal to the Kentucky DAPC together with the written report no later than sixty days after the end of the quarter being reported.

3.9.1 Quarterly Summaries

First, Second, Third, and Fourth Quarterly Summaries are not included in this volume, but are available for review in the Ashland offices.

3.9.2 Annual Summary

3.9.2.1 Introduction

Air quality and meteorological monitoring have been conducted for the period August 1, 1980 through July 31, 1981 on a site selected for the construction of a proposed synthetic fuels plant by Ashland Synthetic Fuels, Inc. and Airco Energy Company. The objective has been to document the baseline conditions prior to construction of the facility in order to provide data required to assess the air quality impact of the plant construction and operation.

The air quality monitoring station was established at a site within the proposed plant boundaries after consultation and approval of the location and monitoring instrumentation and methodology by the Kentucky Division of Air Pollution Control. Quarterly reports were compiled of the meteorological and air quality parameters during the monitoring period. This section provides a summary of the data generated over the entire 1-year period as reported in the four quarterly reports. Section 3.4 provides details of the monitoring plan, while Sections 3.9.1 through 3.9.4 contain the quarterly reports.

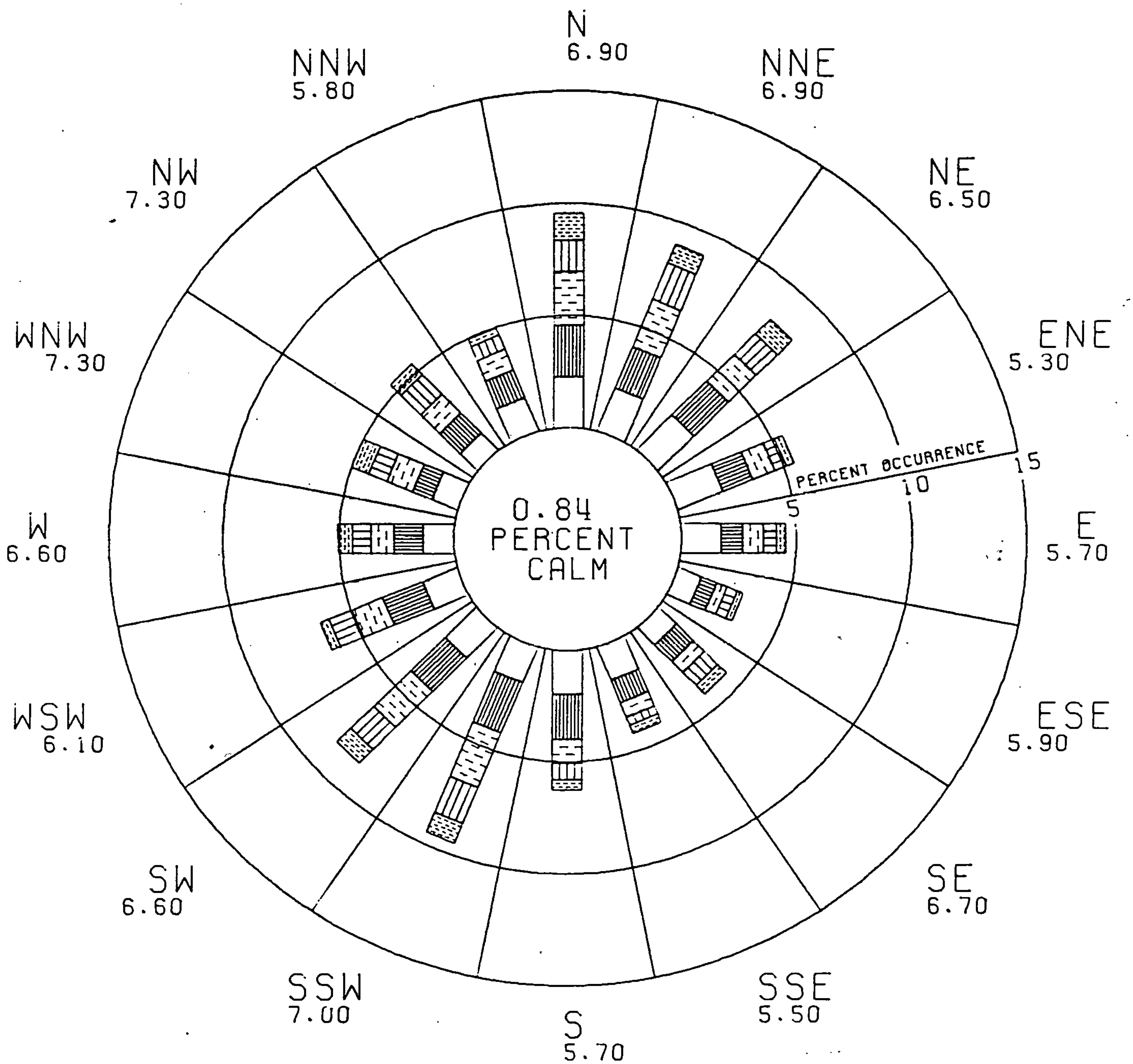
With the exception of some downtime associated with weather or equipment related malfunctions, the monitoring program proceeded smoothly. One incidence of vandalism occurred during the year, but no significant damage occurred. The data recovery was satisfactory and has been shown with the data summary tables. Daily site checks towards the latter part of the program produced significant improvements in the data recovery.

Quality assurance was performed in accordance with the U.S. EPA Prevention of Significant Deterioration (PSD) guidelines. Precision and accuracy statistics were generated through use of span checks, collocated samplers, and audits performed by the Kentucky Division of Air Pollution Control. The data were found to be valid and within the precision and accuracy specifications required for ambient monitoring programs under the PSD program.

3.9.2.2 Meteorology

Wind Speed and Direction - Hourly wind speed and direction data have been summarized and presented as an annual wind rose (Figure 3.10). These same data are presented in tabular form in Table 3.57.

During the August 1, 1980 through July 31, 1981 period, the predominant wind directions were from the southwest to south-southwest sectors and from the north to northeast sectors. This is also the approximate direction of the Ohio River Valley at the site where the 10-m meteorological tower was located. The wind direction data, therefore, indicated that the surface winds at the site were channelized by the river valley and tended to be almost equally distributed along the local river channel in the up- and downriver directions during the year. The annual mean wind speed was 6.4 mph, and the maximum speed for the year was 30.0 mph, measured on March 29, 1981. Wind speeds less than the threshold of the sensor (0.27 m/sec) occurred most often (1.19 percent calm) during the fourth quarter (May through July 1981), while it was most windy (0.19 percent calm) in the third quarter (April through May 1981). The annual value of such calm periods was 0.84 percent of the time at the site. Data recovery was 92.2 percent for the year.



NUMBERS INDICATE SECTOR MEAN WIND SPEED

WIND SPEED RANGE

- 0.0- 3.0 MPH
- 3.0- 6.0
- 6.0- 9.0
- 9.0-12.0
- > 12.0

FIGURE 3.6
ASHLAND SYNTHETIC FUELS

10-METER WIND FREQUENCY DISTRIBUTION
AUGUST 1, 1980 - JULY 31, 1981

1

TABLE 3.9

JOINT WIND FREQUENCY DISTRIBUTION
DATA PERIOD: AUGUST 1, 1980 TO JULY 31, 1981

DATA SOURCE: ASHLAND - 10 METERS
TABLE GENERATED: 09/08/81. 08.16.18.

ASHLAND SYNTHETIC FUELS
AIR MONITORING SYSTEM
BRECKINGRIDGE COUNTY, KENTUCKY
DAMES AND MOORE JOB NO: 11901-001-21

FREQUENCY IN PERCENT

WIND DIR	INTERVALS OF WIND SPEED IN MPH 0.0- 1.5	1.5- 3.0	3.0- 4.5	4.5- 6.0	6.0- 7.5	7.5- 9.0	9.0-10.5	10.5-12.0	>12.0	TOTAL	MEAN WIND SPEED
NNE	.46	1.55	1.05	.95	1.18	1.10	1.09	.68	.90	8.96	6.9
NE	.43	1.71	1.15	.98	.98	.72	.80	.51	.92	8.20	6.5
ENE	.64	1.44	.76	.66	.54	.50	.38	.15	.37	5.43	5.3
E	.45	1.28	.50	.45	.43	.46	.30	.27	.38	4.51	5.7
ESE	.32	.78	.36	.36	.27	.21	.26	.21	.30	3.07	5.9
SE	.38	.73	.59	.46	.41	.28	.38	.46	.52	4.22	6.7
SSE	.37	1.25	.69	.41	.32	.38	.24	.14	.42	4.22	5.5
S	.38	1.63	1.10	.92	.61	.46	.48	.24	.47	6.29	5.7
SSW	.43	1.30	1.26	1.19	1.16	1.47	1.03	.71	.95	9.51	7.0
SW	.50	1.44	1.23	.88	1.14	1.13	.77	.62	.84	8.53	6.6
WSW	.35	1.28	1.03	.85	.72	.72	.61	.46	.41	6.41	6.1
W	.40	.97	.69	.58	.45	.54	.46	.35	.61	5.04	6.6
WNW	.42	.77	.41	.51	.56	.64	.54	.31	.80	4.96	7.3
NW	.37	.67	.71	.57	.63	.53	.77	.45	.67	5.36	7.3
NNW	.52	1.02	.80	.54	.53	.47	.42	.26	.35	4.91	5.8
N	.80	1.45	1.25	1.03	1.20	1.20	.78	.61	1.21	9.53	6.9
CALM	.84									.84	
TOTAL	8.07	19.24	13.58	11.33	11.13	10.82	9.31	6.40	10.13	100.00	6.4

NUMBER OF VALID OBSERVATIONS	8078	92.21 PCT.
NUMBER OF INVALID OBSERVATIONS	682	7.79 PCT.
TOTAL NUMBER OF OBSERVATIONS	8760	100.00 PCT.

Temperature - Hourly average temperature extremes and mean values are summarized below in °K, °C, and °F:

	°K	°C	°F
Maximum	367.3	34.6	94.3
Minimum	254.0	-19.0	-2.2
Mean	327.6	12.6	54.6

Data recovery was 91.7 percent for the year.

3.9.2.3 Air Quality

Sulfur Dioxide - The sulfur dioxide (SO_2) concentrations measured during the one year monitoring period did not exceed any of the Kentucky (or National) Ambient Air Quality standards. The highest and second-highest 3-hour concentrations measured were 0.106 ppm on December 4, 1980 and January 9, 1981 whereas the 3-hour (secondary) standard is 0.500 ppm. The highest and second-highest 24-hour concentrations measured were 0.045 and 0.044 ppm on January 23-24, 1981 and December 4-5, 1980 respectively. These are considerably less than the 24-hour (primary) standard of 0.140 ppm. The annual mean concentration was 0.009 ppm, which is less than 33 percent of the primary annual standard of 0.030 ppm.

Table 3.58 provides a summary of the hourly averaged SO_2 was 96.3 percent for the year.

Nitrogen Dioxide - The highest and second-highest 1-hour average nitrogen dioxide (NO_2) concentrations measured were on February 25, 1981 and were 0.049 and 0.047 ppm respectively. The annual mean concetration

TABLE 3.10

SUMMARY OF SULFUR DIOXIDE CONCENTRATION
AUGUST 1, 1980 TO JULY 31, 1981

	1-HOUR AVERAGE CONCENTRATIONS	3-HOUR AVERAGE CONCENTRATIONS	24-HOUR AVERAGE CONCENTRATIONS
Highest Concentration	0.136 ppm	0.106 ppm	0.045 ppm
Time Period (CST)	12/04/80 16:00 to 12/04/80 17:00	12/04/80 15:00 to 12/04/80 18:00	01/23/81 03:00 to 01/24/81 03:00
Second-Highest Concentration	0.133 ppm	0.106 ppm	0.044 ppm
Time Period (CST)	07/07/81 09:00 to 07/07/81 10:00	01/09/81 12:00 to 01/09/81 15:00	12/04/80 15:00 to 12/05/80 15:00
Ambient Air Quality Standard	N/A	0.500 ppm	0.140 ppm
Number of Exceedances	-	0	0
Arithmetic Mean	0.009 ppm	0.009 ppm	0.009 ppm
Annual Average Standard	0.030 ppm		
Standard Deviation	0.011 ppm	0.010 ppm	0.007 ppm
Percentiles:			
25	0.001 ppm	0.001 ppm	0.004 ppm
50	0.006 ppm	0.006 ppm	0.008 ppm
75	0.012 ppm	0.013 ppm	0.013 ppm
90	0.021 ppm	0.021 ppm	0.018 ppm
95	0.030 ppm	0.029 ppm	0.021 ppm
99	0.055 ppm	0.048 ppm	0.030 ppm
Total Valid Observations	8,432		
Total Invalid Observations	328		
Total Possible Observations	8,760		
Percent Data Recovery	96.3 percent		

was 0.009 ppm as compared to the primary standard of 0.050 ppm. A summary of the hourly averaged NO_2 concentrations is presented in Table 3.59. The data recovery for NO_2 was 83.1 percent, mainly due to equipment malfunctions in the first and seond quarters of monitoring.

Ozone - The ozone (O_3) concentrations measured during the monitoring period did not exceed the Kentucky standard of 0.120 ppm not to be exceeded more than one day a year. The highest and second highest 1-hour readings occurred on the same day, October 9, 1980, between 1400 and 1600 hours, being respectively 0.125 ppm 1-hour average. No other readings over the 0.120 ppm limit were recorded during the year. The mean concentration for the year was 0.029 ppm. The summary of the hourly averaged O_3 concentrations is given in Table 3.60. The O_3 data recovery was 80.9 percent over the year.

Carbon Monoxide - Carbon monoxide (CO) concentrations were barely detectable during most of the year. The highest and second-highest 1-hour average concentrations were 1.568 ppm on August 12, 1980 and 1.519 ppm on December 18, 1980, whereas the 1-hour standard is 35.00 ppm. The highest and second-highest 8-hour average concentrations both occurred on August 12, 1980 and were 1.090 and 0.914 ppm respectively, as compared to the Kentucky Ambient Standard of 9.00 ppm. Table 3.61 presents the annual summary statistics for CO. The annual data recovery was 98 percent.

Reduced Sulfur - Although no air quality standards for total reduced sulfur (TRS) compounds exist, these pollutants were monitored in order to establish a baseline due to possibly high concentrations from a nearby large paper mill approximately 6 miles west of the monitoring site. The

TABLE 3.11

SUMMARY OF NITROGEN DIOXIDE CONCENTRATION
AUGUST 1, 1980 TO JULY 31, 1981

	1-HOUR AVERAGE CONCENTRATIONS
Highest Concentration	0.049 ppm
Time Period (CST)	02/25/81 21:00 to 02/25/81 22:00
Second-Highest Concentration	0.047 ppm
Time Period (CST)	02/25/81 22:00 to 02/25/81 23:00
Ambient Air Quality Standard	N/A
Number of Exceedances	-
Arithmetic Mean	0.009 ppm
Annual Average Standard	0.050 ppm
Standard Deviation	0.006 ppm
Percentiles:	
25	0.005 ppm
50	0.008 ppm
75	0.011 ppm
90	0.017 ppm
95	0.020 ppm
99	0.029 ppm
Total Valid Observations	7,281
Total Invalid Observations	1,479
Total Possible Observations	8,760
Percent Data Recovery	83.1 percent

TABLE 3.12

SUMMARY OF OZONE CONCENTRATION
AUGUST 1, 1980 TO JULY 31, 1981

	1-HOUR AVERAGE CONCENTRATIONS
Highest Concentration	0.125 ppm
Time Period (CST)	10/09/80 15:00 to 10/09/80 16:00
Second-Highest Concentration	0.123 ppm
Time Period (CST)	10/09/80 14:00 to 10/09/80 15:00
Ambient Air Quality Standard	0.120 ppm
Number of Exceedances	2
Arithmetic Mean	0.029 ppm
Standard Deviation	0.020 ppm
Percentiles:	
25	0.013 ppm
50	0.025 ppm
75	0.041 ppm
90	0.058 ppm
95	0.069 ppm
99	0.087 ppm
Total Valid Observations	7,085
Total Invalid Observations	1,675
Total Possible Observations	8,760
Percent Data Recovery	80.9 percent

TABLE 3.13

SUMMARY OF CARBON MONOXIDE CONCENTRATION
AUGUST 1, 1980 TO JULY 31, 1981

	1-HOUR AVERAGE CONCENTRATIONS	8-HOUR AVERAGE CONCENTRATIONS
Highest Concentration	1.568 ppm	1.090 ppm
Time Period (CST)	08/12/80 10:00 to 08/12/80 11:00	08/12/80 08:00 to 08/12/80 16:00
Second-Highest Concentration	1.519 ppm	0.914 ppm
Time Period (CST)	12/18/80 15:00 to 12/18/80 16:00	08/12/80 05:00 to 08/12/80 13:00
Ambient Air Quality Standard	35.000 ppm	9.000 ppm
Number of Exceedances	0	0
Arithmetic Mean	0.267 ppm	0.267 ppm
Standard Deviation	0.169 ppm	0.132 ppm
Percentiles:		
25	0.200 ppm	0.200 ppm
50	0.200 ppm	0.200 ppm
75	0.200 ppm	0.261 ppm
90	0.588 ppm	0.473 ppm
95	0.686 ppm	0.601 ppm
99	0.833 ppm	0.735 ppm
Total Valid Observations	8,588	
Total Invalid Observations	172	
Total Possible Observations	8,760	
Percent Data Recovery	98.0 percent	

highest and second-highest 1-hour average concentrations recorded were 14 μg/m^3 on September 23 and 24, 1980. Since all the TRS, which includes hydrogen sulfide (H_2S), did not exceed 14 μg/m^3, the 1-hour Kentucky Ambient Air Quality Standard for H_2S of 14 μg/m^3 could obviously not have been exceeded. Table 3.62 contains the summary of the hourly averaged TRS concentrations. Data recovery was 99.0 percent for the year.

Total Suspended Particulates: The total suspended particulate (TSP) data indicate that neither the primary annual geometric mean nor 24-hour average primary and secondary standards of 75,260 and 150 μg/m^3, respectively, were exceeded during the year. The highest and second-highest valid 24-hour average values were 116 and 101 μg/m^3, recorded on October 6 and 9, 1980, respectively. These are below the corresponding Kentucky ambient air quality primary and secondary 24-hour average standards of 260 and 150 μg/m^3, respectively.

As part of the particulate sampling program, all filters weighing in excess of a concentration of 113 μg/m^3 were subjected to microsocopic examination to characterize the nature of the dust. Four filters during the year exceeded this value and were tested further. As a result of the examination, it was determined that all four contained from 58 to 85 percent of mineral matter, predominantly of soil origin. Since the monitoring site was located in an active soybean field, possible interference with the sampling by agricultural activity was strongly suspected. No documentation of such activity was indicated in the site log for October 6, 1980. This reading of 116 μg/m^3 (24-hour average) was, therefore, considered valid; however, on June 15, 18 and 24, 1981, readings of 161, 217 and 165 μg/m^3 were found to be influenced by locally entrained

TABLE 3.14

SUMMARY OF REDUCED SULFUR CONCENTRATION
AUGUST 1, 1980 TO JULY 31, 1981

	1-HOUR AVERAGE CONCENTRATIONS
Highest Concentration	14. $\mu g/m^3$
Time Period (CST)	09/23/80 23:00 to 09/23/80 24:00
Second-Highest Concentration	14. $\mu g/m^3$
Time Period (CST)	09/23/80 24:00 to 09/24/80 01:00
Ambient Air Quality Standard	N/A
Number of Exceedances	-
Arithmetic Mean	4. $\mu g/m^3$
Standard Deviation	2. $\mu g/m^3$
Percentiles:	
25	3. $\mu g/m^3$
50	3. $\mu g/m^3$
75	3. $\mu g/m^3$
90	8. $\mu g/m^3$
95	10. $\mu g/m^3$
99	13. $\mu g/m^3$
Total Valid Observations	8,676
Total Invalid Observations	84
Total Possible Observations	8,760
Percent Data Recovery	99.0 percent

dust from plowing and other agricultural activity which was documented by the site checker in the site log and confirmed by the microscopic examination. These samples, therfore, had to be invalidated as not being representative of ambient air quality conditions. The details of the filter analyses are contained in Tables 3.16 and 3.52 of the report.

The annual geometric mean for TSP was 44.7 $\mu g/m^3$ as compared to the standard of 75 $\mu g/m^3$, annual geometric mean. Data recovery for the year was 89.3 percent.

Polyaromatic Hydrocarbons - The particulate samples that were collected during each month were composited and analyzed for polyaromatic hydrocarbon (PAH) content. Of the 17 compounds tested for, small amounts of pyrene, benzo (j) fluoranthene, benzo (a) pyrene and dibenzothiophene only were measured. None of the other 13 compounds were detected at the analytical detection limit. The results for the year have been summarized in Table 3.63. The detection limits, in the picogram range, have previously been provided in Tables 3.20, 3.31, 3.42 and 3.54 of this report.

Trace Elements - The monthly composited particulate samples were analyzed for 13 trace elements. The results are summarized in Table 3.64.

Lead is the only trace element with a National Ambient Air Quality Standard (43 FR 46246 dated October 5, 1978). The standard is 1.5 $\mu g/m^3$ averaged over a calendar quarter. The four calendar quarter lead concentrations were calculated as 0.026, 0.030, 0.070 and 0.003 $\mu g/m^3$ respectively, which are well below the standard. Summer auto traffic impacts are highest in the third quarter as compared to the negligible value during the low traffic winter quarter.

TABLE 3.15

POLYAROMATIC HYDROCARBON CONCENTRATIONS
MEASURED AT THE ASHLAND SYNTHETIC FUELS, INC. MONITORING SITE
AUGUST 1, 1980 THROUGH JULY 31, 1981

COMPOUND	MONTHLY CONCENTRATION (ng/m^3) HIGHEST	2nd HIGHEST	MINIMUM
2-methyl naphthalene	ND	ND	ND
fluoranthene	ND	ND	ND
pyrene	0.8	0.4	ND
benzo (c) phenanthrene	ND	ND	ND
benzo (a) anthracene	ND	ND	ND
chrysene	ND	ND	ND
5-methyl chrysene	ND	ND	ND
benzo (b) fluoranthene	ND	ND	ND
benzo (j) fluoranthene	0.4	Trace	ND
benzo (a) pyrene	1.3	0.9	Trace
O-phenylene pyrene	ND	ND	ND
dibenz (a,H) anthracene	ND	ND	ND
benzo (g,h,i) perylene	ND	ND	ND
2-methyl fluoranthene	ND	ND	ND
dibenz (a,c) anthracene	ND	ND	ND
dibenzothiophene	0.3	0.2	ND
naphthalene	ND	ND	ND

Notes: ND = None detected (below analytical detection limits).

TABLE 3.16
TRACE ELEMENT CONCENTRATIONS MEASURED
AT THE ASHLAND SYNTHETIC FUELS MONITORING SITE
AUGUST 1, 1980 THROUGH JULY 31, 1981

ELEMENT	MONTHLY CONCENTRATION (ng/m^3) HIGHEST	2nd HIGHEST	MINIMUM	MEAN
Arsenic	0.77	0.69	<0.03	0.26
Beryllium	0.98	0.72	0.05	0.35
Cadmium	1.1	0.70	0.54	0.67
Chromium	4.39	3.9	1.2	2.44
Cobalt	4.73	3.46	<0.6	1.65
Iron	464.0	414.1	45.4	213.20
Mercury	0.20	0.19	<0.01	0.09
Lead	123.4	39.2	0.4	29.7
Manganese	28.0	18.2	0.77	8.1
Nickel	11.7	10.4	<0.17	3.5
Titanium	8.98	8.2	<0.1	1.7
Vanadium	1.1	<0.27	<0.1	0.23
Zinc	212.3	210.6	57.3	127.7

Sulfate - The composite particulate samples were also analyzed for sulfates. The maximum, second highest and average monthly values were found to be 15.53 $\mu g/m^3$, 9.99 $\mu g/m^3$ and 7.08 $\mu g/m^3$ respectively. The highest values occurred in the summer months of May, June and July while the lowest were recorded in the autumn period, August through October.

IIT Research Institute
10 West 35 Street, Chicago, Illinois 60616
312/567-4000

August 28, 1981

Mr. Steven A. Frey
Dames & Moore
1550 Northwest Highway
Park Ridge, Illinois 60068

Subject: Letter Report on "Microscopical Analysis of
Three Hi-Vol Filter Samples"
Dames & Moore Purchase Order No. 3360
IITRI Project No. C08636

Dear Mr. Frey:

The microscopical analyses of the three high volume (hi-vol) filter samples submitted for identification and quantification of the total suspended particulate (TSP) have been completed. All of the samples were collected at the same monitoring station and demonstrated TSP levels in excess of the secondary 24-hour TSP standard of 150 μg/m^3. The primary goal of this study was to determine the identity and source(s) of the aerosols collected.

The conclusions presented in this report are based solely on the identification of the compounds in each sample since no information was provided on sampling site locale, particulate emission sources, or meteorological conditions.

1. DISCUSSION OF RESULTS

Mineral particles represented 115.5-147.1 μg/m^3 of the TSP in the samples. Soil-derived mineral types, principally quartz, feldspars and clays, comprised the majority (>93%) of the mineral population. Other soil-derived mineral types in the TSP included trace to minor concentrations of micas, fluorite, and hydrated iron oxides. Carbonate minerals contributed an average of only 4 μg/m^3 of the TSP. The frequent occurrence of carbonate mineral particles coated with clays suggested the carbonates were suspended largely from gravel road surfaces. (Carbonates are generally absent or present in very low concentrations in soils, thus carbonates are assigned to crushed limestone used as road aggregate.)

The presence of both silicate and carbonate mineral types embedded in the rubber tire fragments indicated traffic suspension of soil and probably gravel as a source of some portion of the mineral population. Rubber tire fragments were relatively low in concentration and small in size, while minerals concentrations were high and mineral particle sizes, especially in the ASH-B and ASH-C samples, were large. Typical urban road dust samples analyzed at IITRI generally contain greater numbers and sizes of rubber tire fragments in comparison with minerals concentrations and sizes than observed in these samples. This suggests traffic may not have been the dominant method of mineral suspension. However, it is possible that less vehicle traffic, and thus fewer rubber tire fragments, may be required to entrain minerals from unpaved (soil, gravel) road surfaces than from strongly compacted paved roadways. This supposition and the fact that rubber tire fragment concentrations increased concurrently with minerals concentrations suggested traffic may have been the source of a large portion of the minerals present. The finely dispersed nature of the majority of the clay particles in sample ASH-A (Figure 1) suggested winds may have suspended a portion of the minerals. Clay minerals suspended by traffic tend to be distinctly larger agglomerates. However, the larger mineral grains found in samples ASH-B (Figure 2) and ASH-C (Figure 3) were likely contributed by mechanical suspension even if wind speeds were high (>20 mph). This presumption is based on prior studies by IITRI which have shown that high wind speeds primarily suspend particles that are $\leq$10 µm. Thus, local construction or agricultural activities, in addition to traffic to some extent, seem more probable sources of the bulk of the minerals present.

Combustion source-related emissions represented 22.6-51.7 µg/m^3 of the TSP. Glassy flyash spheres and partially combusted coal fragments present indicated impact from local pulverized coal-burning operations. Trace concentrations of irregularly-shaped particles of glassy flyash were also noted; whether this component was also emitted by a pulverized coal combustion source or was an emission from a less efficient coal combustion operation such as a stoker-type coal burner could not be determined with certainty. Raw coal fragments were present in concentrations nearly equal to the combined concentrations of glassy and partially combusted coal flyash. Both the raw coal and partially combusted coal fragments were observed to have woody structures indicative of soft coal; this suggests these components were contributed by a common source. That secondary ammonium sulfate and nitrate aerosols were present in concentrations concurrent with those of the primary combustion products suggested local coal-burning operations were the primary source(s) of these components. However, distant combustion sources and mobile vehicles are also likely sources of the secondary aerosols. Fine (<3 µm) carbonaceous material represented a minor portion of the TSP. Sources of this component include auto and diesel exhaust as well as fine-fractured carbonaceous combustion products.

Biological aerosols contributed up to 8 µg/m^3 of the TSP. Pollens, spores, conidia, starch grains and plant hairs were the dominant biological particle types present and were probably contributed by local vegetation.

Iron oxides represented 13.0-19.7 µg/m^3 of the TSP. Hematite was the non-magnetic iron oxide most frequently encountered. Soil, street debris, and combustion operations are probable sources of this component.

2. ANALYSIS METHODS

2.1 Sample Descriptions

Three samples collected on 8" x 10" glass fiber filter substrates were submitted for analysis, Table 1. The calculated TSP concentrations are based on a sampling duration of 24 hours.

Figure 1. Sample ASH-A (226); slightly uncrossed polars; 263X. Large white particles are clay-coated quartz fragments; fine, gray background particles are mostly clays.

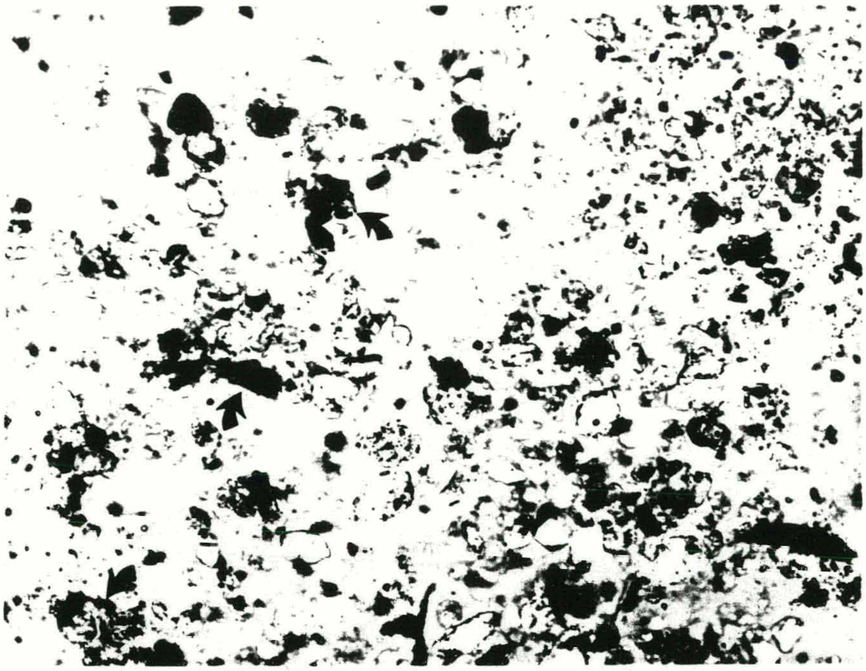


Figure 2. Sample ASH-B (228); slightly uncrossed polars; 263X. Large quartz fragments and (arrows) clay agglomerates are abundant here.

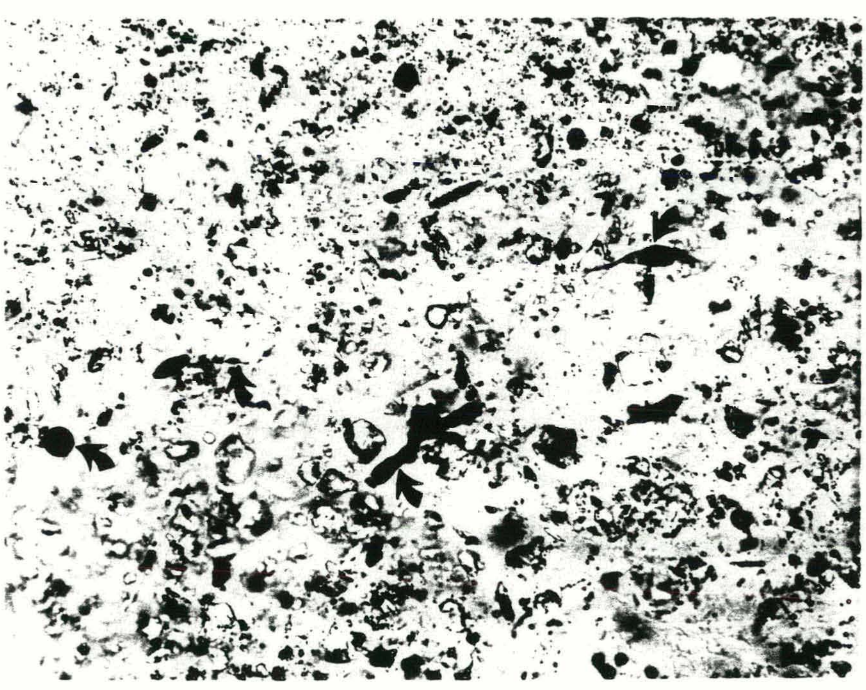


Figure 3. Sample ASH-C (232); slightly uncrossed polars; 263X. Quartz and clay particles are again numerous; arrows point to a large clay-coated carbonate mineral particle, (gray, structured) fungal conidia, and a flyash sphere.

Mr. Steven A. Frey
Dames & Moore

Table 1. SAMPLES SUBMITTED FOR ANALYSIS

Filter No.	Sampling Date	Total Mass (g)	Average Flowrate (cfm)	Calculated TSP Concentration (μg/m³)
ASH-A (226)	6/15/81	0.2528	37.0	169.5
ASH-B (228)	6/18/81	0.3475	38.0	226.8
ASH-C (232)	6/24/81	0.2733	37.5	180.8

An unused filter (no. 133930) from the corresponding lot of the TSP samples was also provided as a blank for low temperature ashing and ion chromatographic analyses.

2.2 Low Temperature Ashing (LTA) Analysis

A precisely measured section (7 in.²) of each filter was desiccated for 24 hours, weighed and then ashed in a radio frequency generated activated oxygen plasma asher. Ashing time for complete removal of combustible materials was two hours at 550 watts.

Upon removal from the asher, the samples were cooled to room temperature in a desiccator and then weighed to determine the mass lost in ashing. From the mass of particles known to be present on the total filter, the mass of particles present on the portion of the filter ashed was calculated by assuming that the total mass of particles was distributed evenly over the filter's effective collection area (7" x 9"). The mass percent of materials lost in the ashing process (% LTA Loss) was then calculated from the measured mass loss (minus the blank value) divided by the mass of particles assumed to be present on the filter section ashed.

This procedure provides a quantitative measure of the total inorganic fraction (mainly minerals and sulfates) and the total organic fraction (rubber tire, coal, biologicals and elemental carbon).

2.3 Ion Chromatographic Analyses for Sulfate and Nitrate

A precisely measured section (7 in.²) was cut from each filter and extracted with distilled, deionized water to dissolve water-soluble salts. The resulting solutions were filtered to remove particles and the remains of the glass fiber filters. The ion concentrations in the filtered extracts were determined with the ion chromatograph after dilution to a known volume.

The areas under the sulfate and nitrate peaks in the anion chromatogram generated for each sample were measured and converted to ion concentrations in the water extract from standard calibration curves. The raw data were then multiplied by the appropriate extract volume and section area correction factors to yield the masses of ions per 7 in^2 of filter. Mass concentrations of sulfate and nitrate in the TSP were then calculated from the mass of ions present on a known filter area (minus the blank value) divided by the mass of total particles present on that area of filter.

2.4 Polarized Light Microscopy (PLM)

2.4.1 Sample Preparation

Sections of each unashed and ashed high volume filter sample were mounted on glass slides in pools of standard immersion oil (n_D = 1.515) under coverslips. The immersion oil rendered the glass fibers invisible, thereby allowing transmission of light and observation of particle types collected on the filter surface and throughout the filter depth.

2.4.2 Particle Identification

The samples were analyzed with a Zeiss optical microscope equipped for polarized light microscopy. Magnifications ranging from 65X through 407X were used in each sample analysis. Optical and physical properties of the particles were observed in each sample in order to identify the particle types. Magnetic properties of particles were observed by holding and moving a small horseshoe magnet near the microscope slide.

The ashed and unashed sections of each filter mounted for PLM analysis were systematically scanned. Measurements of the largest (linear dimension) particle and estimated mean size for each identified particle type were recorded on the appended individual sample report forms during this systematic scan. The top four lines of this form contain the sample identification information. The next line lists the results of the ashing and chemical analyses. The bottom three-fourths of the form are where the microscopical analysis data are recorded.

The identified particle types are grouped on the report form into five major categories which also roughly group the particles according to emission sources. "Minerals" are pavement, gravel and soil components that are suspended by traffic, wind, construction, agriculture, etc., as well as materials suspended by bulk mineral handling or transport activities. Particles readily identified as having been emitted by "Mobile Vehicles" are the rubber tire fragments. "Combustion Products" are both primary (directly emitted as particles) and secondary (particles formed in the atmosphere from conversions and reactions of emitted gases) emissions from large and small scale stationary (and mobile, in the case of secondary aerosols) combustion sources. The opaque, black, fine carbonaceous particles smaller than 3 μm in diameter are primarily elemental carbon, most likely due to vehicle exhausts from cars and trucks. "Biologicals" are mostly natural aerosols primarily emitted by vegetation. The "Miscellaneous" category consists of the non-magnetic iron oxides.

Mr. Steven A. Frey
Dames & Moore

2.4.3 Particle Concentration Measurement

Particle type concentrations were visually estimated by area analysis with the aid of the sulfate and nitrate chemical analysis data and the LTA data. Component concentrations were estimated based on the areal concentrations observed in the as-received sample and in the LTA residue sample.

The anion concentrations were first converted to the ammonium salt concentrations by division with the appropriate factor (0.727 for ammonium sulfate and 0.775 for ammonium nitrate), and these values were entered on the individual sample analysis report forms. The presence of these ammonium salts was verified by polarized light microscopy. From size, frequency and density data, the remaining particle type concentrations were determined in the ashed (non-combustible particle types) and unashed (combustible particle types) filter sections.

3. ANALYSIS RESULTS

Table 2 summarizes the results of the low temperature ashing and ion chromatographic analyses.

The microscopical analysis results are summarized in Table 3; these data were prepared from the individual sample analysis reports included in Appendix A.

4. SUMMARY

Minerals were the primary sample components. Traffic, wind, and probable construction and/or agricultural activities were indicated as the dominant mineral sources. Other significant sample components included combustion source emissions, primarily in the form of secondary ammonium sulfate and nitrate aerosols, and biological particle types.

Respectfully submitted,

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Table 2. LOW TEMPERATURE ASHING AND ION CHROMATOGRAPHY ANALYSIS RESULTS

Filter No.	Sampling Date	TSP ($\mu g/m^3$)	LTA Loss %	LTA Loss $\mu g/m^3$	$SO_4^=$ %	$SO_4^=$ $\mu g/m^3$	NO_3^- %	NO_3^- $\mu g/m^3$
ASH-A (226)	6/15/81	169.5	11.0	18.7	4.9	8.3	2.3	3.9
ASH-B (228)	6/18/81	226.8	13.0	29.4	10.0	22.8	2.7	6.2
ASH-C (232)	6/24/81	180.8	13.8	25.0	9.8	17.7	2.8	5.1

Table 3. SUMMARY OF MICROSCOPICAL ANALYSIS RESULTS

Filter Number	ASH-A (226)		ASH-B (228)		ASH-C (232)	
Sampling Date	6/15/81		6/18/81		6/24/81	
TSP ($\mu g/m^3$)	169.5		226.8		180.8	
	%	$\mu g/m^3$	%	$\mu g/m^3$	%	$\mu g/m^3$
MINERALS						
silicates	68.9	116.8	63.6	144.2	59.8	108.1
carbonates	1.2	2.0	1.3	2.9	4.1	7.4
MOBILE VEHICLE PARTICLES						
rubber tire fragments	1.7	2.9	2.0	4.5	2.3	4.2
COMBUSTION PRODUCTS						
flyash spheres & part. comb. coal	1.3	2.2	2.2	5.0	1.8	3.3
raw coal	1.5	2.5	2.1	4.8	1.8	3.3
fine carbonaceous material	0.8	1.4	1.2	2.7	1.1	2.0
ammonium sulfates	6.7	11.4	13.8	31.3	13.5	24.4
ammonium nitrates	3.0	5.1	3.5	7.9	3.6	6.5
irregularly-shaped glassy flyash	<0.9	<1.5	<0.9	<2.0	<0.9	<1.6
BIOLOGICALS	3.1	5.3	3.2	7.3	4.4	8.0
MISCELLANEOUS	11.6	19.7	7.0	15.9	7.2	13.0
TOTALS	99.8	169.3	99.9	226.5	99.6	180.2

PROJECT	C08636	FILTER NO.	ASH-A (226)
AGENCY	Dames & Moore	TSP ($\mu g/m^3$)	169.5
MICROSCOPIST	ECS	SAMPLING SITE	--
REPORT DATE	8/28/81	SAMPLING DATE	6/15/81

11.0 % COMBUSTIBLE   4.9 % $SO_4^=$ 2.3 % NO_3^-

COMPONENT	CONCENTRATION (WEIGHT %)	GEOMETRIC SIZE, µm MEAN	GEOMETRIC SIZE, µm RANGE
MINERALS			
quartz, feldspars	50.4	10	0.2-89
carbonates	1.2	8	0.2-36
clay, humus	10.3	2	0.5-81
other minerals	8.2	11	1-75
MOBILE VEHICLE PARTICLES			
rubber tire fragments	1.7	12	1-37
COMBUSTION PRODUCTS			
flyash spheres	0.4	3	0.2-25
raw coal	1.5	10	3-105
partially combusted coal	0.9	3	3-36
fine carbonaceous material	0.8	0.2	0.2-3
ammonium sulfates	6.7		A
ammonium nitrates	3.0		A
irregularly-shaped glassy flyash	<0.9		10-25
BIOLOGICALS			
pollens, spores, conidia	1.5		B
plant hairs, fragments	1.5		B
starch	0.1		B
MISCELLANEOUS			
non-magnetic iron oxides	11.6	4	0.2-40

A - Size ranges were not determined since these particles recrystallized on the filter.

B - Size ranges were not determined for these particles because of their low concentrations and obvious natural source.

PROJECT	C08636	FILTER NO.	ASH-B (228)
AGENCY	Dames & Moore	TSP ($\mu g/m^3$)	226.8
MICROSCOPIST	ECS	SAMPLING SITE	--
REPORT DATE	8/28/81	SAMPLING DATE	6/18/81

13.0 % COMBUSTIBLE   10.0 % $SO_4^=$ 2.7 % NO_3^-

COMPONENT	CONCENTRATION (WEIGHT %)	GEOMETRIC SIZE, µm MEAN	RANGE
MINERALS			
quartz, feldspars	50.1	13	0.2-122
carbonates	1.3	8	0.2-65
clay, humus	8.3	6	0.5-86
other minerals	5.2	11	1-81
MOBILE VEHICLE PARTICLES			
rubber tire fragments	2.0	14	1-65
COMBUSTION PRODUCTS			
flyash spheres	0.9	3	0.2-36
raw coal	2.1	12	3-73
partially combusted coal	1.2	3	3-97
fine carbonaceous material	1.2	0.2	0.2-3
ammonium sulfates	13.8		A
ammonium nitrates	3.5		A
irregularly-shaped glassy flyash	<0.9	24	10-100
BIOLOGICALS			
pollens, spores, conidia	2.2	10	B
plant hairs, fragments	0.7		B
starch	0.3		B
MISCELLANEOUS			
non-magnetic iron oxides	7.0	4	0.2-61

A - Size ranges were not determined since these particles recrystallized on the filter.

B - Size ranges were not determined for these particles because of their low concentrations and obvious natural source.

PROJECT	C08636	FILTER NO.	ASH-C (232)
AGENCY	Dames & Moore	TSP ($\mu g/m^3$)	180.8
MICROSCOPIST	ECS	SAMPLING SITE	--
REPORT DATE	8/28/81	SAMPLING DATE	6/24/81

13.8 % COMBUSTIBLE   9.8 % $SO_4^=$ 2.8 % NO_3^-

COMPONENT	CONCENTRATION (WEIGHT %)	GEOMETRIC SIZE, μm	
		MEAN	RANGE
MINERALS			
quartz, feldspars	44.4	11	0.2-97
carbonates	4.1	6	0.2-73
clay, humus	9.3	5	0.5-73
other minerals	6.1	10	1-81
MOBILE VEHICLE PARTICLES			
rubber tire fragments	2.3	15	1-73
COMBUSTION PRODUCTS			
flyash spheres	1.0	3	0.2-32
raw coal	1.8	12	3-101
partially combusted coal	0.8	3	3-109
fine carbonaceous material	1.1	0.2	0.2-3
ammonium sulfates	13.5		A
ammonium nitrates	3.6		A
irregularly-shaped glassy flyash	<0.9	20	10-74
BIOLOGICALS			
pollens, spores, conidia	1.9	10	B
plant hairs, fragments	2.2		B
starch	0.3		B
MISCELLANEOUS			
non-magnetic iron oxides	7.2	4	0.2-105

A - Size ranges were not determined since these particles recrystallized on the filter.

B - Size ranges were not determined for these particles because of their low concentrations and obvious natural source.

Sound

4.0 SOUND

4.1 INTRODUCTION

The range of sound pressured that can be heard by people varies from two-ten-thousand-millionths (2×10^{-10}) of an atmosphere (sound barely audible to humans) to two-thousandths (2×10^{-3}) of an atmosphere (sounds sufficiently loud to be painful). The decibel notation system is used to describe sould levels over this wide physical range. Essentially, the decibel unit compresses this to a workable range using the following logarithmic relationship:

$$\text{Sound level in decibels (dB)} = 20 \log_{10} \left(\frac{P}{P_0}\right)$$

where P_0 is a reference sound pressure required for a minimum sensation of hearing, and

P is the sound pressure

Zero decibels is assigned to the sound level producing a minimum sensation of hearing and 140 decibels to the minimum sound level which is painful to humans. Thus, a range whose upper limit is about 10 million times its lower limit is expressed on a scale of zero to 140.

The human ear does not perceive sounds at low frequencies in the same manner as those at higher frequencies. Low frequency sounds do not seem as loud as those of equal intensity at higher frequencies. The A-weighting network is provided in sound analysis systems to simulate the human ear. A-weighted sound levels are expressed in units of decibels. These A-weighted sound levels are used to evaluate hearing damage risk (OSHA) or community annoyance impact. These values are also used in federal, state, and local noise ordinances.

Sound is variable over time. Consequently, a statistical analysis is necessary to describe the temporal distribution of sound and to compute single-number descriptors that characterize the time-varying sound. This report contains the following statistical A-weighted sound levels:

L_X -- This is the sound level exceeded X percent of the time during the measurement period. For example:

L_{90} -- This is the sound level exceeded 90% of the time during the measurement period and is often used to represent the "residual" sound level.

L_{50} -- This is the sound level exceeded 50% of the time during the measurement period and is used to represent the "median" sound level.

L_{10} -- This is the sound level exceeded 10% of the time during the measurement period and is often used to represent the "intrusive" sound level.

Cumulative Distribution -- The sound level values, usually plotted, of L_X from L_1 to L_{100} for a measurement period.

L_{eq} -- This is the equivalent steady sound level that provides an equal amount of acoustic energy as the time-varying sound.

L_d -- Day sound level, L_{eq}, for the daytime period (0700-2200) only.

L_n -- Night sound level, L_{eq}, for the nighttime period (2200-0700) only.

L_{dn} -- Day-night sound level, defined as:

$$L_{dn} = 10 \log_{10} [(15 \times 10^{L_d/10} + 9 \times 10^{(L_n + 10)/10})/24]$$

Note: A 10 dB correction factor is added to the nighttime sound level.

This chapter presents the results of an ambient sound survey which will be used in the prediction of sound impacts of the proposed plant. Format for this chapter is introduction, sampling methodology and frequency, measurement locations, instrumentation and quality assurance, sound sources, results and discussion, and references.

4.2 SAMPLING METHODOLOGY AND FREQUENCY

The statistics of the ambient sound, for example, L_{10}, are obtained by repeated, uniform sampling of the sound. The samples are used to determine the cumulative distribution of the sound by noting the percentage of time each sound level is exceeded, i.e., L_5, L_{10}, L_{15}, etc.

A Metrosonics db-601 Community Sound Level Analyzer, with a GenRad one-half inch electret microphone, was used. The Metrosonics unit digitally processes the sound level signals to obtain the desired sound level statistics. The cumulative distribution and equivalent sound level, L_{eq}, are computed by this instrument.

For this study the GenRad microphone was mounted on a tripod, five feet above the ground surface and at least 10 feet from any sizable reflecting surface. The instrumentation was calibrated before each measurement period by means of a 1000 Hertz reference signal of 114 dB generated by a GenRad Type 1562A Sound Level Calibrator.

Since wind can cause the microphone to produce spurious signals, the Metrosonics is provided with a wind measuring instrument which temporarily halts the measurements when the wind speed exceeds 12 miles per hour. In addition, meteorological information such as wet and dry bulb tempratures, and wind speed were manually obtained to assure the sound measurement quality.

The instruments were continuously monitored by a trained acoustical technician. The monitoring technician also noted the general condition of the environment and the surrounding noise sources which contributed to the ambient sound levels.

The ambient sound level survey was conducted at six locations on September 4 and 5, 1980. Sound level measurements were made at each location during the morning, afternoon, evening, and nighttime for 20 minute durations.

4.3 MEASUREMENT LOCATIONS

To adequately describe existing sound quality in the area of the proposed plant, a background ambient sound level survey was conducted at six locations near Holt and Addison, Kentucky. The measurement locations are shown in Figure 3.5 and are discussed below. The six locations were selected to provide an adequate spatial description of the present environmental sound at representative noise-sensitive locations where the ambient sound levels may be affected by the proposed project.

Location 1 - Route 144 Near Abandoned House

This site is on Route 144 about 50 feet from the roadway and 40 feet from abandoned house.

Location 2 - Route 144 at Dirt Road in the Town of Holt

This site is on dirt road 50 feet from the roadway and 1/4 mile from Route 144.

Location 3 - Route 144 Near Town of Addison

This site is located on Route 144 50 feet from roadway and 1/2 mile east of the Town of Addison.

Location 4 - New Bethel Road

This site is on New Bethel Road 50 feet from roadway and 1-1/2 miles south of Route 144.

Location 5 - New Bethel Road

This site is on New Bethel Road 50 feet from roadway and 1/4 mile south of Caney Fork Creek.

Location 6 - New Bethel Road

This site is on New Bethel Road 50 feet from roadway and 1-3/4 miles east of Route 144.

4.4 INSTRUMENTATION AND QUALITY CONTROL

Manufacturer specifications are followed for maintenance, calibration and standardization of the Metrosonics dB-602 Community Sound Level Analyzer and the GenRad Type 1562A Sound Level Calibrator. As indicated, the Metrosonics is calibrated in the field prior to each sound monitoring session. Also meteorological data is recorded in the field. During field data collection, field logs are maintained to document daily progress. All measurements are taken by a trained acoustical technician. Data calculations and field logs are reviewed by a senior acoustical specialist.

4.5 SOUND SOURCES

4.5.1 Regional

Kentucky Department of Natural Resources and Environmental Protection, Division of Air Pollution Control contains the Noise Control Section that is responsible for developing regulations to implement "The Kentucky Noise Control Act of 1974". The Act requires the agency to use federal ambient sound standards. EPA has not developed these standards which has resulted in a delay of the state regulations.

Currently the State is involved in monitoring only areas for which complaints have been lodged. The State has not conducted a sound survey in Breckinridge County (personal communication on March 16, 1981 with Tommy Jackson, Division of Air Pollution Control, Noise Control Section, Frankfort, Kentucky).

4.5.2 Site

During the measurement period, the Dames & Moore staff observed the following listed noise sources. These sources contributed to the ambient sound levels which are reported in the Section 4.6.

Location 1 - Morning - Crickets, insects, birds, aircraft, tractor, road traffic, distant train, boat horn.

Afternoon - Road traffic, crickets, insects, aircraft.

Evening - Road traffic, aircraft, insects, crickets.

Nighttime - Crickets, insects, road traffic.

Location 2 - Morning - Distant Route 144 road traffic, crickets, insects, birds, aircraft.

Afternoon - Crickets, insects, military aircraft, distant Route 144 road traffic.

Evening - Distant Route 144 road trafic, aircraft, dogs barking, crickets, insects.

Nighttime - Distant Route 144 road traffic, distant train, crickets, insects.

Location 3 - _Morning_ - Birds, crickets, insects, train, road traffic, aircraft.

Afternoon - Aircraft, insects, crickets, road traffic, birds.

Evening - Crickets, insects, road traffic.

Nighttime - Crickets, insects, road traffic.

Location 4 - _Morning_ - Aircraft, crickets, insects, road traffic, hammering and sawing in large barn, birds, distant tractor.

Afternoon - Crickets, insects, distant tractor, distant train, children playing in distance, aircraft, road traffic.

Evening - Aircraft, road traffic, insects, crickets.

Nighttime - Crickets, insects.

Location 5 - _Morning_ - Road traffic, birds, crickets, insects, aircraft, hammering.

Afternoon - Distant lawnmower, distant hammering, road trafic, aircraft, birds, crickets, insects.

Evening - Crickets, insects.

Nighttime - Crickets, insects.

Location 6 - _Morning_ - Birds, crickets, insects, aircraft, dogs barking, distant road traffic.

Afternoon - Crickets, insects, birds, aircraft, distant and local road traffic, distant hammering, dogs barking.

Evening -

Nighttime - Crickets, insects, dogs barking.

In summary, the dominant artificial sound sources were road traffic, aircraft, train, and boat horn. Locally there are not any industrial facilities that affect the ambient sound level.

4.6 RESULTS AND DISCUSSION

A summary of the statistical sound levels measured at each survey location is presented in Table 4.1. Meteorological conditions during each measurement period is presented in Table 4.2. The summary data include L_1 - the sound level exceeded 1% of the time - which represents the maximum observed sound, and L_{99} - the sound level exceeded 99 percent of the time - which represents the minimum sound. Cumulative distributions of the environmental sound levels are presented in Figures 4.1 through 4.6. The natural sounds and those from distant sources produce a minimum sound whch ranges from 43-56 dB, while the intrusive sounds, which are moderate, range from 49-73 dB. The day-night sound levels, L_{dn}, range from 56.2 to 63.9 dB.

Sound levels at the site boundary presently do not exceed the EPA short term goals for community sound and the Department of Housing and Urban Development's criterion for "normally acceptable" land use for residential housing of 65dB (U.S. Environmental Protection Agency, 1977 and U.S. Department of Housing and Urban Development, 1979) . But, the reason day-night sound levels are as high as indicated are due to the cricket sounds which are typical of quiet rural areas. The high nighttime sound is penalized by 10 dB for the computation of day-night sound levels, since nighttime sound is more annoying than daytime sounds. The L_{dn} descriptor which is useful for describing urban and suburban community noise fails to adequately describe the rural sound climate.

Table 4.1. Summary of A-weighted ambient sound levels - dB

Locations	Periods: Morning	Afternoon	Evening	Nighttime
<u>Location 1</u>				
L_{99}	45	43	44	48
L_{90}	45	44	46	48
L_{50}	46	46	47	49
L_{10}	46	47	48	49
L_1	53	55	49	50
L_{eq}	48	49	48	50
L_d = 48.4				
L_n = 50.0				
L_{dn} = 56.2				
<u>Location 2</u>				
L_{99}	50	46	49	51
L_{90}	50	46	50	52
L_{50}	51	47	51	56
L_{10}	52	48	54	56
L_1	53	73	58	57
L_{eq}	52	59	53	56
L_d = 56.3				
L_n = 56.0				
L_{dn} = 62.5				
<u>Location 3</u>				
L_{99}	45	44	48	49
L_{90}	46	44	49	49
L_{50}	49	45	55	50
L_{10}	50	46	58	51
L_1	53	54	59	51
L_{eq}	49	48	57	51
L_d = 52.7				
L_n = 51.0				
L_{dn} = 57.7				
<u>Location 4</u>				
L_{99}	51	47	51	52
L_{90}	52	49	51	52
L_{50}	52	53	52	52
L_{10}	53	54	52	52
L_1	55	55	53	53
L_{eq}	54	54	53	53
L_d = 53.8				
L_n = 53.0				
L_{dn} = 59.5				

Table 4.1. Continued.

Locations	Morning	Afternoon	Evening	Nighttime
Location 5				
L_{99}	48	46	52	52
L_{90}	48	46	52	53
L_{50}	49	47	52	54
L_{10}	55	48	53	54
L_{1}	65	53	53	55
L_{eq}	54	48	54	55
L_d = 52.5				
L_n = 55.0				
L_{dn} = 61.1				
Location 6				
L_{99}	46	45	-	56
L_{90}	47	45	-	57
L_{50}	48	48	-	57
L_{10}	49	49	-	58
L_{1}	50	56	-	58
L_{eq}	50	50	-	58
L_d = 50.0				
L_n = 58.0				
L_{dn} = 63.9				

Table 4.2. Meteorological conditions during measurement periods

Parameters	Locations			
	LOCATION 1			
Date	9/4/80	9/4/80	9/4/80	9/4/80
Time	0820	1400	1935	2315
Temperature (°C)	25	35	25	26
% Humidity	87	60	87	80
Wind Speed (M/Sec)	<2	3	<2	<2
Wind Direction	Calm	SW	SW	Calm
	LOCATION 2			
Date	9/4/80	9/5/80	9/4/80	9/4/80
Time	0850	1300	1950	2350
Temperature (°C)	26	33	25	24
% Humidity	87	82	87	85
Wind Speed (M/Sec)	<2	<2	<2	<2
Wind Direction	Calm	SW	Calm	Calm
	LOCATION 3			
Date	9/4/80	9/5/80	9/4/80	9/5/80
Time	0935	1330	2025	0045
Temperature (°C)	30	33	25	24
% Humidity	88	77	87	85
Wind Speed (M/Sec)	<2	<2	<2	<2
Wind Direction	Calm	SW	Calm	Calm
	LOCATION 4			
Date	9/4/80	9/5/80	9/4/80	9/5/80
Time	1015	1410	2100	0120
Temperature (°C)	31	34	25	24
% Humidity	82	66	87	85
Wind Speed (M/Sec)	<2	<2	<2	<2
Wind Direction	Calm	SW	Calm	Calm
	LOCATION 5			
Date	9/5/80	9/5/80	9/4/80	9/5/80
Time	1050	1440	2145	0150
Temperature (°C)	33	34	26	24
% Humidity	71	66	80	85
Wind Speed (M/Sec)	2	<2	<2	<2
Wind Direction	SW	SW	Calm	Calm

Table 4.2. Continued

Parameters	Locations		
	LOCATION 6*		
Date	9/5/80	9/5/80	9/4/80
Time	1120	1510	2240
Temperature (°C)	33	32	26
% Humidity	71	65	80
Wind Speed (M/Sec)	<2	<2	<2
Wind Direction	SW	SW	Calm

*At Location 6, no sound level measurements were taken in the evening due to logistical problems.

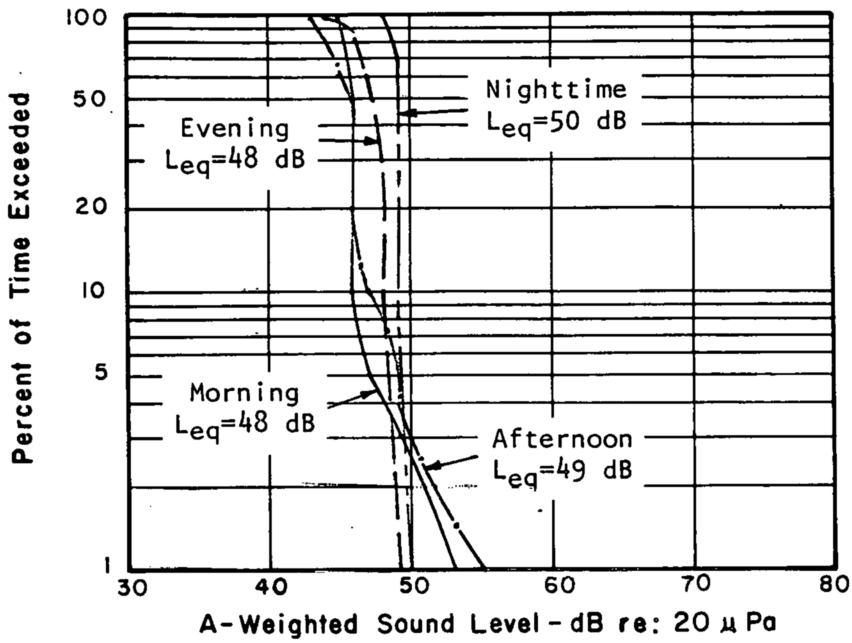

Figure 4.1 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 1 September 4 & 5, 1980

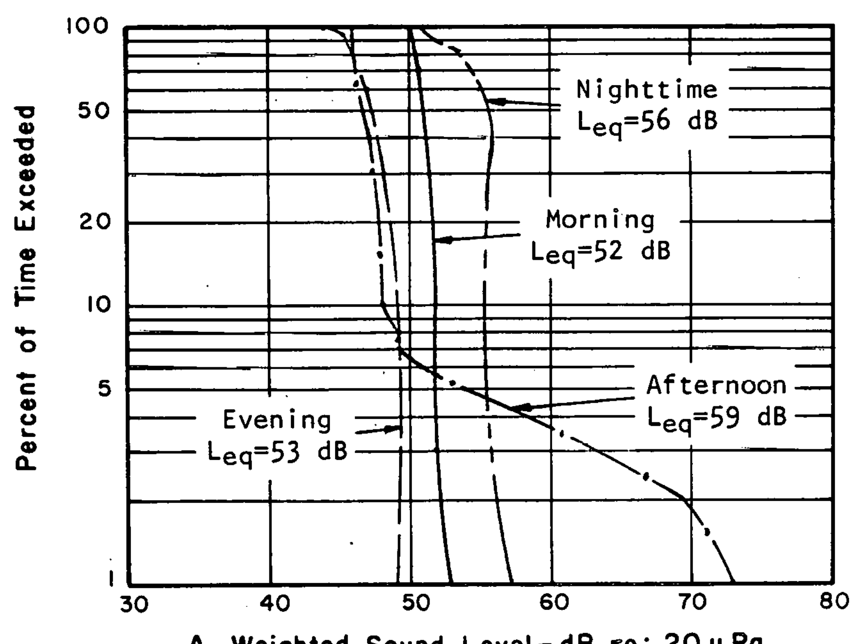

Figure 4.2 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 2 September 4 & 5, 1980

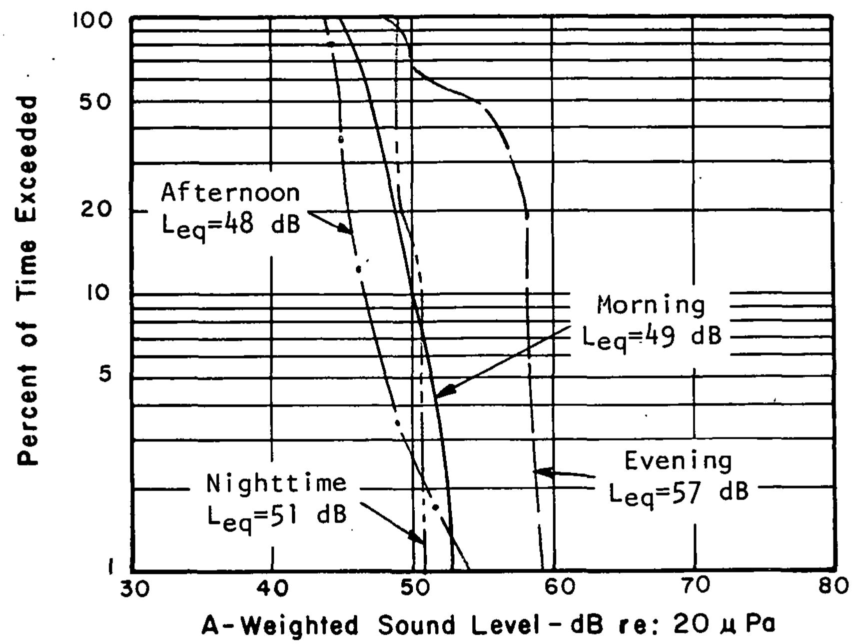

Figure 4.3 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 3 September 4 & 5, 1980

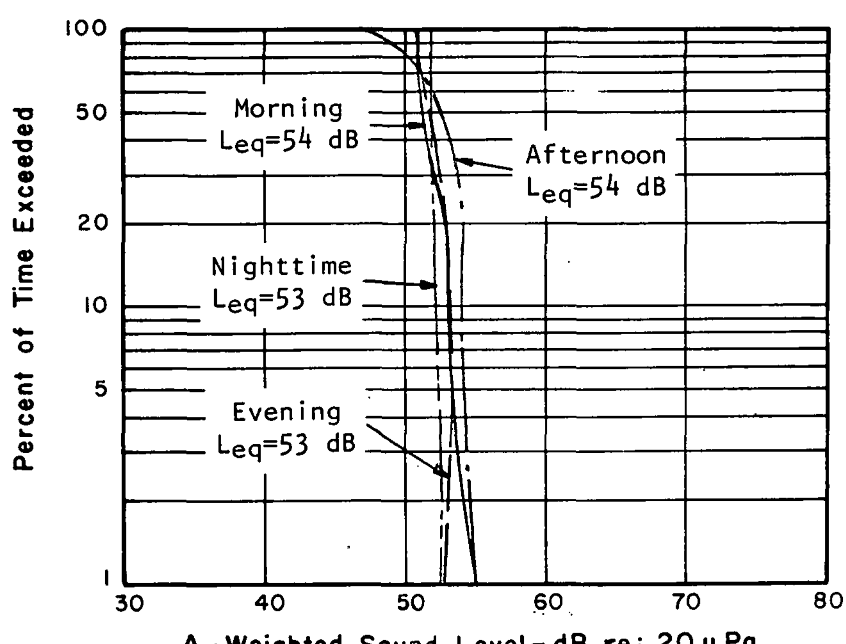

Figure 4.4 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 4 September 4 & 5, 1980

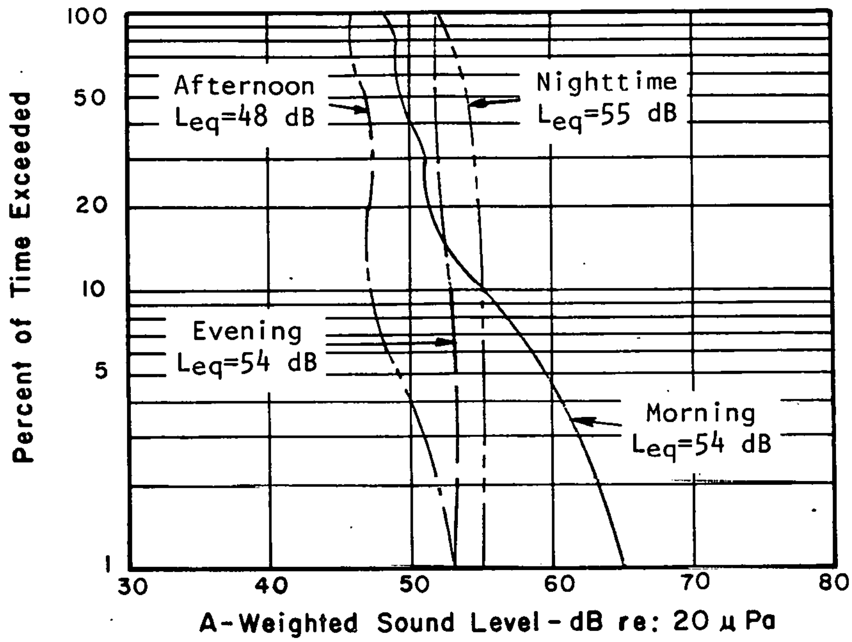

Figure 4.5 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 5 September 4 & 5, 1980

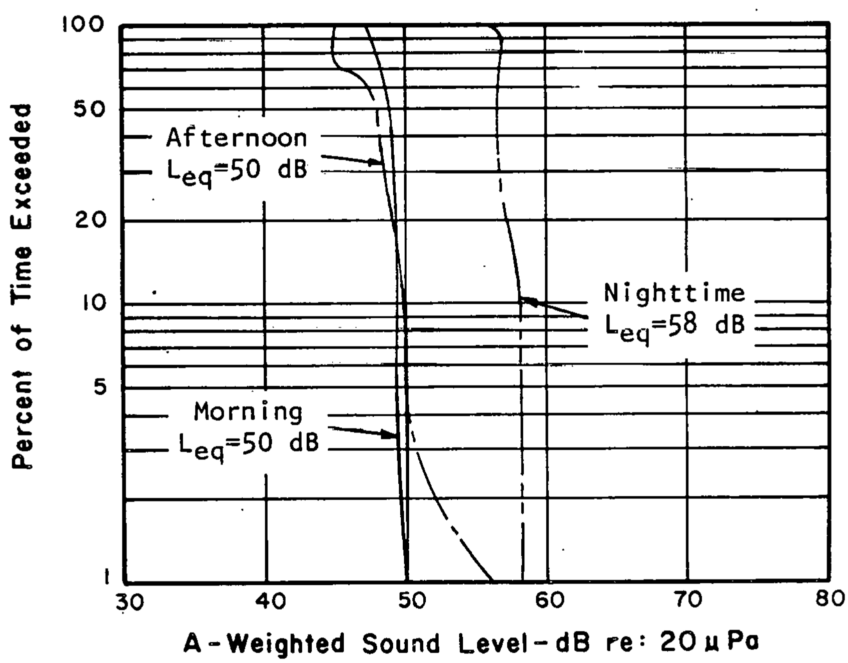

Figure 4.6 Cumulative Distribution of A-Weighted Sound Levels Measured at Location 6 September 4 & 5, 1980

4.7 REFERENCES

U.S. Department of Housing and Urban Development. 1979. DHUD, Environmental Criteria and Standards, 24 CFR 51, July 12, 1979. U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency. 1977. Toward a national strategy for noise control. U.S. Government Printing Office, Washington, D.C.

Aquatic Ecology

5.0 AQUATIC ECOLOGY

5.1 SUMMARY

The two major plankton components, phytoplankton and zooplankton, showed general population characteristics that conformed to those patterns suggested by other Ohio River investigations. Ohio River plankton was typically rich in species and showed temporal variation in taxonomic make up, fluctuating total densities and paucity of individual species abundance. Diatoms were the predominant phytoplankters during this study in the Ohio River. Their relatively high densities were interrupted during the October survey when cryptomonads dominated phytoplankton densities. Zooplankton were comprised primarily of rotifers throughout the Ashland baseline study except during July, when immature copepods were predominant. Phytoplankton and zooplankton communities in Town Creek and Bull Creek were not as taxonomically rich, diverse or abundant as those communities occuring at the Ohio River stations. The phytoplankton communities were much more developed structurally and functionally than comparable zooplankton communities. Overall, plankton communities showed the highest taxonomic richness and total densities during May, 1980 at both creek stations. The only periphyton sampling conducted during July at the Ashland site indicated healthy species assemblage of diatoms, and attched filamentous algae. Base on the samples collected all stations exhibited this characteristic, but it was much more pronounced in the creeks.

Benthic macroinvertebrates collected from the Ohio River stations were comprised of many genera typically occupying many ecological niches and represented numerous functional feeding groups. Overall, the highest macroinvertebrate densities occurred along the lateral margins of the river. Mid-channel densities were generally lowest. Taxonomic richness, the pattern of functional feeding group distribution, and generally diversity and equitability followed this same pattern. The benthic macroinvertebrate communities occurring in the Ohio River were typical for lower river pools. Zoobenthos collected from Bull and Town Creeks showed structurally and functionally complex communities throughout the Ashland study. The benthic organisms here were quite often composed of relatively high densities, very taxonomically rich and diverse fauna, which were comprised of all functional feeding groups.

The macrophytes collected from the study area represented only a sparse distribution of relatively few species. These few species of aquatic macrophytes were located in the Town and Bull Creeks outlet areas in the proximity of the upper embayments.

The mussel fauna in the Ohio River was determined to be comprised of one-half dozen species which were scattered along the Kentucky side of the river. All freshwater mussels collected were located between the Bull Creek outlet and Ohio River Station 3 in firm mud substrate. No unionid mussels were captured from Bull or Town Creeks.

Fish studies on the Ohio River suggest a prevalence of sport fish, such as white crappie and bleugill. Backwater areas were dominated by gizzard shad but are also good producers of sport fish. The upper stations on Town and Bull Creeks seemed to support farily well balanced and healthy fish communities.

Tissue of fish from the Ohio River and Town and Bull Creeks contained low amounts of organic compounds and trace metals. Copper was the only constitment that appeared to be consistently higher than data from the literature.

Mussels from the Ohio River contained greater amounts of trace metals than fishes but generally less than in the sediments. Mercury however, was often more concentrated in the mussels than in the sediments. The concentration of mercury in mussel tissue is not necessarily atypical and the level of mercury accumulation is species dependent.

5.2 BACKGROUND AND OBJECTIVES

The aquatic baseline investigations were designed to provide data on the major taxonomic groups, including phytoplankton zooplankton, macrophytes, benthic macroinvertebrates, and fishes. Also data on body burden in fishes and bivalves (mussels) for selected chemical parameters was measured to allow correlation with sediment and water quality data. Location of sampling stations is presented in Figure 5.1. Particular emphasis was placed on the design of the benthic macroinvertebrate sampling program because of its importance in monitoring construction and operational impacts of the proposed plant.

Benthic macroinvertebrate sampling was conducted on the Ohio River along transects to document the varability between near-shore of each side (Kentucky and Indiana)and the mid-channel. One station was also located above the backwater area on Bull and Town Creeks. A specific program was implemented to document the presence or absence of a commercially viable mussel (bivalve) bed.

The purpose of the fisheries investigations was to determine species composition and relative abundance and distribution of the fishes in the site area. Adult fishes were sampled at each of the three Ohio River station (RM 705, 707 and 708), the backwaters of both Town and Bull Creek and upstream locations on Town and Bull Creek. In addition, ichthyoplankton was sampled once, during the spring of 1980 in the backwaters of Town and Bull Creek.

Section 5.5.6 highlights the results of fish collections made at each of these locations and discusses the relative importance of each of these habitats to the existing fish community.

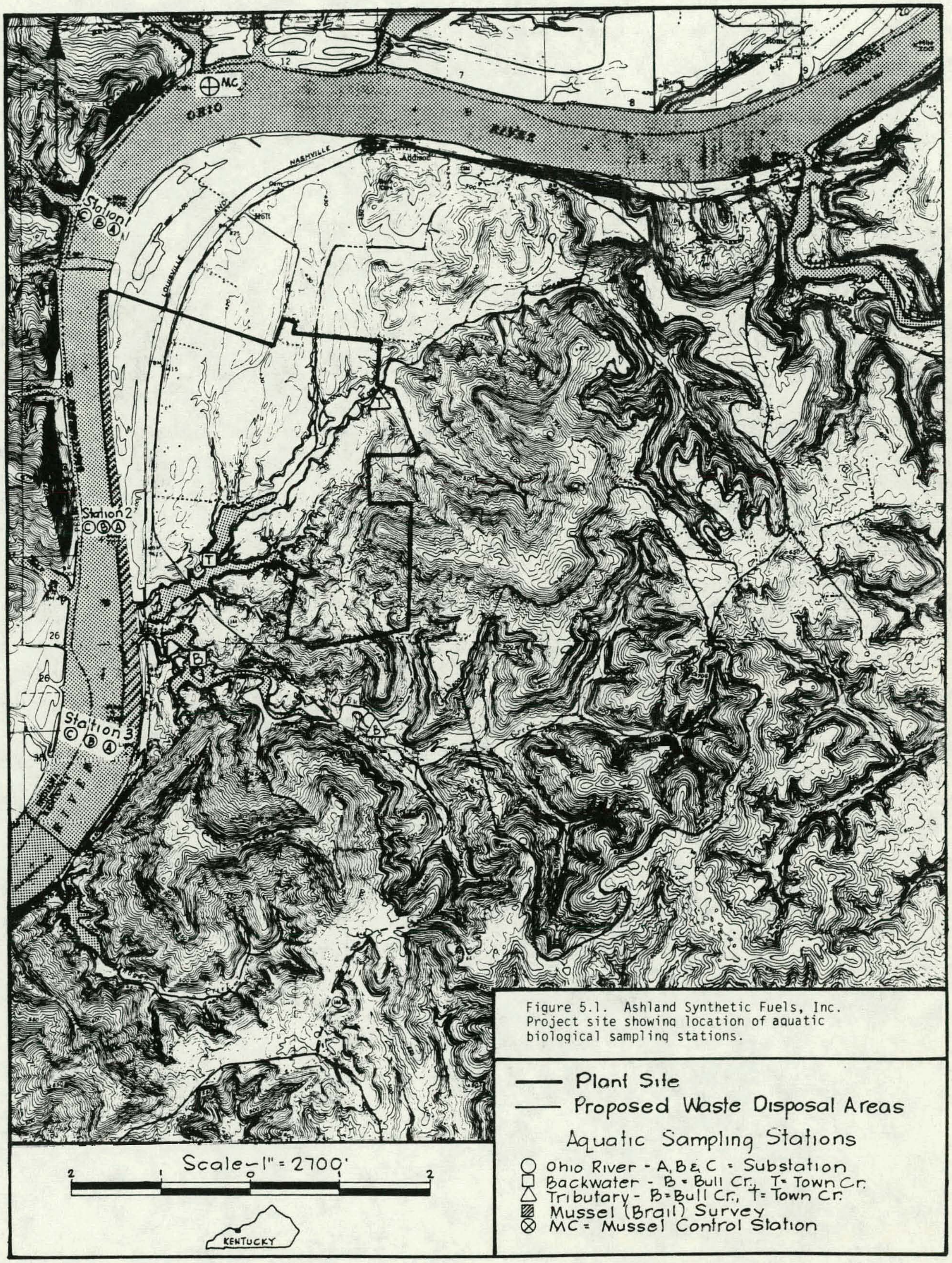

Figure 5.1. Ashland Synthetic Fuels, Inc. Project site showing location of aquatic biological sampling stations.

Limited data are available on chemical analysis of fish and bivalve tissue in the Ohio River. ORSANCO monitors several fish each year throughout the Ohio River Valley but only a few from any one locale. U.S. EPA (in press) analyzed several fish from RM 702-722 in 1979-80 as part of the baseline data gathering for an EIS. There is also a considerable amount of recent literature from other rivers and lakes throughout North America to which the data of the present study can be compared.

The objective of the chemical analysis of fish and mussel tissue was to determine pre-construction levels of trace elements and organic compounds. As aquatic organisms are constantly subjected to the various materials entering the aquatic ecosystem, levels of these materials in their tissues can more fully account for their extent in the environment than instantaneous "grab" water samples. As fish are highly mobile organisms, a baseline control sample is the only usefull control that can be readily attained. However, mussels, which are "sedentary" filter-feeders, can be collected at points up-and downstream of a pollution source and furnish valuable information to the investigator.

5.3 THREATENED AND ENDANGERED SPECIES

The potential occurrence of threatened and endangered species of aquatic organisms at the Ashland site is evaluated by the U.S. Fish and Wildlife Service and the Kentucky Nature Preserves Commission of the Commonwealth of Kentucky. The U.S. Fish and Wildlife Service is legally mandated through the U.S. Department of Interior by the Endangered Species Act of 1973 (PL 96 205 as amended). Kentucky's Nature Preserves Commission is not legally mandated. However, their interest, as well as the U.S. Fish and Wildlife Service, is to promote the protection, preservation and enhancement of the overall status of threatened and endangered wildlife and their habitat. Findings pertaining to aquatic life collected near the Ashland site which have been delegated status by the agencies above are discussed in the following paragraph.

Five mussels in Kentucky and Indiana listed as endangered by the U.S. Fish and Wildlife Service (45 FR, 69361, October 20, 1980) have the potential to occur at the Breckinridge site (see Kentucky Nature Preserves Commission, 1981). These include the tuberculed-blossom pearly mussel (Epioblasma torulosa torulosa), the pink mucket pearly mussel (Lampsilis orbiculata), the orange-footed pearly mussel (Plethobasus cooperianus), rough pigtoe pearly mussel (Pleurobema plenum), and fat pocketbook (Potamilus capax). None of the mussels listed above were collected during the present study. However, one mussel, Plethobasus cyphus (bullhead), which is listed by the Kentucky Nature Preserves Commission as "Special Concern", was collected in the Ohio River. Species with this status are to be monitored until sufficient information concerning its well being is obtained and reclassification to the respective status category is made.

No threatened or endangered fishes are listed for the states of Kentucky or Indiana by the U.S. Fish and Wildlife Service.

5.4 SAMPLING METHODOLOGY AND FREQUENCY

5.4.1 Plankton

Plankton (phytoplankton and zooplankton) samples were collected May 15 and 16, July 16 and 17, October 7 and 8, 1980, and January 15, 1981 from Ohio River Stations 1, 2, 3 and from Town and Bull Creeks.

Whole one liter phytoplankton samples were collected from a depth of approximately 0.2 meter and preserved with Lugol's solution with a final sample concentration of 1 percent. Each phytoplankton sample was concentrated by settling for 120 hours, then the supernatant siphoned and discarded. The concentrated portion was placed in storage bottles and saved for analysis. Analyses of the phytoplankton samples were completed using a Sedgwick-Rafter (S-R) cell and glycerine jelly slides by identifying and counting phytoplankton in standardized Whipple disc strips at 300 X and 600 X, respectively. Proportional count diatom slides were prepared with Hyrax to determine diatom densities and identifications in the ambient samples.

Phytoplankton densities were given as number of cells (excluding Chlorophyta filaments) per ml of water and were calculated from the following equation:

$$\text{Phytoplankton/liter} = \frac{C \times SRV}{S \times WDV} \times \frac{CV}{SV} \times \frac{TV \times 1000}{TV - PV}$$

Where:

C = Number of organisms counted
SRV = Sedgwick-Rafter Cell Volume (1 ml)
S = Number of Whipple disc strips counted
WDV = Whipple Disc Volume of each strip (ml)
CV = Concentrate Volume (ml)
TV = Total Volume (ml)
SV = Sample Volume (ml)
PV = Preservative volume (ml)

Zooplankton samples were collected from the Ohio River, Town Creek, and Bull Creek at a depth of 0.2 meter, using a 12-volt DC centrifugal pump and a Wisconsin style plankton net. Pump calibration was achieved by recording the elapsed time for a known volume of water to pass through it. Each sample was concentrated by passing 100 liters of water through a No. 20 mesh (0.076 mm) plankton net equipped with a brass bucket. The contents of the bucket were washed into storage bottles and preserved in formalin plus glycerine with a final sample concentration of 4 percent. Glycerine was added to the zooplankton samples to preserve sensitive and fragile tissue.

Laboratory analyses of zooplankton were initiated by bringing the concentrate volume to a constant volume for each sample. Subsamples from the zooplankton concentrate were transferred to a 1 ml S-R cell using a wide-orifice pipette. A strip counting method was employed for counting zooplankton at 150X. Depending on the zooplankton density, 1 to 3 ml of the concentrated samples were counted. Glycerine jelly slide mounts were occasionally used for identification of relatively small rotifers, and aided in determination of cladocerns and copepods.

Zooplankton densities, expressed as number of individuals per liter, were determined by using the formula:

$$\text{Number of organisms} = \frac{C \times SRV}{S \times WDV} \times \frac{CV}{SV} \times 1000$$

Where:

C	=	Number of organisms counted
SRV	=	Sedgwick-Rafter Cell Volume (ml)
WDV	=	Whipple Disc Volume of each strip (ml)
S	=	Number of strips counted

CV = Concentrate Volume (ml)
SV = Sample Volume (ml)
1000 = ml/L

The taxonomic keys used for identifying zooplankton and phytoplankton are listed in the reference section (5.7) of this report.

5.4.2 Periphyton

Periphyton was collected July 17, 1980 from various types of natural substrate at Ohio River Stations 1, 2 and 3 (Kentucky side) and from Town and Bull Creeks. Periphyton samples were preserved with 4 percent formalin. The periphyton which was scraped or brushed from the natural substrate, was subjected to laboratory examination methods similar to those used for phytoplankton, except that results were expressed as percent composition for an equal unit-effort of sampling. The taxonomic keys used to identify periphytic algae are provided in the reference section (5.7) of this report.

5.4.3 Aquatic Macrophytes

The presence of significant rooted and floating aquatic macrophyte populations were surveyed visually and through the benthic macroinvertebrate sampling program. Representative specimens were collected, preserved in 4 percent formalin and returned to the Lexington laboratory for identification. The primary objective of this analysis was to determine species composition and qualitative abundance of importance stands when they existed. Taxonomic keys used to identify the few vascular hydrophytes collected are referenced (Section 5.7).

5.4.4. Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected May 13 and 16, July 15 and 16, October 8 and 9, 1980, and January 13 and 14, 1981, from Ohio

River Stations 1, 2 and 3, and from Town Creek and Bull Creek.

Triplicate samples of benthic macroinvertebrates were collected quantitatively with a Ponar dredge (23 x 23 cm) from the Ohio River, and with a Surber square foot sampler (30.5 x 30.5 cm) from Town and Bull Creeks. Ponar benthic samples were washed through a U.S. Standard No. 30 (0.595 mm) wire-mesh sieve. The mesh in the Surber sampler netting was comparable to the U.S. Standard sieve. All benthic macroinvertebrate samples were preserved with formalin at a final sample concentration of 4 percent. Each sample was hand-picked in the laboratory under a 10X magnification lamp. Enumeration was completed on whole organisms under a dissecting scope, or after appropriate microscope slide mounting procedures were accomplished. Taxonomic identifications of prepared mounts were made with the aid of an American Optical binocular scope equipped with variable optics, including 100X oil immersion. All keys used for taxonomic identifications are listed in the reference section (5.7).

The Shannon-Weaver mean species diversity index ($\bar{d}$) was used to calculate community diversity for the benthic data derived from laboratory analysis. This diversity is used to estimate two components of community structure: taxonomic richness and distribution of individuals among the taxa. Mutually, these components of diversity help indicate the health or general well-being of the aquatic environment.

Community diversity was calculated using the following machine formula presented by Lloyd, Zar, and Karr (1968):

$$\bar{d} = C/N\ (N\log_{10}N - n_i\log_{10}n_1)$$

Where:

$\bar{d}$ = Mean community diversity
C = 3.321928 (converts base 10 log to base 2 (bits))
N = Total number of individuals
n_i = Total number of of individuals in the i^{th}

5.4.5 Mussels

Freshwater mussels (Bivalvia: Unionidae) were collected in July and October, 1980, and January, 1981 in the immediate vicinity of the proposed plant site (Figure 5.1). The two principle methods used to collect bivalves were brailing and reconnaissance along each creek on the site. Live mussels and occasionally relic mussels were collected. Brailing was completed in the Ohio River along the Kentucky side out to depths of approximately 9-11 meters. Brailing was not conducted in deeper water because of the potential limitations for this device in deeper water and because of the lack of favorable habitat as determined by sediment analyses from benthic macroinvertebrate sampling prior to brailing. Sampling limitations of brail appear to be related to the numerous variable encountered while sampling, as well as inherent to specific types of brailing apparatus (Fuller 1978, Krumholz 1970, Williams 1969, Taylor 1980). Brailing is presently considered an important mussel collecting method because it is efficient in producing reliable presence/absence data and causes generally mior mussel mortality (Fuller 1980).

Each embayment area of Bull and Town Creeks was brailed in irregular pattern in attempts to collect potential pond mussels. Both creek channels, which are confluent with the Ohio River, were brailed nearly their entire lengths. Visual checks were also made of the shoreline area for possible relic mussels.

Brailing in the Ohio River was conducted three times during 1980 and 1981 for the collection of mussels. The mussel inventory includes those organisms collected for tissue analyses during the October 1980, and January 1981 surveys. During these surveys mussel tissue was collected at the up river control station and Ohio River Station 3. In October, 1980 a mussel investigation of the Ohio River adjacent to the proposed site was conducted to determine species composition and extent of potential beds. Mussels were captured during the completion of a series of perpendicular brail tows covering distances from 15 meters to 153 meters from the shore and from 31 meters to 305 meters paralleling the shore. Distance from the shoreline and length of the tows were estimated Bausch & Lomb range finder binoculars by measuring increments on a stadia rod which was located on the river shoreline. Three general areas were brailed: from Ohio River Station 1 to Station 2, from Ohio River Station 2 to the Bull Creek outlet, and from the Bull Creek outlet to Ohio River mile marker 708.2 (Ohio River Station 3). Presence/absence mussel sampling was conducted in two phases, first to determine if potentially large mussel beds were present, and secondly, to define extent of those mussel beds, if located.

The first phase of the brailing effort was initiatd by towing the crow-foot bar (brail) along predetermined transects. The brail was retrieved and checked for mussels during and at the end of each linear tow. If mussels were present, they were tagged, numbered and tentatively identified, then placed into a five gallon pail containing ambient water and carbonated water which acts as an anesthetic. The brailing procedure continued into the second phase of sampling effort if mussels were collected. The second phase continued until the investigator was satisfied that additional brailing would not result in substantial increases in number of mussels, or add significant numbers of new taxa, within the immediate vicinity of the Ashland site. The first phase was concluded if mussels were not collected along the transect and these results were noted; depth, substrate type and location of transect. Mussels which were placed into the anesthetic solution were fixed in 10 percent aqueous formaldehyde then preserved in 70 percent alcohol upon arrival at the laboratory.

Laboratory analyses included the separation of internal parts from the valves, cleaning the valves and inspecting each specimen to confirm identifications. Taxonomic references, as well as information useful in studying Bivalvia: Unionidae, include the following authors; Burch (1975), Fuller (1974, 1978, 1980), Murray & Leonard (1962), Starrett (1971), Neel & Allen (1950), Stansbery (1962), Heard (1975) and Pennak (1978). If an identification was questionable, the mussel was packaged and sent to Dr. J. Williams at Eastern Kentucky University in Richmond, Kentucky, for verification. A voucher collection of the freshwater mussels collected near the Ashland site is presently being maintained at Dames & Moore's Lexington Office.

The brail used to collect mussel during the three aquatic biological surveys were of two lengths (1 meter and 3 meters) and constructed of similar materials to that of Krumholz (1970). Each brail utilized a 1 inch galvanized pipe which accomodated numerous 1/8 inch trot line strands 28 inches in length. These strands were spaced evenly across the pipe at intervals of 2 1/2 to 3 inches. Each strand had three crow-feet attached along its lower portion, spaced evenly over the last 7-10 inches. The crow-feet were constructed of No. 9 steel wire and recurved 180° with the long axis of the crow-foot. The bridle, or harness, was constructed of 'dog' chain and clipped to the galvanized pipe at three points. The harness formed a low oblique triangle to which a 5/8 inch tow line was attached. The three point bridle enhanced proper positioning of the bar when in tow over the river bottom.

5.4.6 Fishes

Fish were sampled on a quarterly basis from May of 1980 through January of 1981. At the Ohio River stations, adult fish were collected with hoopnets, a boom electrofisher, and one mini-experimental gillnet. The mouths of Town and Bull Creeks were electrofished only (Figure 5.1).

Hoopnets, three feet in diameter with varying mesh sizes (1.25 to 5.08 cm or 0.5 to 2.0 inch), were set throughout the site and generally fished for 72 hours. The nets were checked and fish were processed at 24 hour intervals.

The electrofisher consisted of a Smith-Root Type VI pulsed DC unit attached to boom-mounted anodes and a multi-structure cathode suspended off the bow of a 4.8 meter (16 foot) boat. The anodes were mounted on two separate circular arrangements, similar to the improved design of Novotny and Priegel (1974). The electrofisher unit, powered by a 3000 watt alternator, was operated at 424 v.d.c. and 60 pulses per second. Fish stunned by the electrical field were captured with a 3.6 meter (12 foot) dip net and placed in a holding tank until the conclusion of sampling at each station. Electrofishing collections are expressed as catch per one minute of actual shocking time.

A 3.6 meter (12 foot) mini-experimental gillnet was fished at Ohio River stations 2 and 3 periodically during the October, 1980 sampling. The purpose of this was to perhaps catch some additional species not vulnerable to hoopnetting or electrofishing along the near shore area. The effort produced only one new species, the quillback, and so was discontinued.

The upper Town Creek and Bull Creek stations (Figure 5.1) were fished by seining, for approximately 30 minutes each, with a 3 meter, 0.6 cm (10 foot, 0.25 inch) mesh seine. Catch per unit effort figures were not expressed for seining.

For each collection made, fish were identified, weighed (in grams or pounds/ounces), measured (in millimeters), and examined for general external condition. Fish that seemed parasitized or in poor general health were noted in the field log. Fish that could not be identified in the field were preserved in 10 percent formalin and returned to the laboratory for positive identification. Any new or unique species were also returned to the lab and preserved as voucher specimens. The following references were used in identifying fishes in the laboratory: Clay (1975), Pflieger (1975), Scott and Crossman (1973), Troutman (1957), and Eddy (1974). All references made to adult fishes follow the taxonomic guidelines of the American Fisheries Society Committee on Names of Fishes (Bailey, et. al., 1970).

As diversity within a biotic community is considered a measure of its relative stability, species diversity indices were calculated according to Margelef (1951). This expression of diversity is as follows:

$$d = \frac{S-1}{\ln N}$$

Where: d = diversity

S = number of species

N = total number of individuals

and provides a numerical comparison of the complexity of fish communities within the study area. This index was found by McErlean and Mihursky (1969) to be independent of sample size. Although the Margelef (1951) index is less sensitive than the Shannon-Weaver index to the component of diversity, due to distribution of individuals among species, it does provide a useful comparison of relative diversity between sampling stations (Dames & Moore, 1975).

The backwaters of Town and Bull Creeks were sampled for icthyoplankton (IP) once during the day, and once during the night, in May of 1980 (Figure 5.2). Three tows, hauling duplicate nets, were made in each creek both day and night. This produced six samples per creek both day and night, or a total of 24 samples.

Tows were made from a 4.8 meter (16 foot) Jon boat powered by a 40 hp Mercury outboard motor. Duplicate samples were taken simultaneously by towing one net on each side of the boat (Figure 5.3). The nets used were fabricated from 505 micrometer Nitex mesh, bridled 75 cm diameter at the mouth, and conical in shape with a 3.5:1 length-to-mouth ratio. Prelabeled 1 liter plastic sample jars were screwed into the cod-end of each net. A TSK flowmeter was suspended in the center of the mouth of each net to record the volume of water passing through it and a depressor was used to hold the nets below the surface of the water. Due to the shallow nature of these water bodies, all tows were taken just below the surface. Shallow water also mandated that the boat be driven at a slow speed to keep the nets from riding above the surface. Approximately 15 minutes of towing time was required to allow filtering of approximately $150 m^3$ of water, on the average, per sample.

When a tow was completed, the sides of the net were washed to flush debris and organisms into the sample jar. Formalin was then added to the sample to approximate a solution of 10 percent formalin. Flow meter readings were taken and recorded at this time for later calculation of sample volume.

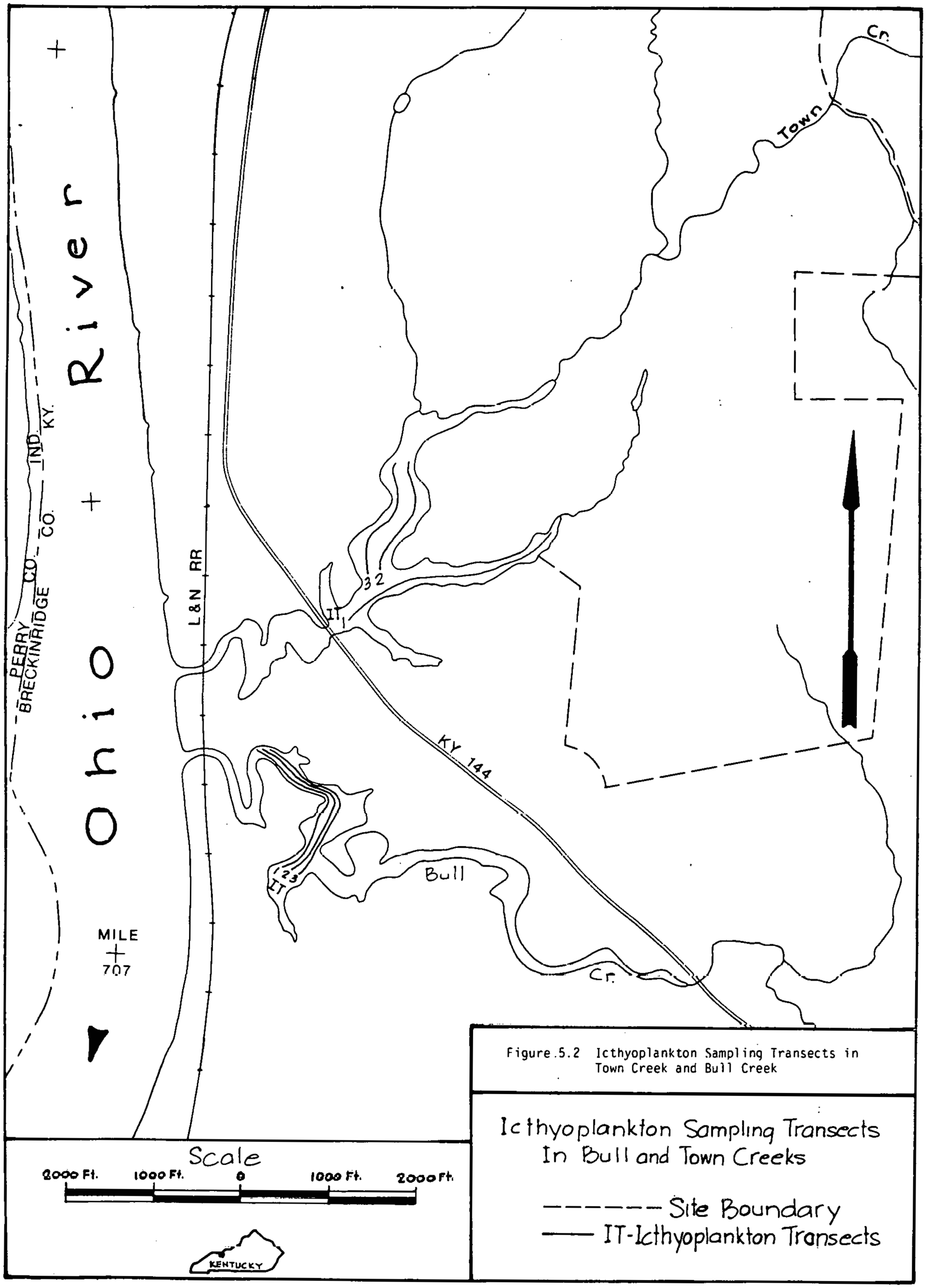

Figure 5.2 Icthyoplankton Sampling Transects in Town Creek and Bull Creek

Icthyoplankton Sampling Transects In Bull and Town Creeks

------ Site Boundary
—— IT-Icthyoplankton Transects

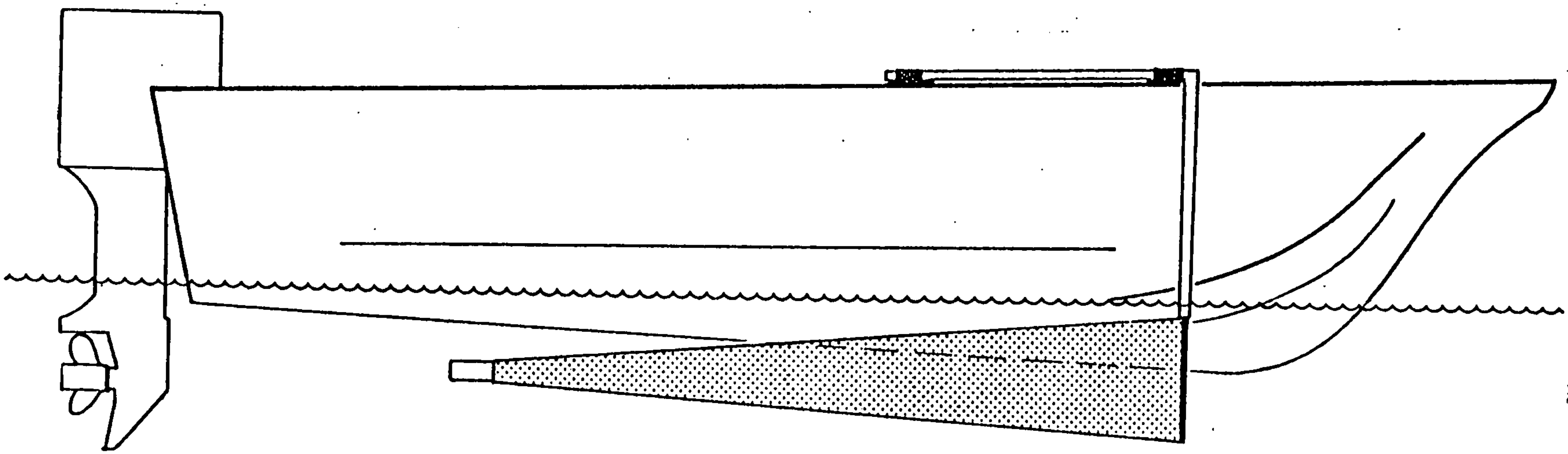

Figure 5.3 Ichthyoplankton sampling apparatus used in backwaters of Town and Bull Creeks.

Source: WAPORA, 1980

Upon return to the laboratory, samples were washed in a No. 60 U.S. Standard Testing Sieve (250 micrometer openings) and then placed in white enamel trays for sorting under 3x illuminated magnifers. Due to the high density of organsims in some samples, all those resulting from filtration of more than 100m^3 of water were split to either 1/2 or 1/4, using a Folsom Plankton Splitter.

Fish larvae and adults were sorted from debris and placed in vials containing 60 percent isopropanol. The contents of each vial, labeled by station, were examined under a dissecting microscope to identify organisms to the most specific taxon practical. The following references were used: Hogue, et al. (1976), Jones, et al. (1978), Hardy (1978), Connor (1979), Wang and Kernehan (1979), Lippson and Moran (1974), Seifert (1969), and Hoyt (1979).

Sample volumes were calculated using a formula supplied with the flowmeters, as follows:

$$V = CNA$$

where:

V = sample volume in m^3;

C = the calibration factor for the meter;

N = the number of revolutions recorded during a tow; and,

A = the mouth area of the net in m^2.

Densities are expressed as numbers per 100m^3 of water filtered.

5.4.7 Tissue Analysis

Fishes were taken for chemical tissue analysis from the Ohio River and the upper portions of Bull and Town Creeks in the spring and fall of 1980. Parameters selected for analysis, trace elements and organics, were also tested in the sediments and water. Fishes were collected during regular population sampling, tagged and placed on ice prior to freezing. Samples were then shipped to the laboratory on dry ice.

In the river, three carp (omnivores) and three white crappie (carnivores) were collected on each date. These fish were of sufficient size to obtain a muscle tissue analysis. In the creeks, a carnivorous centrarchid (sunfish) and a member of the minnow family were the target fish. However, in the spring only bluegill and longear sunfish were taken from Bull Creek. If of sufficient size, these creek fish were analyzed for muscle tissue; if too small, whole fish samples of one or several small fish were used. As from the river, six samples from each creek were analyzed on each date. As whole fish includes internal organs, these samples would generally be expected to contain higher levels of certain trace elements than muscle tissue alone.

Bivalves (mussels) were collected from the Ohio River during the Fall Survey from the Station 3A area and an upstream control area on the Indiana side at RM 704. Mussels kept for analysis included one *Proptera alata* and two *Obliquaria reflexa* from the control station, and one *Proptera alata*, one *Plethobasus cyphyus* and a composite of three *Corbicula manilensis* from Station 3A.

In January, 1981 no mussels could be obtained from the control area, but four *Obliquaria reflexa* were collected at Station 3A.

All mussels selected for tissue analysis were immediately placed on ice in the field, and later were frozen and sent to Howard Laboratories, Inc.

(For a complete discussion of mussel sampling, see Section 5.4.5 and 5.5.5.1).

5.5. RESULTS AND DISCUSSION

5.5.1 Plankton

5.5.1.1. Ohio River

Results of the plankton sampling program conducted in the Ohio River at Stations 1A, 2A and 3A (Figure 5.1) on May 15, July 16, October 7, 1980 and January 15, 1981 are presented for its two major components, phytoplankton and zooplankton.

Phytoplankton are microscopic free-floating plants which typically make up an important ecological component of the Ohio River ecosystem. Planktonic plant flora are important because they occupy the lowest trophic level in the aquatic food web and are often consumed by many types of higher life forms including herbivorous macroinvertebrates, forage fish, and occasionally vertebrates such as water fowl and wading birds. Thus, in certain instances, the general health and physical well being of these consumers may be directly or indirectly dependent on phytoplankton.

In addition to biotic relationships, important abiotic considerations concerning the phytoplankton environment may be determined too. Knowledge of phytoplankton taxonomic composition and selected chemical and physical measurements may provide useful confirmative information for water quality as well as possible predictions concerning potential nuisance algal growth. Historically, the most significant problems with nuisance algae are biofouling of filter systems, screens, pumps and other types of water handling equipment. Plantonic algae may also affect the taste and odor of water, and are occasionally sources of aesthetic degradation.

Ambient phytoplankton sampling data are presented in Table 5.1 through 5.4. Quarterly trends of total phytoplankton density and number of

Table 5.1 Phytoplankton (Cells/ml) Collected on May 15, and 16, 1980 from the Ohio River, Bull Creek and Town Creek.

	Stations				
Taxa	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Chlorophyta					
Actinastrum hantzchii	48.45	26.45	83.26		
Ankistrodesmus convolutus	14.96	29.25	30.94		
Ankistrodesmus falcatus	185.47	98.90	168.92		
Ankistrodesmus falcatus var. mirabilis		2.80	3.57		
Ankistrodesmus sp.					10.98
Chlamydomonas sp.				25.05	13.97
Closterium sp.	0.99		1.18		
Cosmarium sp.				2.00	
Crucigenia quadrata	0.99	4.18	2.39		
Mougeotia sp.				66.13	
Quadrigula sp.	2.00				
Scenedesmus bijuga	2.00	4.18	2.39		
Scenedesmus quadricauda	7.99	6.98	38.08		
Scenedesmus sp.		2.80	1.18		
Spirogrya sp.					2.00
Staurastrum sp.				4.01	
Tetrastrum sp.			1.18	4.01	
Ulothrix tenuissima	2.99	9.74	1.18		
Ulothrix sp.					0.99
Vovolcaceae			1.18		
Undetermined coccoid				27.05	10.98
Total Chlorophyta	266.24	185.28	336.63	128.25	38.92

Table 5.1 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Chrysophyta					
Achnanthes minutissima	15.60	3.07	57.17	287.56	146.09
Achnanthes sp.			16.32	23.45	11.87
Asterionella formosa	21.84	21.45	57.17		
Cocconeis pediculus			16.32		3.93
Cyclotella glomerata	24.84	26.46	22.93		
Cyclotella meneghiniana	43.52	14.70	45.85		
Cyclotella pseudostelligera			7.68		
Cyclotella sp.				9.02	20.94
Cymbella ventricosa					33.93
Cymbella sp. 1		3.06	8.16	26.39	47.40
Cymbella sp. 2				11.75	15.80
Diatoma sp.		3.07	8.16		
Dinobryon sp.					0.99
Diploneis sp.					3.93
Eunotia pectinalis		3.07			
Eunotia sp.				2.94	7.87
Fragilaria contronensis	3.12				
Fragilaria brevistriata			16.32		
Fragilaria sp.	3.12	12.26			
Gomphonema olivaceum				2.94	19.74
Gomphonema sp.					3.93
Melosira ambigua	118.09	55.84	183.62		
Melosira varians	12.42	2.95			
Melosira italica	49.73	94.06	221.89		
Meridion circular					3.93
Navicula spp.	9.36	12.26	16.32	14.68	59.21
Nitzschia acicularis		18.38	24.51	23.45	
Nitzschia dissipata	9.36		16.32	26.39	55.27
Nitzschia linearis					7.87
Nitzschia palea	12.48	6.12	8.16	8.81	78.95
Nitzschia paradoxa					11.87

Table 5.1 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Nitzschia sp.	3.12			5.87	63.20
Pinnularia sp.	3.12	6.12	8.16	2.94	
Stephanodiscus astre	118.09	85.25	137.76		
Stephanodiscus invisitatus	192.65	41.13	390.26		
Surirella sp.				5.87	11.87
Synedra acus	9.36	6.12	24.51		
Synedra rumpens		12.26	8.16		
Synedra ulna			16.32		
Synedra sp.				8.81	7.87
Tabellaria sp.	6.24				
Total Chrysophyta	656.06	427.63	1312.07	460.87	616.46
Cyanophyta					
Anabeana sp.			1.18		
Chroococcus limneticus		1.38			
Chroococcus spp.	2.00	4.18	1.18		8.97
Dactylococcopsis smithii		1.38	1.18		
Microcystis sp.	2.00	1.38	7.14		
Phormidium sp.					0.99
Oscillatoria spp.				2.00	14.95
Total Cyanophyta	4.00	8.32	10.68	2.00	24.91
Cryptophyta					
Cryptomonas sp. 1	44.87	43.16	39.26		
Cryptomonas sp. 2	70.81	13.91	73.77		
Total Cryptophyta	115.68	57.07	113.03		

Table 5.1 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Euglenophyta					
Euglena spp.	10.98	13.91	20.23		
Phacus sp.	3.98		1.18	0.99	
Total Euglenophyta	14.96	13.91	21.41	0.99	0.00
Total Density	1056.94	692.21	1793.82	463.86	680.29
Total Taxa	33	35	43	23	29

Table 5.2 Phytoplankton (Cells/ml) Collected July 16 and 17, 1980 from the Ohio River, Bull Creek and Town Creek.

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Chlorophyta					
Actinastrum hantzschii	7.65	6.12			
Ankistrodesmus falcatus	15.30	6.12			
Chlamydomonas sp.	22.95				
Closteriopsis longissima	7.65				
Crucigena quadrata	7.65	24.48	18.36		6.12
Crucigena tetrapedia		6.12			
Eudorina sp.	15.30	6.12			
Mougeotia sp.	15.30	24.48			
Pandorina morum					61.20
Pediastrum duplex	7.65	6.12	6.12		
Scenedesmus quadricauda	7.65	6.12	6.12		6.12
Ulothrix sp.		6.12	6.12		
Volvolcacceae	7.65				55.08
Undetermined filament	15.30				
Undetermined coccoid			6.12		12.24
Total Chlorophyta	130.05	91.80	42.84	0	140.76
Chrysophyta					
Achnanthes minutissima	19.55	4.24	5.01	13.27	5.26
Achananthes lanceolata		21.51		0.66	1.91
Amphora sp.		4.24			
Asterioniella gracillima	19.55		22.69		
Cocconeis pediculus					
Cyclotella meneghiniana	74.17	94.52	65.57		1.43
Cyclotella stelligers	15.61	8.58			

Table 5.2 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Chrypsophyta					
Cyclotella sp.				0.66	0.95
Cymbella spp.		4.24	7.57	7.96	
Diatoma vulgare	7.80			0.66	
Diploneis sp.				6.64	
Eunotia sp.				0.66	0.48
Fragilaria brevistriata	11.75	4.24			
Gomphonema olivaceum		4.24			
Gomphonema sp.					1.43
Hanitzschia sp.			2.50		
Melosira ambiqua	31.21	21.51			
Melosira distans	480.48	623.05	380.73		3.35
Melosira granulata	140.64	124.01	201.71		0.48
Melosira varians			12.60		0.48
Meridion circular		4.24			
Navicula sp. 1	3.52		22.96	9.96	4.30
Navicula sp. 2	7.80	21.51		2.66	1.43
Navicula spp.				0.66	
Nitzschia acicularis	7.80	4.241	5.01		
Nitzschia angustata				0.66	
Nitzschia dissipata	7.80				
Nitzschia filiformis	3.86	8.51		2.66	
Nitzschia palea	15.61		10.09	1.99	2.87
Nitzschia sp.					0.48
Pinnularia spp.	11.75		2.50	1.33	0.95
Pleurosigma sp.			2.50	0.66	0.48
Rhoicosphena curvata		8.58	2.50		
Rhopalodia sp.				0.66	
Stephanodiscus sp.	7.80	4.24	2.50		
Surirella spp.		4.24		1.99	0.48

Table 5.2 Continued

	Stations Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Synedra actinastroides	15.61	30.09	2.50		
Synedra ulna	3.86	4.24	10.09	1.33	3.82
Total Chrysophyta	886.17	1004.87	758.76	55.07	30.58
Cryptophyta					
Cryptomonas sp. 1	130.05	12.24		201.96	140.76
Cryptomonas sp. 2	53.55				
Cryptomonas sp. 3	84.15	12.24	6.12	6.12	
Total Cryptophyta	267.75	24.48	6.12	208.08	140.76
Cyanophyta					
Chroococcus spp.	7.65		12.24		6.12
Microcystis inserta	15.30				6.12
Oscillatoria subbrevis			18.36		
Oscillatoria spp.	30.60				
Spirulina princeps		6.12			
Total Cyanophyta	53.55	6.12	30.60		12.24

Table 5.2 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Euglenophyta					
Euglena spp.	15.30	12.24		18.36	12.24
Phacus sp.				12.24	
Trachelomonas sp.					12.24
Total Euglenophyta	15.30	12.24	0	30.60	24.48
Pyrrhophyta					
Ceratium sp.					6.12
Total Pyrrhophyta					6.12
Total Density	1352.82	1139.51	838.32	239.75	354.94
Total Taxa	37	33	25	22	28

Table 5.3 Phytoplankton (Cells/ml) Collected October 7, and 8, 1980, from the Ohio River, Bull Creek, and Town Creek.

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Chlorophyta					
Actinastrum hantzchii	2.98	1.58	6.34		
Ankistrodesmus sp.	1.58				
Crucigena quadrata	1.58				
Pandorina sp.	1.58	2.98	17.90		
Pediastrum duplex	6.34		4.76		
Scenedesmus sp.	2.98				
Ulothrix spp.	53.71	71.62	98.47		
Total Chlorophyta	70.75	76.18	127.47	-0-	-0-
Chrysophyta					
Achnanthes minutissima			1.87	1.49	1.11
Achnanthes lanceolata		0.61	1.24	5.97	0.55
Asterioniella sp.	0.49	0.61			
Cocconeis sp.			0.63		0.55
Cyclotella dubius	1.95	10.52	5.61		
Cyclotella meneghiniana	8.95	11.15	19.33		
Cyclotella sp.				0.74	
Cymbella sp.				0.74	
Diatoma sp.		0.61			
Diploneis Smithii				1.49	
Denticula elegans				0.74	
Fragilaria sp.	1.46	0.61	0.63	1.49	
Gomphonema sp.			0.63	0.74	
Gyrosigma scalproides				2.24	
Mallomanas sp.				23.87	2.98
Melosira ambigua	66.84	56.95	66.71		
Melosira distans	16.59	32.20	14.34		
Melosira granulata	5.36	6.80		0.74	
Melosira italica	3.42				
Melosira varians	6.34	5.57	0.63		
Navicula spp.	1.95	2.48	3.12	8.94	4.42
Nitzschia acicularis			1.24	4.48	

Table 5.3 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Chrysophyta					
Nitzschia dissipata					1.66
Nitzschia filiformis				0.74	
Nitzschia holsatica	3.90	16.10			
Nitzschia palea	0.49			0.74	0.55
Nitzschia sigmoidae		0.61		2.24	3.87
Nitzschia spp.	0.49			2.98	0.55
Pinnularia sp.		0.61			
Rhoicosphena curvata					1.66
Stauroneis sp.				1.49	
Stephanodiscus sp.	4.39	1.22	2.49		
Synedra acus	6.34	2.48	5.61		
Synedra ulna				0.74	
Total Chrysophyta	128.30	149.30	124.08	62.60	17.90
Cyanophyta					
Anabaena sp.	1.58	2.98	2.98		
Aphanocapsa spp.	20.89	26.86	53.71		
Coelosphaerium sp.	7.93	26.86	2.98		
Microcystis sp.	23.87	47.74	32.82		
Oscillatoria spp.	12.68	2.98	11.94	5.97	
Unidentified spp. 1	32.83	26.86	17.91		
Unidentified spp.2				5.97	11.93
Total Cyanophyta	99.78	134.28	122.34	11.94	11.93
Cryptophyta					
Cryptomonas sp. 4	1095.13	1074.24	936.98		
Cryptomonas sp. 3	71.32	98.47	44.76		
Total Cryptophyta	1166.45	1172.71	981.74		
Total Density	1465.28	1532.30	1355.63	74.54	29.83
Total Taxa	30	27	26	21	11

Table 5.4 Phytoplankton (Cells/ml) Collected on January 15, 1981, from the Ohio River, Bull Creek, and Town Creek.

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Chlorophyta					
Actinastrum hantzchii	10.80	7.20	1.80		
Ankistrodesmus convolutus	54.02	64.82	43.22		
Ankistrodesmus falcatus	68.43	50.42	57.62		
Ankistrodesmus sp.	21.61	21.61	18.08	1.19	
Chlamydomonas spp.	18.01	39.61	68.42		
Crucigenia sp.		1.80	3.60		
Dictyosphaerium spp.	0.72	9.00	3.60		
Micractinium sp.	3.60	10.80			1.19
Scenedesmus quadricauda	3.60	3.60	14.41		1.19
Volvocaceae		10.80			
Unidentified coccoid	3.60	3.60	3.60		2.38
Total Chlorophyta	184.39	223.26	214.28	1.19	4.76
Chrysophyta					
Achnanthes lanceolata				4.02	7.64
Achnanthes minutissima	4.61	16.31		20.10	15.28
Asterioniella formosa	368.61	530.04	316.55		
Cocconeis sp.		8.14		1.34	2.55
Cyclotella meneghinana	36.86	40.77	38.76		
Cyclotella sp.				4.02	2.55
Cymbella sp.				14.74	7.64
Diatoma sp.	9.22	24.46	12.92		
Dinobryon sp.	39.62	43.22	57.62		
Eunotia sp.	4.61			1.34	
Fragilaria crotonensis	82.94		25.84		2.55
Gomphonema sp.				4.02	2.55

Table 5.4 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Gyrosigma sp.				2.68	
Melosira granulata	9.22	16.31			
Melosira italica	271.85	220.17	239.03		
Meridion circulare		8.14		7.44	10.19
Navicula spp.	4.61	8.14	12.92	16.08	17.83
Neidium sp.				1.34	2.55
Nitzschia acicularis		16.31		14.74	43.30
Nitzschia dissipata	13.82	24.46	19.38	4.02	7.64
Nitzschia sp.	4.61	24.46	6.46	2.68	2.55
Nitzschia angustada					53.49
Pinnularia sp.		8.14		2.68	
Stauroneis sp.				1.34	
Stephanodiscus astrea	18.43	73.39	38.76		
Stephanodiscus invisitatus	405.48	481.11	510.36	5.36	2.55
Synedra acus	13.82	73.39	19.38	1.34	2.55
Synedra ulna	4.61		12.92	2.68	7.64
Surirella sp.				1.34	17.83
Total Chryosphyta	1292.92	1616.96	1310.90	113.30	208.88
Cyanophyta					
Oscillatoria sp.	1.19	3.60		9.58	10.80
Phormidium sp.		10.80	7.20	19.19	11.99
Total Cyanophyta	1.19	14.40	7.20	28.77	22.79
Cryptophyta					
Cryptomonas spp.	18.01	7.20	21.61	11.99	32.41

Table 5.4 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Total Cryptophyta	18.01	7.20	21.61	11.99	32.41
Euglenophyta					
Euglena sp.	1.19	3.60	3.60		
Trachelomonas spp.	14.41	10.80	10.80		15.59
Total Euglenophyta	15.60	14.40	14.40		15.59
Total Density	1512.11	1876.22	1568.39	155.25	284.43
Total Taxa	29	33	26	24	25

taxa were less variable than for taxonomic make up in the Ohio River phytoplankton population. Total plantonic algal abundance was greatest during the January, 1981, sampling when average density reached 1652.24 cells/L (range 1512.11 - 1876.22). The lower phytoplankton density was recorded for July, 1980, with a mean density of 1110.22, and a range between 838.32 - 1852.82 cells/L. Results of phytoplankton abundance showed total density during May, 1980, (mean 1180.99 cells/L) more closely resembled the July density, and that for October, 1980, (mean 1451.07 cells/L) more closely resembled the January, 1981, density. Taxonomic composition of the phytoplankton population observed during the survey showed a converse relationship to that of algal density. During May and July when the lowest phytoplankton densities occurred, the number of phytoplankton taxa was highest. The number of phytoplankton taxa was lowest during October and January when phytoplankton was generally most abundant. Phytoplankton taxonomic composition ranged from 26-30 taxa (mean 28) during October to 33-43 taxa (mean 37) in May. Taxonomic composition and density of phytoplankton, combined, showed a distinct pattern from the quarterly sampling data.

The pattern of predominant algae groups which occurred showed, in part, typical temporal succession at the Ashland site. For example, numerical composition of specific algal groups indicated significant shifts from May to January of total phytoplankton densities by nearly tenfold. These major trends are as follows. During each of the sampling periods the three most abundant phytoplankton groups comprised from 95 percent - 97 percent of overall densities. In May, Chrysophyta (golden-brown algae) ranged from a numerical composition of between 62 percent - 73 percent at the three Ohio River Stations. The green algae, Chlorophyta, made up 19 percent - 27 percent, and cryptomonads (Cryptophyta) consisted of between 6 percent and 11 percent of phytolankton densities. Golden-brown algae were still most abundant during July (66 percent - 91 percent) and green algae densities decreased to 5 percent - 10 percent while the Cryptophyta increased their overall abundance slightly (1 percent - 20 percent). During the October survey a substantial decline of nearly nine fold in Chrysophyta density occurred. The abundance of Chlorophyta remained stable but Cryptophyta density increased from 4 to 10 fold at the various Ohio River stations, now comprising of up to 80 percent of the phytoplankton population. The blue-greens, Cyanophyta, generally showed peak abundance (9 percent composition) in Ohio River during October. Another significant shift in overall abundance of Chrysophyta plankton occurred in January. Chrysophyta increased from its lowest densities during October (9 percent - 10 percent composition) to relatively high January densities, 84 percent - 86 percent composition. The greens increased their abundance only slightly during January and Cyanophyta densities diminished to their previously low numbers. Cryptomonads reduced their overall populations by 50 fold in January to comprise of only 0.3 to 1.4 percent of the Ohio River phytoplankton densities. Englenophyta, the pigmented flagulates, did not comprise of over 1.2 percent of phytoplankton densities during the 1980-81 Ohio River sampling program. Like the major changes which occurred for the overall phytoplankton algae groups, specific taxonomic alterations were also noted.

Quarterly variations in the make up of specific plantonic algae followed trends similar to those discussed for the major groups. Generally, when that particular major algal group was abundant so were its taxonomic components. The number of taxonomic components ranged from a minimum of 25 taxa at Ohio River Station 3 during July, to the maximum of 43 taxa at Ohio River Station 3 during May. Phytoplankton taxa which were predominant during May included Melosira ambiqua, Melosira italica, Stephanodiscus astre and, the most abundant Stephanodiscus invisitatus (209 cells/ ml, mean density) (Chrysophyta). Ankistrodesmus falcatus was the predominant Chlorophyta, showing a maximum density of 185 cells/L.

The most abundant plantonic algae observed during the July survey, Melosira distans reach the maximum diatom density of 623 cells/ml (495 cells/ml mean) during the 1980-81 Ashland survey. Melosira granulata attained a mean density of 156 cells/ml and another diatom, Cyclotella meneghiniana reached a mean density of 78 cells/ml. Although Chrysophyta were, overall, the most abundant during July, one taxa from the second most abundant group of algae (Cryptophyta) attained relatively high densities, too. This taxa was Cryptomonas spp. which ranged from 6 cells/ml to 130 cell/ml.

The most important planktonic algae collected during the October survey consisted of five taxa from four major taxonomic groups, Cryptophyta, Chlorophyta, Chrysophyta and Cyanophytya. Cryptophytes were predominant making-up a mean density of 1007 cells/ ml, the highest density for a single taxon (Cryptomonas spp.) during the Ashland survey. Other abundant taxa included the diatom (Chrysophyta) Melorisa ambiqua with a mean density of 64 cells/ml; the green filamentous algae, Ulothrix, sp. with a mean density of 75 cells/ml; and two less abundant taxa, Aphanocapsa spp., and Microcystis sp. (Cyanophyta) which showed mean densities of 34 cells/ml and 35 cells/ml, respectively.

January phytoplankton densities, as noted previously, were the highest during the 1980-81 Ashland survey. These realtively high densities were attributed primarily to overall high population levels of both pennate and centric diatoms in January. The taxonomic make up of this group of plantonic flora consisted of three abundant species each of which showed mean densities in excess of 244 cells/ml. The most abundant representative was Stephanodiscus invisitatus which had a mean density of 466 cells/ml (range 405 cells/ml to 510 cells/ml). Asterionella formosa showed the highest single density of 530 cells/ml, its mean density was 405 cells/ml. Melosira italica was also an important component of the January phytoplankton, it reached a mean density of 244 cells/ml. Other taxa which appeared as a significant proportion of the plankton included the green algae Ankistrodesmus convolutus and Ankistrodesmus falcatus with mean densities of 57 cells/ml and 54 cells/ml, respectively.

Phytoplankton characteristics such as taxonomic compositions, community structure, density, and general spatial patterns reported for the three Ashland Ohio River stations suggested many simularities to previous studies in lower Ohio River pools. Historically, Chrysophyta, mostly Bacillariophycae, make up large proportions of ambient phytoplankton densities. Chlorophyta often comprise the next largest proportion. Cyanophyta occur in relatively low numbers during early summer, and eulgenophyta and Cryptophyta generally have the lowest densities. In mid to late summer and early fall, Cyanophyta may become more prevalent than the greens (Seilhemer, 1963; Williams, 1963, 1972; Anderson, et. al., 1965; Dames & Moore 1975, 1979). Higher tempeatures and low flow accompied by proper nutrient concentrations, have been cited as reasons for increased blue green growth in late summer and early fall. During these occasions blue green blooms are possible (WAPORA, 1974-1975).

During the coarse of this investigation no significant abnormal frequency, distributional, or related temporal or spatial patterns were observed between the three Ohio River stations. Futhermore, there is no definitive evidence indicating that the general phytoplankton characteristics, overall trends or patterns, and ecology were under going anything more than typical changes within the variability of the Cannelton Pool.

Zooplankton are the free-floating animal segment of the net plankton samples collected from the three Ohio River stations, 1A, 2A, 3A. Zooplankton are important members of the aquatic environment because, like phytoplankton, they are potential sources of food for many higher life forms. Their general abundance, diverstiy, and physical well being may provide some indication as to the overall quality of the aquatic environment.

Results of the zooplankton sampling program are presented in Tables 5.5 through 5.8. The total number of zooplankton taxa collected from the three Ohio River stations ranged from 4 in July to 15 during the May, and October, 1980 surveys. Plantonic rotifers were the most taxonomically diverse and abundant zooplankton group during the quarterly Ashland surveys. Rotifera typically made up from 67 percent - 97 percent of the total densities during May, October and January. Both the microcrustacea groups, Copepoda and Cladocera, were generally comprised of few taxa and had low densities during this project. Copepoda were predominant only during the July survey when relatively large numbers of immature nauplii occured in the samples. Cladocera did not comprise more than 2 percent of the total zooplankton density during the quarterly surveys.

Zooplankton were most abundant during the October survey when mean total density was 467 individuals/L (range 233/L to 889/L). The lowest

Table 5.5 Zooplankton (Individuals/L) Collected May 15, and 16, 1980, from the Ohio River, Bull Creek and Town Creek.

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Taxa					
Rotifera					
Asplanchna sp.	0.82	0.59	0.72		
Brachionus calyciflorus		0.14			
Brachionus dimidiatus		0.30			
Brachionus urceolaris	1.50	1.91	0.72		
Conochilus sp.		0.14	0.29		
Euchlanis sp.		0.30			
Filinia sp.	1.16	0.44			
Kellicottia longispina	1.66	0.89			
Keratella cochlearis	23.17	11.36	4.33		
Keratella quadrata	18.34	13.86	2.74	1.29	
Lepadella ovallis				4.49	
Lepadella sp.				1.28	2.81
Monostyla lunaris				2.57	
Monostyla sp.	1.00				
Notholca spp.	0.50	0.74	0.58	2.24	1.40
Polyarthra sp	14.51	8.55	1.30		
Ploesoma sp.	0.34				
Synchaeta sp.	35.52	17.56	5.77		
Trichocerca cyclindrica					7.72
Trichotria sp					5.62
Undetermined	1.34		1.01		
Total Rotifera	99.87	56.78	17.46	11.87	17.55

Table 5.5 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Copepoda					
Cyclopidae		0.74			
Immature copepods	2.66	2.95	0.58		25.28
Total Copepoda	2.66	3.69	0.58	0.00	25.28
Total Density	102.53	60.47	18.04	11.87	42.83
Total Taxa	13	15	10	5	4

Table 5.6 Zooplankton (Individuals/L) Collected on July 16, and 17, 1980 from Ohio River, Bull Creek and Town Creek.

Taxa	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Rotifera					
Asplanchna sp.			1.91		
Brachionus angularis	0.92	0.33	2.25		
Brachionus budapestinensis		0.50	0.53		
Brachionus caudatus		0.83			
Brachionus havanaensis					0.26
Conochiloides sp.		0.17			
Euchlanis sp.					0.39
Filinia sp.			0.53		0.48
Keratella cochlearis	0.26	0.83	1.83		0.35
Keratella quadrata	1.32	0.67	0.31		
Monostyla bulla		0.42		4.96	
Notholca spp.			1.58		1.45
Polyarthra sp.			4.05		
Pompholyx sp.				0.23	
Synchaeta sp.		0.42	0.96		
Trichocerca sp.			0.63		
Trichotria tetractis				1.27	0.92
Total Rotifera	2.50	4.17	14.13	6.46	3.85
Cladocera					
Daphnia sp.		0.17	0.33		
Chydorus sp.		0.17			
Total Cladocera	0	0.34	0.33	0	0

Table 5.6 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Copepoda					
Cyclopidae		3.63	3.92	0.46	1.14
Immature copepods	22.74	53.44	71.47	4.96	4.36
Total Copepoda	22.74	57.07	75.39	5.42	5.50
Total Density	25.24	61.58	89.85	11.88	9.35
Total Taxa	4	12	13	5	8

Table 5.7 Zooplankton (Individuals/L) Collected on October 7, and 8, 1980 from Ohio River, Bull Creek and Town Creek.

Taxa	Stations: Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Rotifera					
Asplanchna spp.	5.36	1.52	1.84		
Brachionus angularis	9.65	3.04	2.76		
Brachionus calyciflorus	34.30	32.68	92.00		0.84
Brachionus caudatus			0.92		
Brachionus quadradentatus	1.07				
Conochilus unicornis	84.69	27.36	577.76		
Keratella cochlearis	2.14	3.04	22.08	3.28	
Keratella quadrata	1.07		0.92		
Lecane luna				13.12	1.68
Platyias patulus				3.28	
Ploesoma truncatums	8.58	29.64	7.36		
Polyarthra sp.	84.69	57.76	52.44		0.84
Trichocerca spp.	1.07		1.84		1.68
Undetermined		0.76	1.84		
Total Rotifera	232.62	155.80	761.76	19.68	5.04
Cladocera					
Bosmina sp.	6.43	6.84	5.52		
Daphnia sp.	2.14	0.76	9.20	13.12	
Chydorus sp.	1.07			6.56	
Total Cladocera	9.64	7.60	14.72	19.68	-0-

Table 5.7 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Copepoda					
Cyclopidae	13.94	53.96	46.92		
Immature copepods	24.66	15.20	65.32	32.80	9.27
Total Copepoda	38.60	69.16	112.24	32.80	9.27
Total Density	280.86	232.56	888.72	72.16	14.31
Total Taxa	15	12	15	6	5

Table 5.8 Zooplankton (Individuals/L) Collected on January 15, 1980 from Ohio River, Bull Creek and Town Creek.

Taxa	Stations Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Rotifera					
Ascomorpha sp.		1.61	1.00		0.50
Asplanchna sp.	0.17	0.69	0.20		
Brachionus angularis			0.40		
Brachionus urceolaris	0.34	0.46	0.60		
Kellicottia longispina			0.20		
Keratella cochlearis	0.34	1.15	1.80		
Keratella hiemalis	0.17				
Lecane mira				0.52	0.12
Notholca spp.	0.34			2.22	0.12
Polyarthra sp.	1.53	4.85	3.00		
Synchaeta sp.		0.46	1.00		
Testuainella sp.				0.17	
Trichocerra sp.		0.23			
Trichotria tetractis					0.12
Total Rotifera	2.89	9.45	8.20	2.91	0.86
Cladocera					
Alona sp.				1.05	
Chydorus sp.				0.17	
Pleuroxus sp.				1.92	0.12
Total Cladocera				3.14	0.12

Table 5.8 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Copepoda					
Cyclopidae	0.17				
Immature copepods	0.34	0.69	0.60	0.87	0.12
Total Copepoda	0.51	0.69	0.60	0.87	0.12
Total Density	3.40	10.14	8.80	6.92	1.10
Total Taxa	8	8	9	7	6

zooplankton density occurred during January, 1981. At this time mean total zooplankton density was 7.45/L and ranged from 3/L to 10/L. Zooplankton densities for predominant taxa, as well as shifting emphasis in taxonomic make up varied quite substantially during the quarterly Ashland plankton surveys.

During May when total densities ranged from 18 to 103 organisms/L Rotifera taxa were relatively abundant. The most common taxa collected consisted of Synchaeta sp.(20/L), Keratella cochlearis (12.7/L), Keratella quadrata (11.7/L) and Polyarthra sp. which attained a mean density of 8.3/L. Copepoda densities were generally low during the May survey, ranging from less than 1/L to nearly 4/L. Cladocera were not collected during this survey.

Mean total zooplankton densities in Ohio River during July did not change substantially over those reported for May. However, the taxa present did change; Copepoda made up the predominant portion of zooplankton, comprising of 84 percent to 93 percent copepod nauplii. Their maximum density reached 71/L at Ohio River Station 3. Although two types of Cladocera were collected, Daphnia sp. and Chydorus sp., their densities were very low (<1 organisms/L). The Rotifera were represented by six taxa which occured in numbers over 1/L, they were Asplanchna sp., Brachionus angularis, Keratella cochlearis, Keratella quadrata, Notholca spp., and Polyarthra sp. There was a noted tendency for zooplankton density and number of taxa to increase progresssing from Station 1 to Station 3 during the July survey. This pattern was also prevelant during the January 1981 survey.

In addition to showing the highest total zooplankton density, the October plantonic fauna also showed the best overall taxonomic richness and distribution of taxa among its major taxonomic groups. Again, Rotifer typically consisted of the high percentage of zooplankton organisms. Maximum Rotifer densities were reached during the quarterly surveys in October (range 156/L to 762/L) and were comprised of several important taxa. They were, Conochilus unicornis which attained a mean density of 223/L, Polyarthra sp., reached a mean density of 65/L, and Brachionus calyciflorus attained a mean density of 53/L. Conochilus unicornis reached the highest taxon density, at Ohio River Station 3, of 578/L. Cyclopoid copepods showed a mean density of 38/L during the October sampling period while individual Cladocera taxa did not make up more than 6/L (Bosmina sp.).

The January zooplankton data represented the opposite extreme to that presented for October. Overall densities, number of taxa and general taxonomic richness certainly was not evident. Rotifera made up the predominant portion of total densities but were comprised of few taxa which were individually abundant. Polyarthra sp. had the highest density of nearly 5/L while copepod densities were all below one organisms per liter and no cladocera were collected.

Seilheimer (1963) estimated a mean annual total zooplankton density of 281 organisms per liter in the Ohio River. The maximum he reported was 3,160 organisms/liter on July 15, 1962 at Louisville, Kentucky. During the A.B. Brown environmental study conducted by Dames and Moore (1979) in the Uniontown Pool, maximum zooplankton density was 645/L for 18 taxa in July. The maximum zooplankton density reported by Dames and Moore (1974-75), again in the Uniontown Pool, was nearly 18 organisms/L in October.

Many Rotifera taxa have appeared in the Ohio River, at times as many as 33 (Dames and Moore 1979). Numerous other studies have shown that annually up to 54 species of Rotifer have been identified from the Ohio River (Williams, 1963, Seilheimer, 1963, ORANCO, 1962; WAPORA, 1975, Dames and Moore, 1975, 1979). The information above indicates that zooplankton populations fluctuate quite dramatically in the Ohio River.

Results of the Ashland zooplankton sampling program have shown that these data represent similarities in general Ohio River population trends when compared to previous studies. During the coarse of the Ashland study zooplankton community characteristics have remain within the broad spectrum of ranges thought to occur under generally normal environmental circumstances in the lower Ohio River.

5.5.1.2 Bull Creek

Phytoplankton and zooplankton samples collected from Bull Creek indicated that these communities were similar to those for Town Creek. Most of the patterns examplified by the plankton community in Town Creek were quite similar to Bull Creek. Overall, phytoplankton and zooplankton densities and species assemblages were slightly higher in Bull Creek. The lack of continous replenishment of these organisms from a permanent upstream source has a significant impact on the resulting community as indicated by these data.

5.5.1.3 Town Creek

The phytoplankton collected from Town Creek consisted of a relatively rich and diverse fauna. Highest diversity, and moderate to high densities were obtained. Zooplankton densities and taxonomic richness were depressed throughout the Ashland Baseline Study. This is believed to be due to the lack of upstream sources for replenishing these organisms.

5.5.2 Periphyton

5.5.2.1 Ohio River

Natural submerged periphyton substrates were sampled on July 16, 1980, from three Ohio River Stations, 1A, 2B, 3B (Figure 5.1). The purpose for this sampling was to establish relative abundance of the many algae taxa which typically occupy this niche, and to show the basic structure of the periphytic algal community. Evaluations such as this could provide additional ecological data for the Ashland baseline from which specific evaluations for primary production and water quality may be determined (Cairns et. al., 1972, McIntire, 1968).

The number of taxa collected from the rock, (epilithic), and stick (epidendritic) substrate ranged from 25 to 26 which represented a relatively rich shoreline algal flora (Table 5.9). Most of the periphyton taxa collected from the Ohio River were Chrysophyta (yellow-greens) which consisted of mostly pennate diatoms (Bacillariophyceae). Blue-green algae, Cyanophyta, made up the next highest nunber of taxa in the periphyton community. Seven types of blue-green algae, most of which were Oscillatoria, were present. Green-algae, Chlorophyta, were comprised of 5 taxa but their relative abundance in the samples collected were always less than 2 percent composition. The most abundant algae were Chrysophyta and Cyanophyta.

Chrysophyta consisted of between 92 percent and 98 percent of the natural substrate periphyton communities. The predominant taxon was Navicula sp. 1, a pennate diatom which ranged from 37 percent to almost 54 percent composition of the samples. Other relatiely abundant pennate diatoms included Fragilaria brevistriata, Gomphonema olivaceum, and Achnanthes minutissima and composited, these microscopic plants made up a total

Table 5.9 Relative abundance of periphyton (percent composition) collected July 16, and 17, 1980, from the Ohio River, Bull Creek and Town Creek.

	Stations				
Taxa	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Chlorophyta					
Cladophora sp.	0.29	0.67	0.50	3.57	3.61
Closterium sp.				0.27	
Microspora sp.			0.75		
Mougeotia sp.	0.29			0.27	
Ulothrix sp.	0.89				
Volvocaceae	0.29				
Percent Composition Chlorophyta	1.76	0.67	1.25	4.11	3.61
Chrysophyta					
Achnanthes Lanceolata	4.10	0.48	0.80	7.29	2.64
Achnantes minutissima	5.63	1.92	7.20	23.96	25.06
Amphipleura pellucida				0.52	
Amphora sp.				2.08	2.08
Asterioniella gracillima	0.51				
Cocconeis pediculus			0.80	7.29	3.52
Cyclotella meneghiniana			2.00		
Cyclotella stelligers	0.51	0.48	0.40		
Cymbella sp. 1				1.04	6.16
Cymbella sp. 2				1.56	0.88
Diatoma vulgare				0.52	0.44
Diploneis sp.				3.12	0.88

Table 5.9 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Chrysophyta (Continued)					
Epithema sp.				3.12	
Eunotia sp.	0.51	0.96		1.56	
Fragilaria brevistriata	6.14	6.75	11.20	1.04	
Gomphonema olivaceum	4.10	18.24	0.80	9.38	1.32
Gomphonema sp.	1.02	0.96	0.40	9.38	8.35
Melosira ambigua	4.10	4.32	4.40		
Melosira varians	7.17	6.24	5.20		3.96
Navicula sp. 1	51.20	36.97	53.61	3.12	8.79
Navicula sp. 2	1.54	3.36	0.80	0.52	4.84
Navicula mutica	2.56	0.48	0.40		
Nitzschia angustata				2.08	
Nitzschia dissipata			0.80	2.60	15.83
Nitzschia filiformis		1.44	1.60		
Nitzschia lacunarum					0.44
Nitzschia palea			2.00	2.08	1.32
Nitzschia spp.	1.54	4.32			
Pinnularia sp.	0.51	0.96		1.56	0.88
Pleurosigma sp.		0.48	2.00	0.52	1.76
Rhoicosphena curvata		0.96	2.80		
Rhopalodia sp.				0.52	
Stauroneis sp.				2.08	0.44
Surirella sp. 1				1.56	3.52
Surirella sp. 2					0.44
Synedra actinastroides		1.92			
Synedra ulna	0.51	0.96	0.40	1.04	0.44
Undetermined centric				0.52	

Table 5.9 Continued

	Stations				
	Ohio River 1	Ohio River 2	Ohio River 3	Bull Creek	Town Creek
Percent Composition Chrysophyta	91.65	92.20	97.61	90.06	92.79
Cyanophyta					
Anabaena sp.	0.29	0.45		0.27	
Lyngbya sp.	0.29			1.37	0.90
Oscillatoria formosa				0.55	
Oscillatoria limnetica	0.29	2.23		0.82	1.20
Oscillatoria limnosa			0.12		
Oscillatoria subbrevis	3.17	4.01	0.50	0.27	0.60
Oscillatoria tenuis			0.12	2.20	
Phormidium sp.	2.30	2.45	0.37		
Percent Composition Cyanophyta	6.34	9.14	1.10	5.48	2.70
Euglenophyta					
Euglena spp.	0.29	0.22		0.27	
Phacus spp.					0.60
Trachelomonas sp.					0.30
Percent Composition Euglenophyta	0.29	0.22	0	0.27	0.93
Total Taxa	26	25	25	36	28

Total Percent Composition = 100% ± 0.1

mean composition of 21 percent. The centric diatom Melosira varians and Melosira ambiqua comprised 6.2 and 4.3 percent composition of the overall periphyton communtiy.

The predominant blue-green taxa were Oscillatoria subbrevis (2.6 percent composition) and Phormidium sp. (1.7 percent composition). Total blue-green algae sample composition ranged from 1 percent to slightly over 9 percent. Although Euglenophyta (pigmented flagelates or euglenoids) were present in the Ohio River samples, they did not comprise more than 0.3 percent composition of periphyton samples.

Based on the few samples which were collected in July, 1980, similar periphyton taxa occurred at the three Ohio River stations. The greatest similarity was shown between stations 1 and 3 then between 2 and 3, and 1 and 2. Eighty-one percent of the taxa occurring in the periphyton samples were common to the three Ohio River stations. These very general observations indicate that the overall aquatic environment along the river shoreline was similar. This perhaps indicates that environmental variables are similar too. The consistency and uniformness of the aquatic environment along the Kentucky boundary has been discussed in detail earlier.

5.5.2.2. Town Creek

The natural periphyton community identified from primarily rock substrate at Town Creek was comprised of 28 algal taxa (Table 5.9). As indicated by all periphyton sampling during July (Ohio River and Bull Creek), diatoms were the predominant flora. Diatoms (Chrysophyta: Bacillariophycyceae) were comprised of 22 taxa and made up nearly 93 percent relative abundance at Town Creek. The predominant pennate diatoms included Achnanthes minutissima which comprised of 25 percent composition, and

Nitzschia dissipata which made up nearly 16 percent composition of relative periphyton abundance. Three additional diatom taxa, *Navicula* sp.1, *Gomphonema* sp., and *Cymbella* sp. 1, comprised of between 6 percent and 9 percent composition of periphyton numbers. Only one Chlorophyta taxa was collected from Town Creek, *Cladophora* sp. The blue-greens included two species of *Oscillatoria*, and *Lyngby* sp. The only euglenoid taxa collected were *Phacus* spp., and *Trachelomonas* sp.

The periphyton community located in Town Creek showed fewer taxa and community structure differences compared to Bull Creek. Additionally, only 56 percent of the taxa were present at both stations. These observations indicate, in part, that endemic environmental variables may be responsible for these differences.

5.5.2.3 Bull Creek

Periphyton samples were obtained from Bull Creek on July 17, 1980, from mostly a natural rock substrate. Analyses of these samples resulted in the identification of 36 periphyton taxa; 26 of which were pennate diatoms (Chrysophyta: Bacillariophyceae) (Table 5.9). Bacillariophyceae made up 90 percent of the Bull Creek periphyton community in which *Achananthes minutissima* was most abundant (24 percent composition). Additional diatom taxa collected from Bull Creek and considered relatively abundant included *Gomphonema olivaceum* and *Gomphonema* sp. Each consisted of just over 9 percent of the periphyton population. The diatoms *Achnanthes lanceolata* and *Cocconeis pediculus* comprised of 7.3 percent of the periphyton. Non-diatoms occuring in Bull Creek included the green filamentous algae, *Cladophora* sp., and the blue-greens *Oscillatoria tennis* and *Lyngbya* sp. Relative algal abundance of the major groups, Chlorophyta, Cyanophyta, and Euglenophyta, did not exceed a relative composition of 6 percent.

5.5.3 Aquatic Macrophytes

Aquatic macrophytes are freshwater vascular plants which may occupy three basic zones or habitats, submerged, emergent and floating. Submerged macrophytes are those anchored in the substrate and typically have floating leaves, and reproduction structures that rise above the water surface. Emerged, or emergent aquatic vegetation is generally associated with shallow water and mud substrate habitat in which plants root. Emergent hydrophytes may be either rooted upright plants with shoots that extend well above the water surface, or plants with floating leaves. Floating aquatic plants have true leaves and roots and float on the water surface (U.S EPA, 1973).

Macrophyton are beneficial to the overall ecology of the aquatic environment in many ways. Submerged and emerged hydrophytes provide habitat for complex assemblages of macroinvertebrates and cover for fish particularly young-of-the-year. Live and decomposed plant tissue is often a primary source of food for herbivorous macroinvertebrates. Aquatic macrophytes may also serve as a natural substrate on which diverse and complex periphyton (algae) communities develope. The complex plant animal community that is often associated with macrophyton may also become food for an assortment of higher vertebrates such as amphibians, wading birds, water fowl and mammals. All of these factors combined help enhance the development of complex freshwater and related terrestrial communities in or near areas of abundant macrophyton growth.

5.5.3.1 Ohio River

During the coarse of the Ashland Baseline Study aquatic macrophytes were not visually sited nor were they collected in benthic macroinvertebrate grab samples from the Ohio River. The fact that aquatic plants did not occur at the Ohio River Stations is not atypical. Generally the shifting sand and associated bottom sediments so often encountered along the river shoreline, and erosional wave zone, are not conducive to the propogation of aquatic vascular plants. Furthermore, the relatively high turbidity of river water restricts light penetration which also inhibits aquatic plant growth (U.S. EPA, 1973).

5.5.3.2 Town Creek

Three species of aquatic macrophytes were collected from the Town Creek embayment area. This shallow backwater environment supported two types of emergent shore line plants and one submerged species. The emergent hydrophytes were *Sagittaria latifolia*, the Water Plantain, and *Saururus cernuus*, Lizard's Tail. A Pondweed, *Potamogeton* sp. was the submerged variety. Field observations indicated that a generally sparse population of aquatic macrophytes occured near the confluence of Town Creek and the embayment area.

No aquatic macrophytes were colleted at the upstream station on Town Creek.

5.5.3.3 Bull Creek

Two of the aquatic macrophytes which occurred in the Town Creek embayment area also occurred in the Bull Creek embayment area. They were, the Water Plantain, *Sagittaria latifolia* and Lizard's Tail, *Saururus cernuus*. Both of these plants are emergent shoreline varieties which typically inhabit shallow muddy area. The overall concensus for relative abundance of aquatic plants in the Bull Creek area was similar to that for Town Creek, sparse.

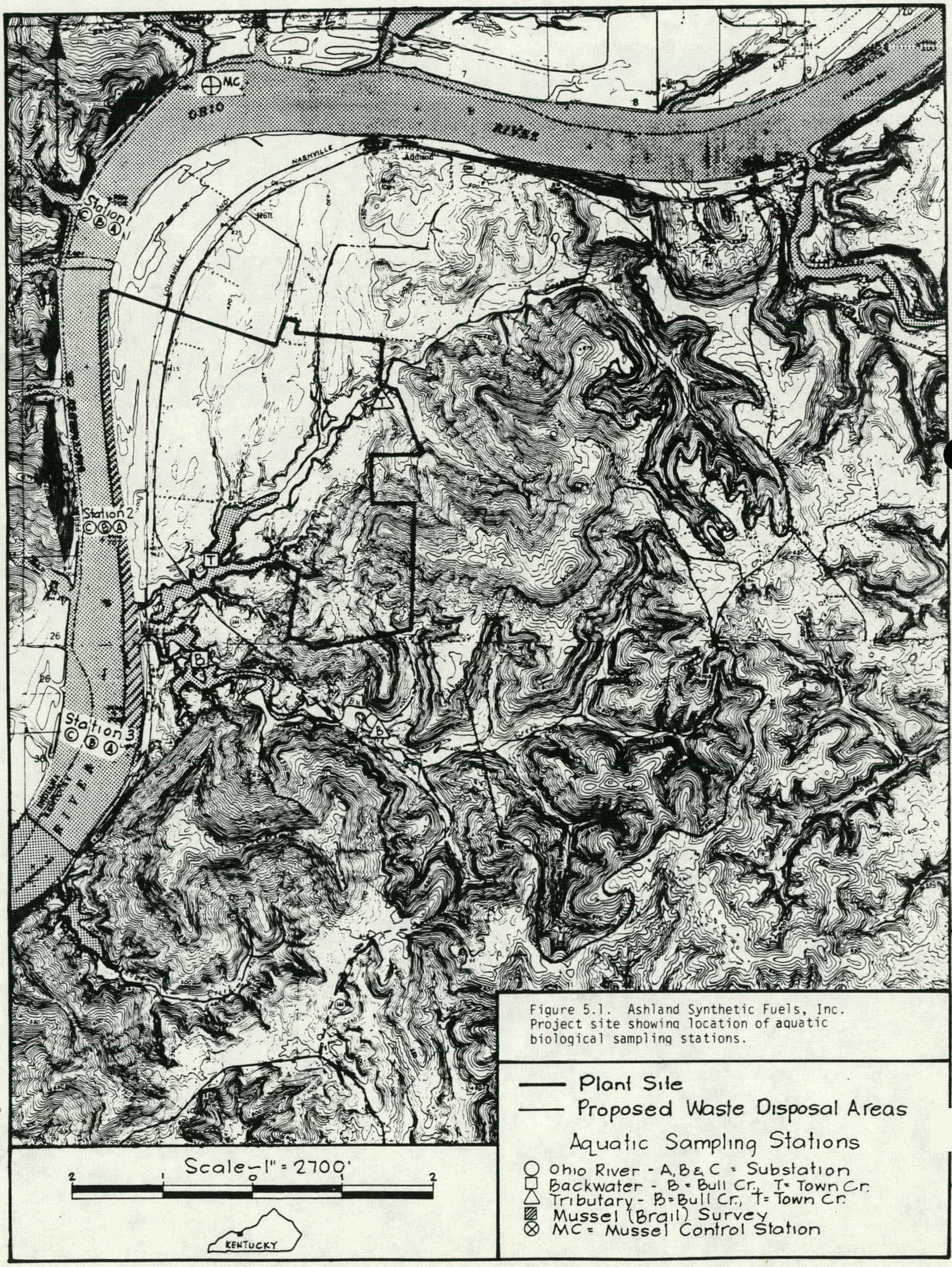

Figure 5.1. Ashland Synthetic Fuels, Inc. Project site showing location of aquatic biological sampling stations.

5.60 B

5.5.4 Benthic Macroinvertebrates

5.5.4.1 Ohio River

Benthic macroinvertebrates were collected from nine sampling stations on the Ohio River on May 13, July 15, and October 8, 1980, and on January 13, 1981, in the vicinity of the proposed plant site. Three stations, consisting of three substations each, were located on the Ohio River. So that a cross section and a longitudinal section of the river channel was surveyed, Stations 1A, 1B and 1C (A, B, and C are designated substations herein) were located at Ohio River Mile (ORM) 705, Stations 2A, 2B and 2C at ORM 707, and Stations 3A, 3B and 3C at ORM 708.2. Substation A was located near the Kentucky side of the river channel, Substation B was situated at mid-channel, and Substation C was located near the Indiana side of the river channel (Figure 5.1).

The benthic macroinvertebrates collected during the quarterly surveys were those macroscopic animals which spend at least part of their life cycle in or on the river bed substrate and are retained by a U.S. Standard Number 30 sieve (0.595 mm). Benthic macroinvertebrates may be referred to as benthic invertebrates, zoobenthos, aquatic invertebrates or macroinvertebrates, benthic fauna, benthic organisms and macroinvertebrates. The zoobenthos discussed in this section is exclusive of Bivalvia: Unionidae, fresh-water mussels, which are discussed in Section 5.5.5.

Aquatic macroinvertebrates occupy many types of habitat and fill a variety of ecological niches. They are an important portion of ecological baseline studies because they provide essential information on the aquatic food web, especially, that pertaining to secondary production. Benthic organisms typically make-up many functional feeding catagories and fulfill several broad trophic relationships. Benthic macroinvertebrates are often consumed by fish and other higher vertebrates including amphibians, a variety of waterfowl and wading birds, and occasionally mammals. Results of these studies may provide very useful information determining the overall well being of the aquatic environment as well as provide interpretative information for identifying potential physical and/or chemical pertuberations.

Benthic invertebrates such as Corbicula manilensis (Bivalvia: Corbiculidae), the Asiatic clam, may also become nuisance organisms. There are presently many documented occasions in which Corbicula have received persistent studies and evaluation of its extensive bio-fouling capability. Other benthic organisms may also become sources of problems depending on site specific characteristics of the aquatic environment and specific engineering requirements for industry.

Ecological measurements for documenting baseline characteristics of benthic macroinvertebrate communities in the Ohio River are derived from four types of analyses. These are analysis of: (1) taxonomic composition and structure, (2) density, (3) community diversity and equatibility, and (4) identification of basic functional feeding groups.

Analysis of taxonomic composition and structure is completed by construction of lists of benthic fauna collected and the respective number of individuals within each taxa. Macroinvertebrate density may be expressed for a taxon, group of organisms, or more often, for a particular sampling station or group of sampling stations. Density of benthic macroinvertebrates is expressed as number of organisms per meter squared (M^2), and is derived from converting the mean number of organisms in the original benthic grab sample.

Community diversity is a measure of taxonomic richness and the distribution of individuals among the taxa collected at a particular station. Equitability is the measure of the "evenness" of the distribution of those individuals and their respective numbers among the benthic community taxonomic composition (U.S. EPA 1973).

The functional feeding groups herein are used to exemplify types of benthic macroinvertebrate feeding habits, and the overall composition of organisms comprising these feeding habits. Four basic functional feeding groups are used to account for the variety of feeding modes for the taxa of benthic invertebrates collected from the Ohio River. These are: (1) detritivores, (2) herbivores, (3) omnivores, and (4) carnivores. They are defined using Cummins (1973), Cummins (1979), and Cummins and Klug (1979) general classification for functional feeding. Detritivores are those organisms which feed most frequently in/on ultra-fine silt and mud particles to the more coarse decomposed leaf and higher plant debris. Benthic invertebrates collected from fine to coarse detritus substrates may feed as filter or suspension collectors of fine particulate matter, or they may be shredders of the more coarse plant debris. Detritivore shredders are frequently found mining higher decomposed plant tissue including leaves, stems and other tissue parts.

Herbivorous macroinvertebrates encompass a broad range of organisms that feed primarily on living plant material. They are comprised of shredders, miners, collectors and scrapers, and feed on a large variety of living plant material including plantonic filamentous and diatomaceous algae, periphytic algae, higher plants and related organic matter.

Omnivores are those benthic macroinvertebrates which most often consume both plant and animal material. These organisms may have similar feeding modes as those discussed above, or may typify carnivore/scavenger type feeding habits. Carnivores thrive predominantly on living and dead animal tissue, fluids, or parts. The preditory habits of carnivores are comprised of two types, swallowers and piercers.

In studying and evaluating the functional feeding groups making up the taxonomic composition of zoobenthos obtained from the Ohio River, it is assumed that overlap or facultative habits occur. The extent, or frequency of facultative feeding behavior and habits were not always definitive, and therefore, organisms were classified as to "best fit" for predominant feeding groups. The "best fit" was based on numerous literature sources including primarily the following authors: Cummins (1973, 1979), Cummins and Klug (1979), Merritt and Cummins (1978), Pennak (1979), Roback (1957), Johannsen (1969), Curry (1966), Gale and Lowe (1971). Additionally, those benthic organisms which could not be classified into their primary functional group were placed into a category of undetermined. Their densities were included in the percent composition calculations and recorded accordingly.

Evaluation of the ecological characteristics discussed above concerning the Ohio River benthic macroinvertebrate communities, combined with other biotic and abiotic variables which were either observed, measured, or estimated during the quarterly surveys, contribute to the eventual complete assessment of major benthological relationships in the study area. The more important biotic and abiotic relationships are discussed in the following paragraphs as they apply to the results of the benthic macroinvertebrate sampling program.

During the four sampling programs 58 taxa of benthic macroinvertebrates were collected from the nine Ohio River substations. The predominant insect (Insecta) organisms were typically comprised of Diptera, while the most abundant non-insect taxa were comprised mostly of freshwater segmented worms, Oligochaeta. Diptera were represented by 21 taxa consisting primarily of the midges (Chironomide) Coelotanypus spp., Polypedilum spp., and Ablabesmyia spp.; and included the phantom midge (Culicidae) Chaoborus sp. Additional insect taxa which appeared quite often throughout the duration of the project included: the burrowing mayfly, Hexagenia limbata (Ephemeroptera); Gomphus sp. (Odonata) a burrowing dragonfly; and two relatively common genera of net-spinning caddisflies (Trichoptera), Chematopsyche spp. and Hydropsyche spp.

The most frequently occurring non-insect taxa were comprised largely of tubificid worms (Oligochaeta: Tubificidae). These included such detritivores as Branchuria sowerbyi, Limnodrilus hoffmeisteri, Limnodrilus caparedeanus, and less often Peloscolex sp. The Asiatic clam Corbicula manilensis (Bivalvia: Corbiculidae) a filter feeding omnivore, was moderately abundant and occurred frequently in the study area. An additional non-insecta taxa which appeared less frequently than those organisms above, but was occasionally found to be locally abundant, was the small crustacean Gammarus spp. (Amphipoda: Gammaridae).

The extremes for number of taxa colleced at the nine Ohio River substations ranged from the minimum of 3 during July, 1980 at Stations 1B and 3B to a maximum of 18 at Station 2C during the January, 1981 survey. Overall taxonomic composition in the benthic macroinvertebrate communities was the highest during January and the lowest during July (Table 5.10 through 5.13).

The higher number of taxa reported during January, especially insects, was expected since this is generally within the time period in which many immature life forms (larvae and nymphs) over-winter. This is futher substantiated because of the generally higher densities of insect fauna collected during January. This phenomenon envolving periodicy of insect life cycles occurred during the October survey to a limited extent, too.

The sampling information collected from the cross section of the Ohio River at the proposed plant site showed generally depressed numbers of taxa in mid-channel than along its edges (Figure 5.4 through 5.7). This pattern was certainly expected since it was probable that relatively few aquatic macroinvertebrates tolerate the physical and occasionally irregular environmental variables at mid-channel. On most occassions during this study very few taxa were collected from mid-channel; the number of taxa ranged from 3 to 11 during July and January, respectively. The higher number of taxa occurring at Station 2B in January was due to favorable substrate condition, flow, and other overall physical factors which enhanced benthic community development. Additionally, as shown by Figure 5.7, apparently these environmental conditions favored a diagonal pattern of high zoobenthic densities from Station 3C to 2B to 1A. The indirect effects of stream regulation seem apparent in producing this pattern.

Benthic macroinvertebrate taxa did not show particularly uniform or consistent longitudinal patterns from Ohio River Station 1, downriver to Station 3. It was only evident that the mean number of taxa at these river stations were slightly more uniform during October and January, than during May and July (Figure 5.8).

Table 5.10 Benthic macroinvertebrates (density/M^2) collected May 13 and 16, 1980, from the Ohio River, Bull Creek and Town Creek.

	Ohio River									Bull	Town
	1A	1B	1C	2A	2B	2C	3A	3B	3C	Creek	Creek
Taxa											
Arthropoda											
Insecta											
Ephemeroptera											
Baetis sp.										21.5	35.7
Caenis sp.										43.1	39.5
Hexagenia limbata				44.6		57.4	95.7				10.8
Paraleptophlebia debilis										7.1	7.1
Stenonema sp.		6.4	76.5						19.1	25.1	3.6
Odonata											
Agrion sp.										3.6	
Neurocordulia molesta			38.3								
Trichoptera											
Chematopsyche spp.			344.4		6.4	9.6			31.9		
Hydropsyche spp.			19.1						6.4		
Polycentropus sp.			19.1								
Pupa			9.6								
Coleoptera											
Dubiraphia sp.											25.1
Dytiscidae										3.6	
Elmidae adult										3.6	3.6
Stenelmis sp.										3.6	
Diptera											
Ablabesmyia sp.			9.6								3.6
Adults										17.9	
Chaoborus sp.	6.4										
Chironominae pupa		12.8								14.4	14.4
Chironomini pupa										17.9	7.1

Table 5.10 Continued

	1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
	Ohio River										
Taxa											
Chironomus spp.											86.1
Cladotanytarsus sp.										86.1	
Coelotanypus spp.					6.4	19.1	25.5		6.4	3.6	
Cricotopus spp.										7.2	43.1
Cryptochironomus (S.S.)sp.										28.7	53.8
Cryptochironomus sp. 1		63.8			6.4						
Cryptochironomus sp. 2		51.0						12.8			
Dicrotendipes sp.										10.8	
Endochironomus sp.										14.4	46.6
Harnischia sp.											3.6
Hemerodromia sp.			9.6								
Heterotrissocladius sp.									6.4	28.7	
Lauterborniella sp.											3.6
Microtendipes aberrans											3.6
Nanocladius sp.										3.6	
Orthocladiinae pupa										10.8	3.6
Orthocladius sp.										3.6	
Paratendipes albimanus								6.4		118.4	247.6
Paratendipes connectens		25.5						165.8			
Polypedilum sp.			66.9	6.4				6.4		25.1	17.9
Polypedilum fallax										21.5	
Procladius sp.											21.5
Psectrocladius sp.										14.4	
Pseudochironomus sp.									6.4		
Stictochironomus sp.		6.4								218.9	1758.3
Tanypodiinae pupa										10.8	3.6
Tanytarsini										3.6	3.6
Tanytarsus spp.					6.4			6.4		14.4	39.5
Thienemannemyia group									6.4	93.3	
Trissocladius sp.										3.6	
Undetermined spp.		44.6								10.8	
Total Insecta	6.4	210.5	593.1	51.0	25.6	86.1	121.2	197.8	83.0	893.7	2486.5

Table 5.10 Continued

Taxa	1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
	Ohio River										
Crustacea											
Amphipoda											
Gammarus sp.	6.4		57.4	12.8							
Isopoda											
Lirceus sp.										46.7	
Decapoda											
Orconectes sp.									6.4		
Annelida											
Hirudinea											
Oligochaeta											
Immature tubificids	574.1			720.8	25.5	382.7	905.8	19.1	19.1	17.9	3.6
Branchuria sowerbyi							12.8				
Limnodrilus claparedeanus	452.9			57.4		153.1	6.4				
Limnodrilus hioffmeisteri	912.2			261.5	6.4	162.6	293.4			14.4	10.8
Limnodrilus sp.				31.9		28.7	31.9				3.6
Peloscolex spp.	114.8					19.1				3.6	
Undetermined Naididae						9.6					
Mollusca											
Bivalvia											
Corbicula manilensis							19.1	19.1	25.5		3.6
Undetermined Unionacean							12.8				
Nemotoda										3.6	
Total Non-Insecta	2060.4	0.0	57.4	1084.4	32.0	755.8	1282.2	38.3	51.0	86.2	21.6

Table 5.10 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Total Density	2066.8	210.5	650.5	1135.4	57.5	841.9	1403.4	236.0	134.0	979.9	2508.1
Total Taxa	6	7	10	7	6	9	9	7	10	37	29
Community Diversity($\bar{d}$)	1.80	2.41	2.30	1.56	2.28	2.25	1.62	1.60	3.01	4.16	1.96
Equitability(e)	0.69	0.86	0.69	0.56	0.88	0.71	0.51	0.57	0.91	0.81	0.40

1 A = Kentucky Side, B = Mid Channel, C = Indiana Side

Table 5.11 Benthic macroinvertebrates (density/M^2) collected July 15 and 16, 1980 from the Ohio River, Bull Creek and Town Creek.

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Taxa											
Anthropoda											
Insecta											
Ephemeroptera											
Baetis sp.										14.4	32.3
Caenis sp.										93.3	25.1
Stenonema sp.										43.1	43.1
Odonata											
Gomphus sp.	25.5		25.5	25.5		6.4			6.4		
Coenagriidae											3.6
Megaloptera											
Sialis sp.											3.6
Trichoptera											
Chematopsyche spp.			76.5		6.4				19.1	7.2	570.5
Hydropsyche spp.			19.1			6.4				3.6	132.8
Psychomyiid group			6.4								
Coleptera											
Dubiraphia sp										7.2	61.1
Elmidae adults											93.3
Stenelmis sp.										14.4	111.2
Hemiptera											
Microvelia sp.										17.9	
Diptera											
Ablabesmyia sp.						6.4				28.7	32.3
Adults										3.6	
Ceratopogonidae										7.2	
Chironomus spp.											3.6
Coelotanypus spp.	6.4					44.7					
Cryptochironomus (S.S.) sp.										7.2	
Cryptochironomus sp.1		6.4									

Table 5.11 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Taxa											
Cryptocladopelma sp.										7.2	
Hemerodromia sp.											10.8
Microtendipes aberrans										147.1	
Polypedilum sp.	6.4	19.1									43.1
Procladius sp.						6.4					
Rheotanytarsus sp.											3.6
Stictochironomus sp.										168.6	
Simulium vittatum											3.6
Tatytarsini puape											7.2
Tanytarsus spp.										3.6	
Xenochironomus sp.										7.2	
Total Insecta	44.7	25.5	127.5	25.5	6.4	70.3	-0-	-0-	25.5	581.5	1180.8
Crustacea											
Amphipoda											
Gammarus sp.	6.4		12.8			6.4					
Isopoda											
Asellus sp.			6.4								
Lirceus sp.										3.6	10.8
Decapoda											
Orconectes sp.			6.4							7.2	10.8
Annelida											
Hirundinea											
Helobdella sp.	6.4					6.4					

Table 5.11 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Oligochaeta											
Immature tubificids	276.3			318.9	146.7	542.3	1033.4	6.4	133.9	10.8	3.6
Branchuria Sowerbyi					6.4	6.4	19.1				
Limnodrilus caparedeanus	6.4			12.8			51.0		38.3		
Limnodrilus hoffmeisteri	178.6		6.4	185.0	70.2	127.6	752.7		108.5		
Limnodrilus sp.				6.4			19.1				
Peloscolex spp.	12.8				6.4	19.1	31.9	6.4			
Lumbriculidae											3.6
Mollusca											
Bivalvia											
Corbicula manilensis	51.0	6.4		31.9	57.4	95.7	38.3	25.5	25.5		
Sphaerium sp.						12.8	6.4				
Coelenterata											
Hydroida											
Hydra sp.			6.4								
Total Non-Insecta	537.9	6.4	38.4	555.0	287.1	816.7	1951.9	38.3	306.2	21.6	28.8
Total Density	582.6	31.9	165.9	580.5	293.5	887.0	1951.9	38.3	331.7	603.1	1209.6
Total Taxa	11	3	9	6	6	13	8	3	6	20	21
Community Diversity ($\bar{d}$)	2.09	1.39	2.48	1.62	1.82	1.97	1.52	1.25	2.05	3.13	2.82
Equitability (e)	0.60	0.87	0.78	0.63	0.70	0.53	0.51	0.79	0.79	0.72	0.64

Table 5.12 Benthic macroinvertebrates (density/M^2) collected October, 8, and 9 from the Ohio River, Bull Creek and Town Creek.

	Ohio River									Bull	Town
	1A	1B	1C	2A	2B	2C	3A	3B	3C	Creek	Creek
Taxa											
Arthropoda											
Insecta											
Ephemeroptera											
Baetis sp.											7.2
Caenis sp.				6.4						43.1	100.5
Hexagenia limbata	6.4					19.1				3.6	
Leptophlebia sp.											61.0
Stenonema sp.											3.6
Odonata											
Agrion sp.											10.8
Gomphus sp.	12.8	6.4	6.4	25.5		6.4			6.4		
Macromia sp.										Q^{-a}	
Nehallenia sp.						6.4					
Megaloptera											
Sialis sp.										14.3	10.8
Trichoptera											
Chematopsyche spp.										17.3	1119.5
Hydropsyche spp.											14.3
Coleoptera											
Dubiraphia										64.3	3.6
Dytiscus sp.										3.6	
Stenelmis sp.										39.5	

Table 5.12 Continued

	Ohio River									Bull	Town
	1A	1B	1C	2A	2B	2C	3A	3B	3C	Creek	Creek
Hemiptera											
Microvelia sp.										Q	
Diptera											
Ablabesmyia sp.						6.4					61.0
Brillia sp.											7.2
Aedes sp.										3.6	
Cardiocladius sp.											10.8
Ceratopogonidae										491.6	17.9
Chaoborus sp.	6.4	76.5		51.0	63.8	12.8	76.5	31.9	76.5	17.9	14.3
Chironomus sp.	12.8	19.1		19.1			6.4		12.8	25.1	541.8
Coelotanypus sp.	12.8		63.8	6.4		12.8	57.4	6.4	6.4		
Dicrotendipes sp.										10.8	193.7
Glyptotendipes sp.										3.6	3.6
Harnischia sp.										3.6	
Heterotrissocladius sp.											14.3
Kiefferulus sp.										25.1	7.4
Microtendipes aberrans											21.9
Micropsectra sp.											21.9
Orthocladius sp.											21.9
Paralaeterborniella sp.										3.6	7.2
Paratendipes albimanus											
Paratendipes connectens		25.5									
Pentaneura sp.										7.2	
Polypedilum fallax										3.6	
Polypedilum sp.			19.1		31.9				6.4	3.6	132.8
Procladius sp.							6.4	6.4		7.2	25.1
Rheotanytarsus sp.											21.5
Stenochironomus sp.						427.4					3.6
Stictochironomus sp.										43.1	35.9
Tabanus sp.										46.6	35.9
Tanytarsus sp.										39.5	78.9

Table 5.12 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Tipula sp.										7.2	25.1
Tribelos sp.											28.1
Undetermined pupae		6.4	6.4		6.4						43.1
Total Insecta	51.2	133.9	95.7	108.4	102.1	491.3	146.7	44.7	108.5	929.5	2705.6
Crustacea											
Isopoda											
Lirceus sp.											3.6
Decopoda											
Orconectes sp.										7.2	3.6
Bryozoa											
Cristatella mucedo				6.4							
Annelida											
Hirundinea											
Glossiphoniidae			12.8			6.4					
Oligochaeta											
Immature tubificids	759.1	12.8	676.2	63.8	51.0	204.1	784.6	2463.7	752.7	104.1	43.1
Branchuria sowerbyi							25.5		51.0		
Dero sp.						6.4			6.4		
Limnodrilus caparedeanus	12.8										
Limnodrilus hoffmeisteri	223.3		114.8	12.8		63.8	497.6	618.8	312.6	3.6	
Limnodrilus sp.	25.5		12.8	12.8	44.6	76.5	229.6	370.0	82.9	3.6	

Table 5.12 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Lumbriculidae									6.4		
Nais sp.											14.3
Peloscolex sp.			19.1		6.4			25.5			
Tubificidae with hair setae			6.4		6.4	6.4	6.4				6.4
Mollusca											
Bivalvia											
Corbicula manilensis	127.6	108.4	153.1	382.1	280.7	108.4	57.4	51.0	70.2		
Psidium sp.										122.0	25.1
Sphaerium sp.						6.4				10.8	
Gastropoda											
Ferrissia sp.										3.6	35.9
Helisoma sp.										10.8	14.3
Plurocera sp.	6.4		25.5								
Physa sp.											28.7
Total Non-Insecta	1154.7	121.2	1020.7	478.5	389.1	478.4	1601.1	3534.0	1282.2	265.7	183.4
Total Density	1205.9	255.1	1116.4	586.9	491.2	969.7	1747.8	3578.7	1390.7	1195.2	2899.0
Total Taxa	11	7	12	10	8	15	10	8	12	34	43
Community Diversity ($\bar{d}$)	1.73	2.14	2.01	1.87	2.00	2.51	2.12	1.38	2.07	3.38	3.46
Equitability (e)	0.50	0.76	0.56	0.56	0.67	0.64	0.64	0.46	0.58	0.68	0.64

a-Qualitative, not used for calculating community diversity (d)

Table 5.13 Benthic macroinvertebrates (density/M^2) collected January, 13 and 14, 1981 from the Ohio River, Bull Creek and Town Creek.

	Ohio River									Bull Creek	Town Creek
	1A	1B	1C	2A	2B	2C	3A	3B	3C		
Taxa											
Arthropoda											
Insecta											
Ephemeroptera											
Baetis sp.										7.2	3.6
Caenis sp.										18.0	68.4
Hexagenia limbata	6.4		6.4		6.4	19.2			6.4		36.0
Leptophlebia sp.											82.8
Stenonema sp.										32.4	54.0
Plecoptera											
Alocapnia sp.										43.2	50.4
Immature			6.4					108.8			
Odonata											
Gomphus sp.	32.0			6.4		6.4					
Promogomphus sp.	6.4										
Megaloptera											
Sialis sp.											10.8
Trichoptera											
Chematopsyche spp.											97.2
Psychomyiid spp.											14.4

Table 5.13 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Coleoptera											
Dubiraphia sp.										7.2	
Stenelemis sp.										36.0	7.2
Diptera											
Ablabesmyia sp.				6.4					19.2		
Brillia sp.											10.8
Ceratopogonidae										43.2	3.6
Chaoborus sp.		6.4		12.8		25.6	12.8		134.4		
Chironomus sp.	25.6	19.6		179.0	19.2	12.8	172.8		121.6	7.2	46.8
Coelotanypus sp.				32.0	6.4	38.4	64.0				
Conchapelopia sp.										7.2	57.6
Cricotopus sp. 1						6.4				82.8	345.6
Cricotopus sp. 2										43.2	
Cryptochironomus sp.	6.4		25.6	83.2	6.4	89.6	25.6				
Crysops sp.						6.4				7.2	
Dicrotendipes sp.											14.4
Diplocladius sp.										7.2	36.0
Einfeldia sp.							19.2				
Endochironomus sp.	6.4										
Heterotrissocladius.sp.											10.8
Kiefferulus sp.										18.0	
Larsia sp.										14.4	
Microtendipes aberrans											162.0
Orthocladiinae pupae											10.8
Paratendipes connectens		6.4						6.4			
Paratendipes sp.										3.6	
Polypedilum sp.		6.4				121.6					
Procladius sp	19.2			6.4	25.6	6.4	6.4				
Stictochironomus sp.										18.0	
Trichocladius sp.										54.0	32.4
Trissocladius sp.										14.4	90.0
Total Insecta	102.4	38.4	38.4	326.4	64.0	332.8	300.8	115.2	281.6	464.4	1245.6

Table 5.13 Continued

	Ohio River									Bull	Town
	1A	1B	1C	2A	2B	2C	3A	3B	3C	Creek	Creek
Crustacea											
Amphipoda											
Gammarus sp.				6.4				6.4			
Hyalella sp.											7.2
Isopoda											
Lirceus sp.											39.6
Annelida											
Oligochaeta											
Aulodrilus sp.	25.6	12.8	6.4						44.8		
Branchuria sowerbyi	51.2				25.6	32.0	12.8	6.4	32.0		
Dero sp.			6.4							3.6	
Limndrilus hoffmeisteri	128.0	25.6		25.6	524.8	76.8	147.2	12.8	262.4	7.2	
Limnodrilus sp.		25.6		57.6	390.4	12.8	12.8	25.6	262.4		10.8
Lumbriculidae										3.6	
Nais sp.											3.6
Peloscolex sp.	345.6				12.8	25.6				7.2	3.6
Immature Tubificids	2112.0	64.0	6.4	322.8	1324.8	1312.0	876.8	102.4	3808.0	18.0	43.2

Table 5.13 Continued

	Ohio River 1A	1B	1C	2A	2B	2C	3A	3B	3C	Bull Creek	Town Creek
Mollusca											
Bivalvia											
Corbicula manilensis	294.4	204.8	313.6	25.6	358.4	121.6	25.6	44.8	140.8		
Sphaerium sp.											7.2
Gastropoda											
Physa sp.			25.6			6.4					
Plurocera sp.						6.4					
Total Non-Insecta	2956.8	332.8	348.4	448.0	2636.8	1593.6	1075.2	198.4	4550.4	39.6	115.2
Total Density	3059.0	371.2	396.8	774.4	2700.8	1926.4	1376.0	313.6	4832.0	540.0	1360.8
Total Taxa	13	8	9	12	11	18	11	8	10	24	29
Community Diversity (a)	1.64	2.13	1.26	2.48	2.03	1.97	1.87	2.29	1.31	4.04	3.92
Equitability (e)	0.44	0.67	0.42	0.69	0.59	0.47	0.54	0.76	0.39	0.88	0.81

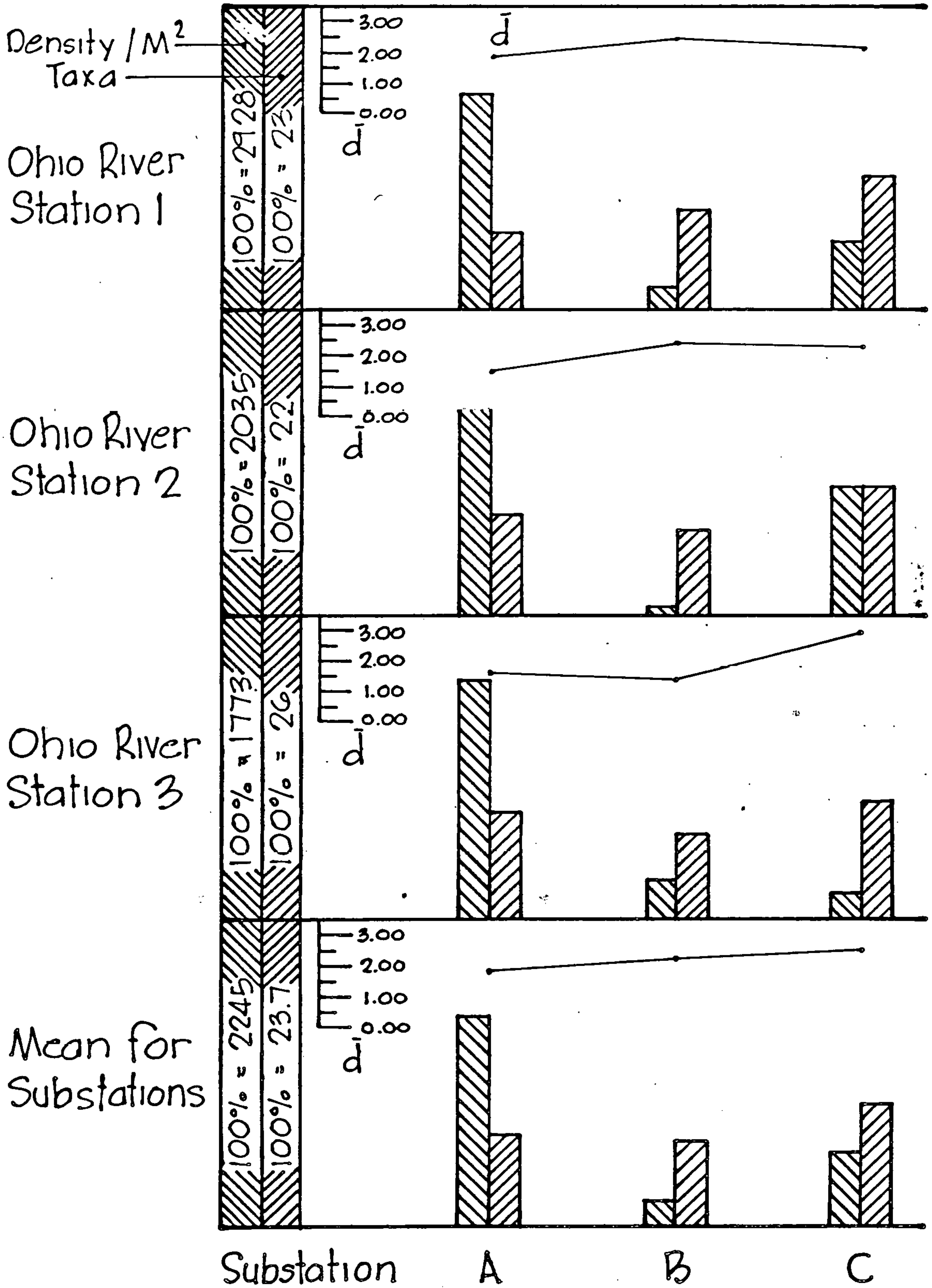

Figure 5.4 Cross section comparison of benthic macroinvertebrate density, number of taxa and community diversity at Ohio River Stations on May 13, 1980.

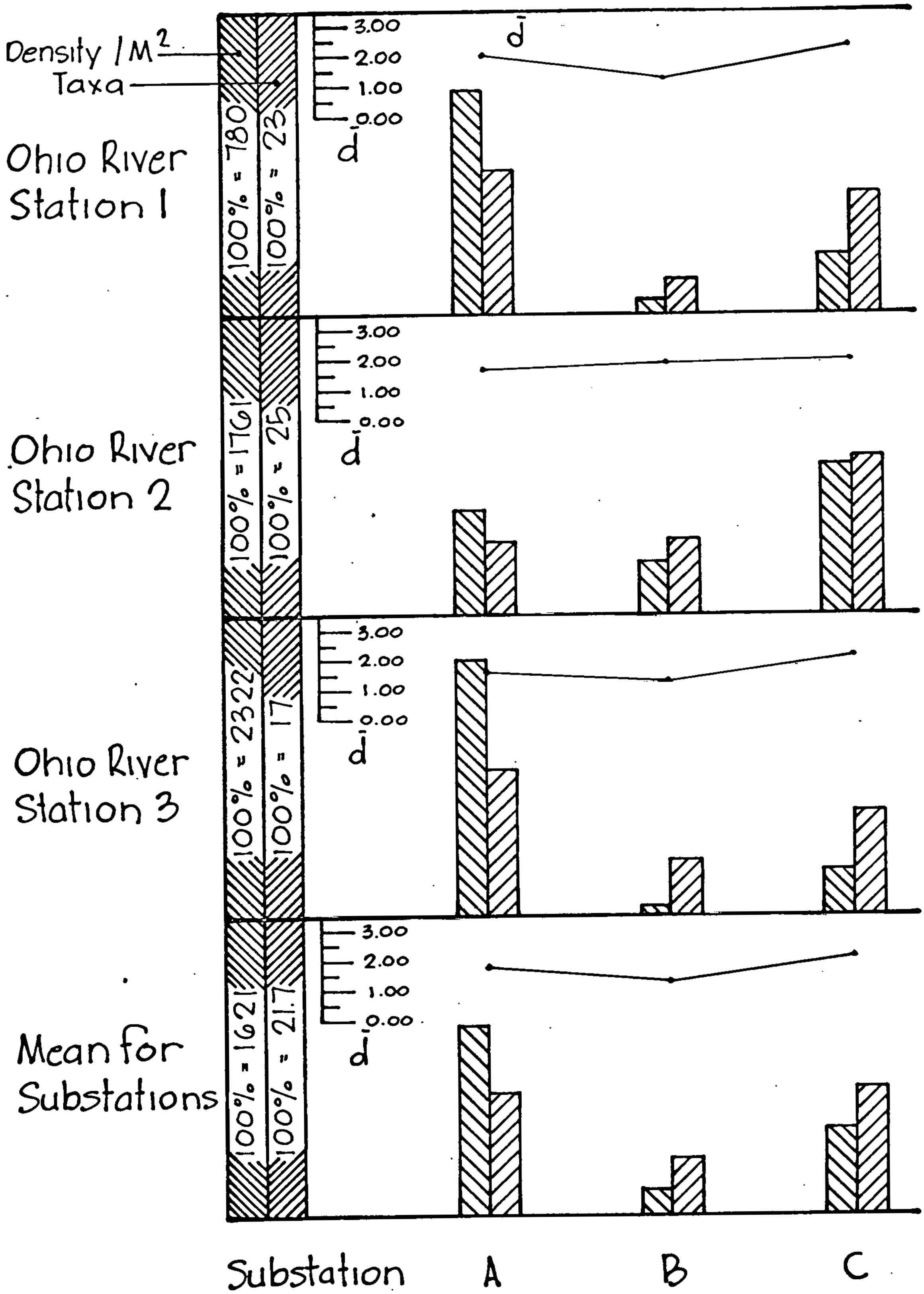

Figure 5.5 Cross section comparison of benthic macroinvertebrate density, number of taxa and community diversity at Ohio River Stations on July 15, 1980.

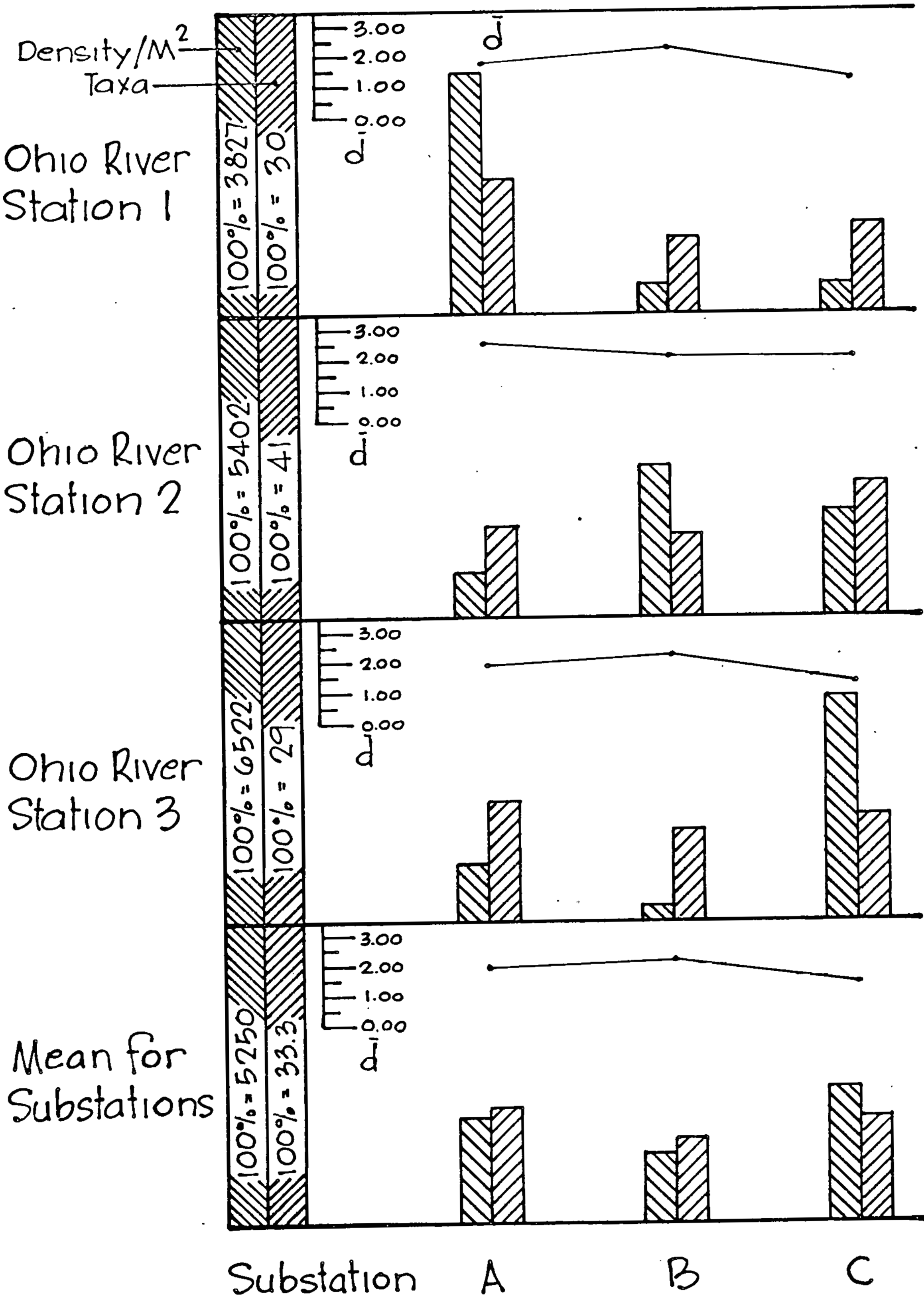

Figure 5.6 Cross section comparison of benthic macroinvertebrate density, number of taxa and community diversity at Ohio River Stations on October 8, 1980.

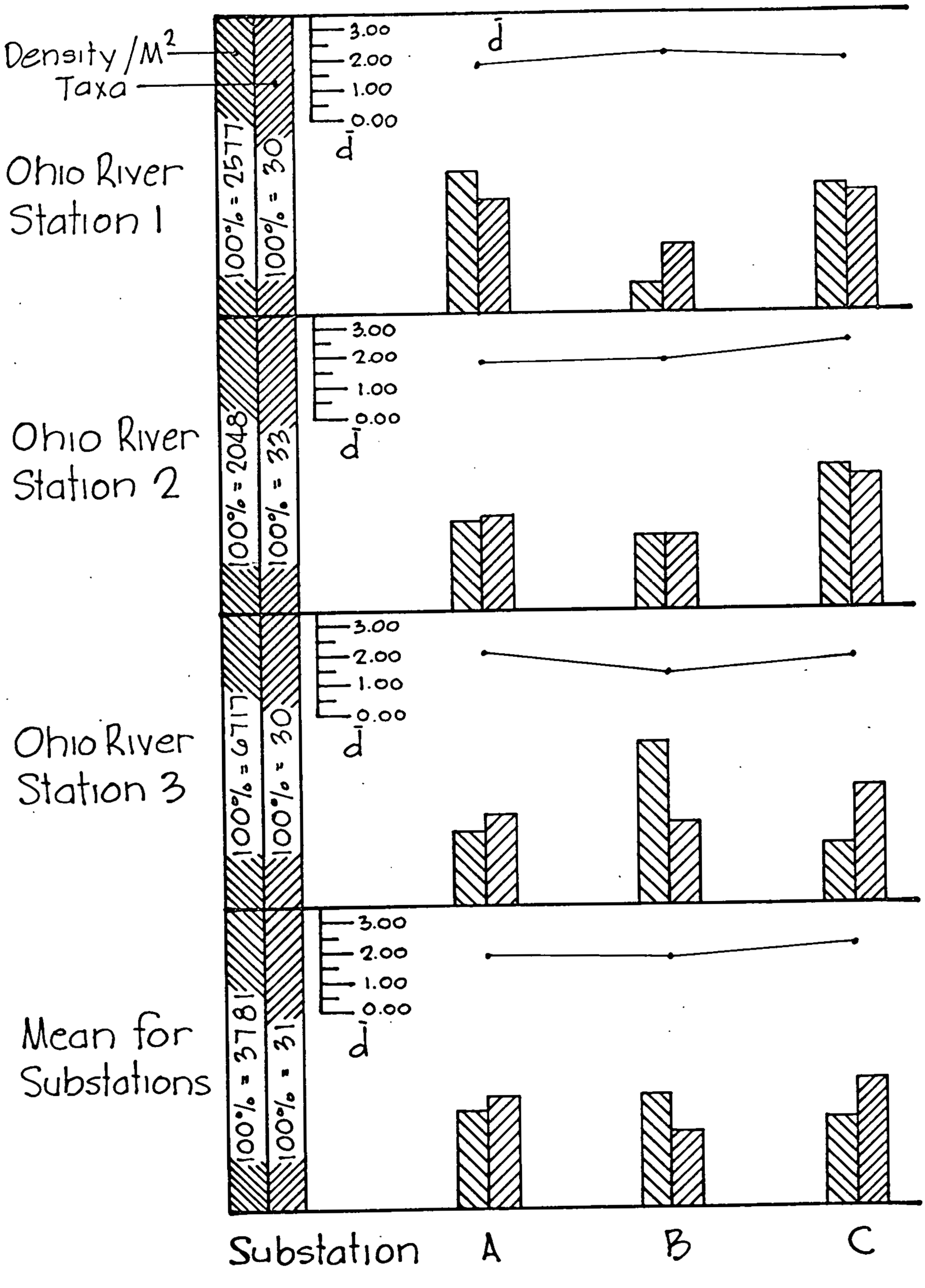

Figure 5.7 Cross section comparison of benthic macroinvertebrate density, number of taxa and community diversity at Ohio River Stations on January 13, 1981.

Benthic macroinvertebrate densities were quite variable throughout the Ohio River study area. The highest insect densities were, in part, attained by midges such as Stenochironomus sp., which reached a maximum density of $427/M^2$ at Station 2C during the October survey. During January, Chironomus sp. maintained relatively high densities ranging from 172.8 to $179.2/M^2$ at Station 2A and 3A, respectively. The highest midge density in May was attributed to Paratendipes connectens ($165.8/M^2$) at Station 3B. Other insect taxa also reached relatively high abundance. For example, the caddisfly, Chematopsyche spp., obtained a maximum density of $344.4/M^2$ during May, at Station 1C. Hexagenia limbata, and other insect taxa, including these additional midge taxa, Polypedilum spp, Coelotanypus spp, Cryptochironomus spp, and Chaoborus sp., appeared to be moderately abundant at specific stations in the Ohio River. Generally highest densities were corrolated with favorable habitat characteristics analogous with the particular functional feeding types of respective taxa. This corrolation was more evident for the predominant benthic insect organisms and was especially pronounced for non-insect benthic fauna such as the segmented worms (Tubificidae).

Tubificids were typically very abundant at Ohio River stations with substrates composed of decomposed detritus. Detritus substrates were more often located along the lateral margins of the river, but occasionally loose detritus deposits occurred at mid-channel when low flow or low current velocity conditions existed. The predominant tubificid detritivores occurring in the sediments were Limnodrilus sp., Branchuria sowerbyi, and Peloscolex sp. Limnodrilus hoffmeisteri was the most abundant worm; it reached a density of $912.2/M^2$ during the May survey at Station 1A.

Immature tubificids, which were likely comprised of several taxa, often made up the dominant portion of benthic density. During January the immature worms were collected in numbers as high as $3808/M^2$ at Station 3C from fine to coarse detritus sediments. During the coarse of this study it was apparent that the substrate-organism relationship existed specially for the tubificids, but also for other zoobenthic taxa. At least one benthic organism did not indicate this ecological relationship to the substrate.

Corbicula manilensis did not show a definitive positive relationship as discussed above. The Asiatic clam was distributed throughout numerous bottom types as indicated by its moderate abundance and distribution at all Ohio River stations. Corbicula showed maximum densities during the October and January surveys when they reached $382.7/M^2$ at Station 2A, and $358.4/M^2$ at Station 2B, respectively. The substrate type at both stations was composed of numerous particle grades of decomposed vegetation. Corbicula were abundant in substrates of sand where it reached densities between 19.0 and $108.4/M^2$, and also occurred in comparable numbers in the firm, compact sand-gravel-rubble substrates typically encountered along the erosional bank on the Indiana side of the channel. Fuller (1978, 1980) concluded from intensive mussel investigations on the upper Mississippi River that Corbicula were distributed in much the same manner.

Total macroinvertebrate densities changed substantially throughout the 1980 and 1981 sampling period. The lowest benthic macroinvertebrate densities were consistently recorded from mid-channel Stations 1B, 2B and 3B. On only a few occasions were densities higher in mid-channel than along the edges of the river. For example, during October at Station 3, total benthic invertebrate densities were highest in mid-channel, as were the densities during January at mid-channel Station 2B. This was attributed to the presence of relatively high numbers of Corbicula manilensis and Tubificidae, especially immature tubificids, in isolated deposits or sediment anomolies of detritus which comprised favorable substrate for these organisms. Additionally, the flow in Channelton Pool during the periods of benthological sampling was relatively slow. Stream regulation, such as the Ohio River is subjected to, commonly alters previous ecological, physical, and chemical characteristics which later may have direct and indirect influences on the benthic macroinvertebrate community (Ward & Stanford 1979, Whitton 1975; Hynes 1972).

Maximum benthic densities occurred most often at the lateral channel Substations A and C. Overall, mean total densities were slightly higher along the Kentucky side of the Ohio River in the soft detritus sediments. However, the highest total macroinvertebrate density (4832/M^2) occurred at Station 3C in January, 1981. Total macroinvertebrate densities were consistently higher during January, especially at the lateral river channel Substations A and C, and consistently lower during July, especially at Ohio River Stations 1 and 2.

Mean total macroinvertebrate densities for the three Ohio River stations during May, July, October, and January showed definitive trends (Figure 5.8). During the first survey in May, macroinvertebrate densities decreased in progressing downstream from Station 1 through 3. During July, October, and January, total benthic densities generally increased in progressive order, from the upstream Station 1 to downstream Station 3.

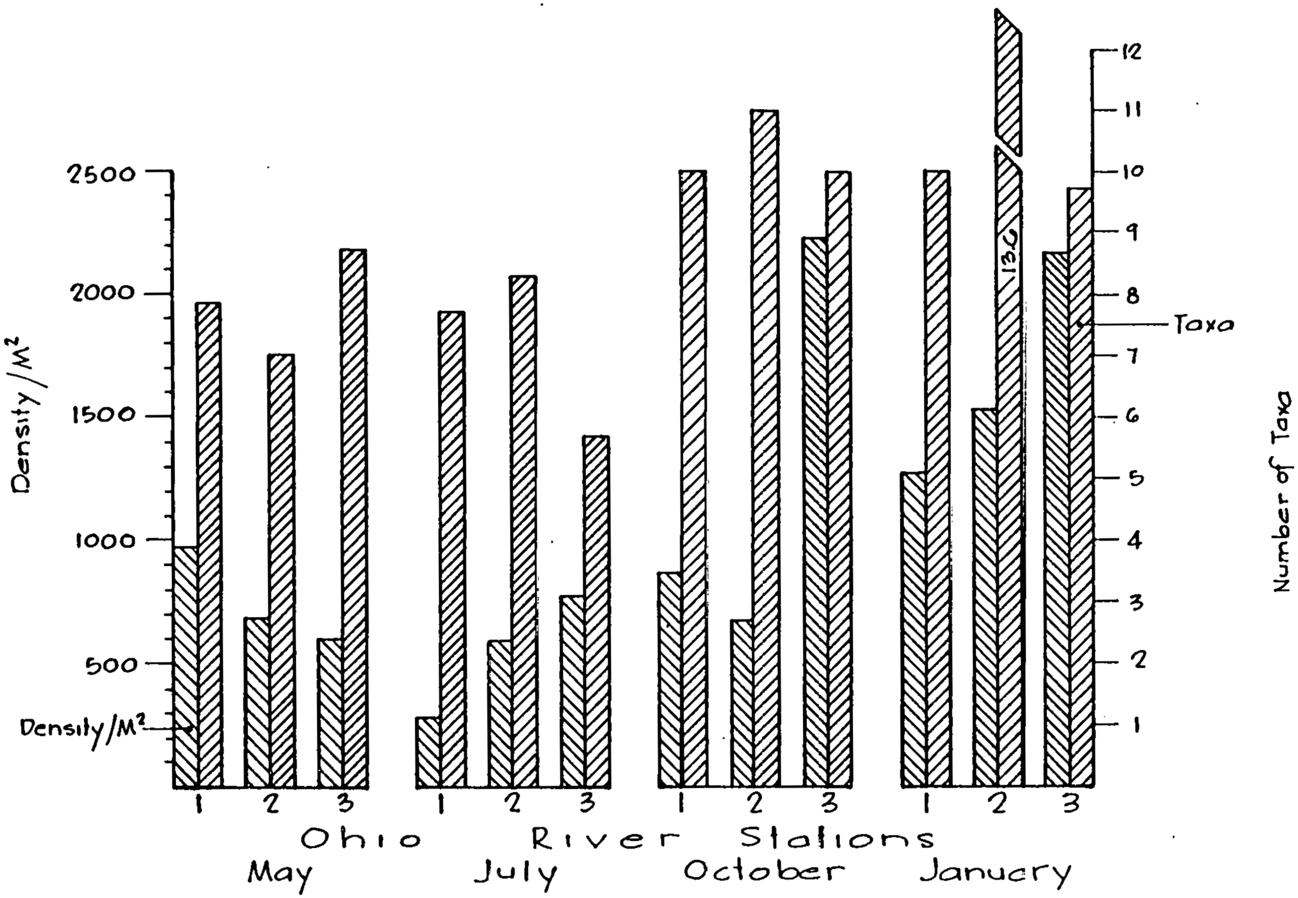

Figure 5.8 Longitudinal comparison of benthic macroinvertebrate density and number of taxa at Ohio River Stations on May 13, July 15, October 8, 1980 and January 13, 1981 (Composite Substation Data).

Community diversity ($\bar{d}$) ranged from 1.25 at Station 3B during July, to 3.01 during May, at Station 3C. During the course of the benthological study community diversity was typically higher along the Indiana side of the Ohio River. This was especially evident during May, July, and October, 1980. During January, 1981 diversity was slightly higher at the mid-channel substations, and in May, although diversity was highest at sub-stations C, mid-channel stations had the second highest diversity. The highest community diversity observed along the Indiana side of the river reflects (ecologically) structually and functionally balanced benthic communities which tended to be established in or on firm gravel and rock substrates. Lower diversity values tended to reflect the generally non-productive mid-channel habitat, and those benthic communities which were established in the soft-fine mud and debris situated along the Kentucky side of the river. The communities established in these sediments were typically dominated by detritivores such as tubificid worms and occasionally very low densities of organisms comprised of other functional feeding groups.

Benthic macroinvertebrates occurring at substation C locations were generally comprised of ecologically balanced portions (number of individual) of herbivores, omnivores, carnivores, and detritivores (Figure 5.9 through 5.11). The detritivore complex usually included segmented tubificids as well as insect components. Herbivores included most of the mayflies, caddisflies, and generally numerous types of midges. Omnivores were most often comprised of insect taxa and occasionally included crustaceans. Carnivores most often occurred at the substations C and were comprised of several taxa including various types of predatory midges and odonates.

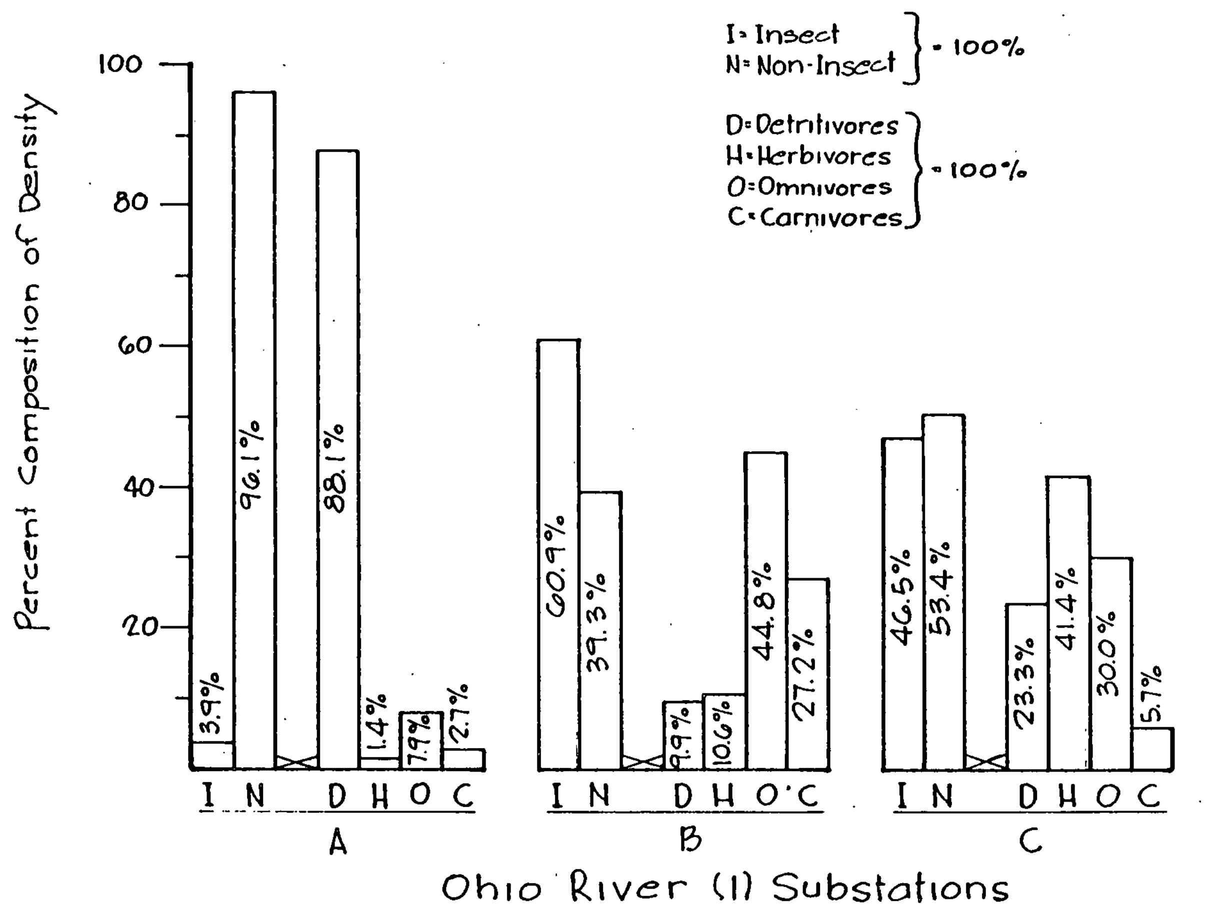

Figure 5.9 Cross section comparison of benthic macroinvertebrate functional feeding groups for Ohio River Station 1 (Composite Survey Data).

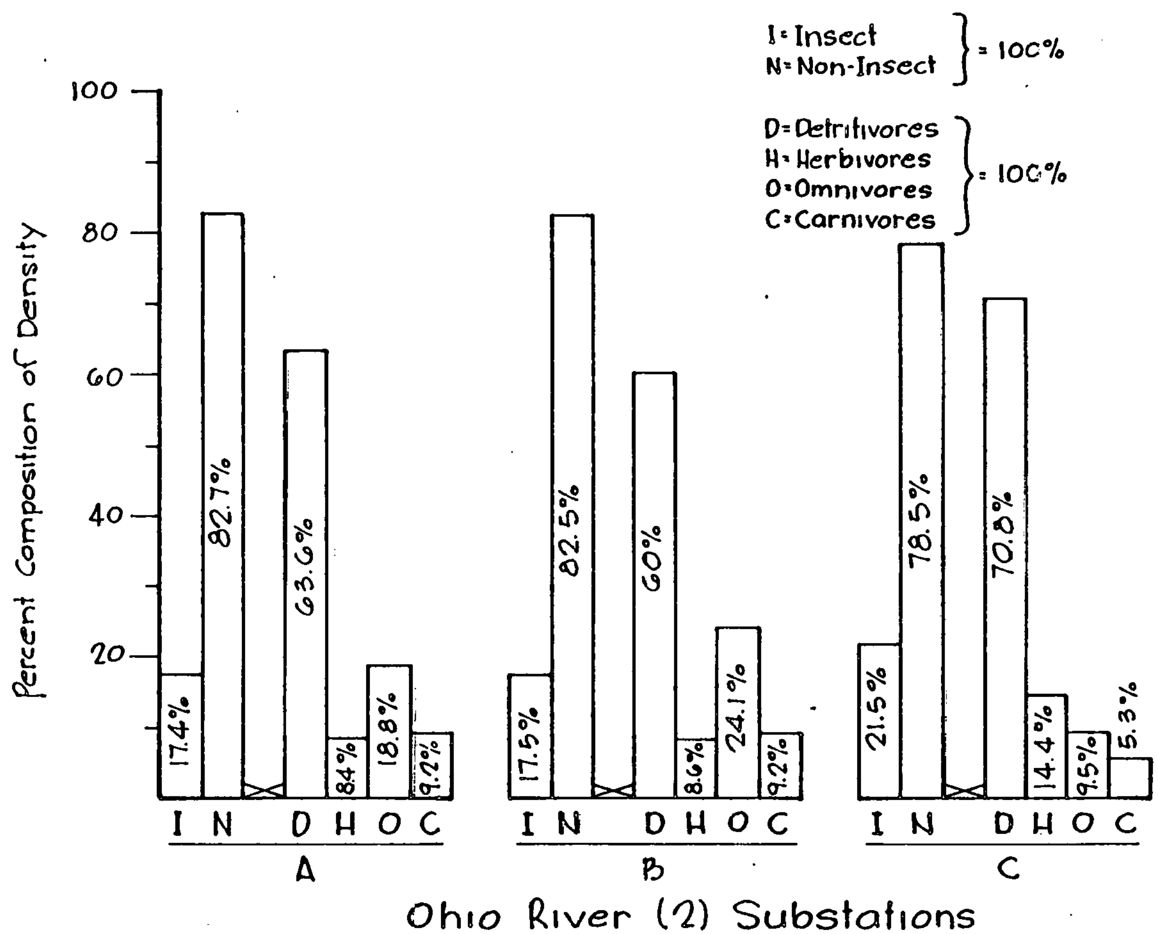

Figure 5.10 Cross section comparison of benthic macroinvertebrate functional feeding groups for Ohio River Station 2 (Composite Survey Data).

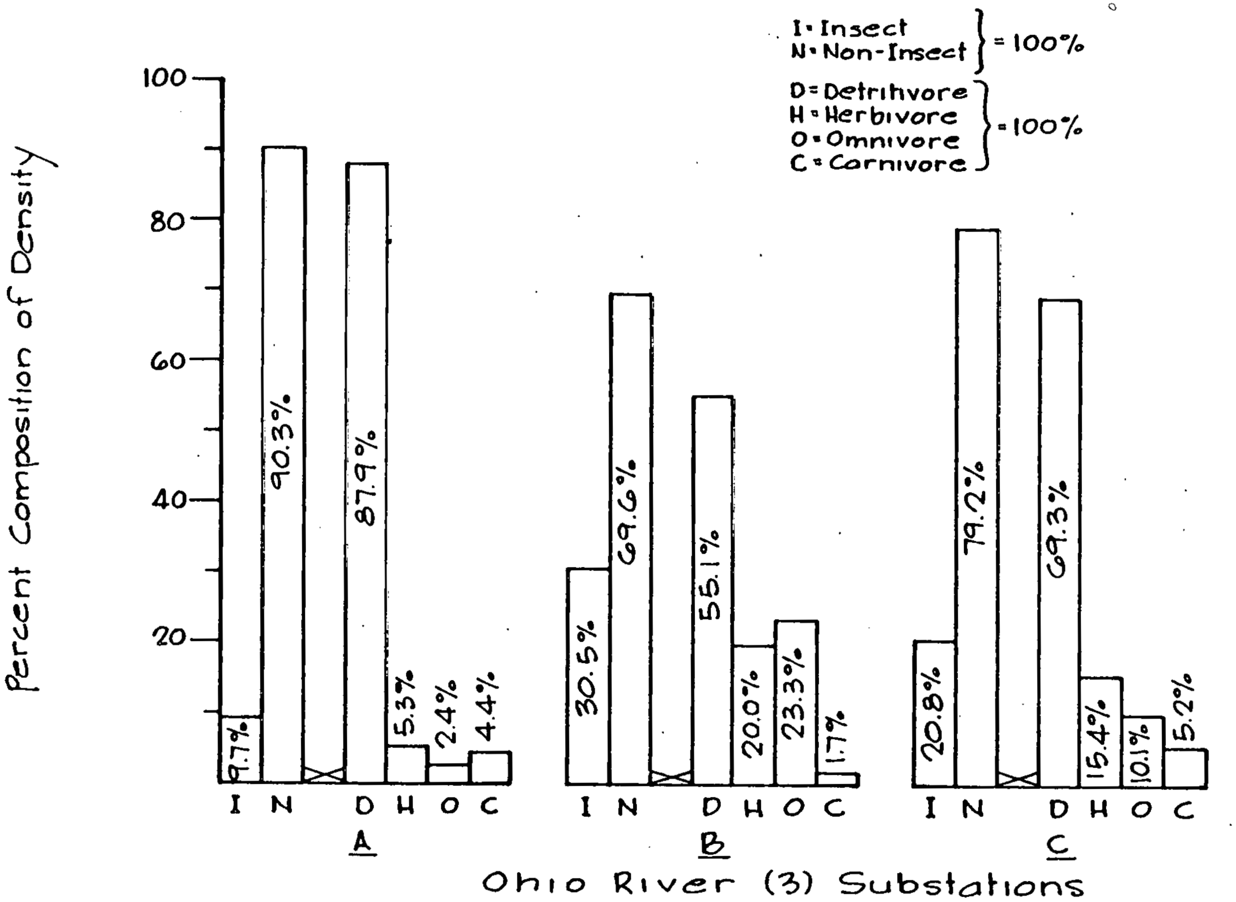

Figure 5.11 Cross section comparison of benthic macroinvertebrate functional feeding groups for Ohio River Station 3 (Composite Survey Data).

Comparison of equitability (e) among the nine Ohio River substations showed a range between 0.39 at Station 3C (January) and 0.91 at Station 3C (May). Equitability showed trends similar to that of benthic macroinvertebrate community diversity in the study area. For example, equitability was typically higher at substation C locations, and lower at the substation A locations. Although the mid-channel macroinvertebrate community was generally sparse, equitability was relatively high compared to Ohio River Station 1, Substation A which usually had very productive communities. The low equatibility for Stations 1A, 2A and 3A also tended to follow that pattern described for diversity. After evaluating these two components of the benthic macroinvertebrate community at the nine Ohio River stations there is little doubt that substrate types played a major role influencing their outcome.

Several of the ecological implications derived from evaluating functional feeding habits of benthic macroinvertebrates collected from the nine Ohio River stations have been discussed earlier. In general, those benthic communities showing patterns of diverse, uniformly proportioned taxonomic structure which comprised of an evenly proportioned number of individual among the basic functional feeding groups concurrently showed high diversity, equitability, and favorable community heterogenity. These more structurally and functionally complex communities occurred most often at stations 1C, 2C and 3C, near the Indiana side of the Ohio River (Figure 5.9 through 5.11). Although superficially benthic macroinvertebrate communities located at mid-channel Stations 1B, 2B and 3B occasionally resembled those at the substations C, mid-channel communities were generally devoid of taxanomically rich fauna, and had lower total macroinvertebrate densities. Substations A benthic communities exhibited the greatest homogenity, or least complexity both in taxonomic structure and ecological function. Those zoobenthic communities were occasionally comprised of up to 96.1 percent oligochaetes, primarily tubificids. Cross sectional patterns of the distribution of benthic organisms based on their functional feeding habits were generally well defined during the Ashland study. Longitudinal patterns for this same component did not show such definitive comparisons.

The longitudinal pattern established from compositing substation data are summarized in Figure 5.12. Station 1 (1A, 1B, 1C collectively) showed a moderately heterogeneous mixture of zoobenthos which consisted of the most uniform distribution of functional feeding macroinvertebrate groups. Station 2 (2A, 3B, 2C collectively) and 3 (3A, 3B, 3C collectively) showed more irregular proportions of benthic organisms distributed among the functional feeding groups. This longitudinal pattern indicated that the downstream station (1) had the most favorable benthic macroinvertebrate communities; higher diversity of functional feeding groups in proportion to number of organisms collected.

The benthic macroinvertebrates collected from nine substations on the Ohio River near the proposed plant site were composed of many typical insect and non-insect taxa. Historical benthological data showed many of the taxa collected from various locations in the lower Ohio River area similar including specific references to the Uniontown and Cannelton Pools. Recent zoobenthic data indicates that these similarities are especially true within the Cannelton Pool, and to a limited extent the Uniontown Pool. (Dames & Moore 1979, 1975, 1977, U.S. EPA (in press), Elbert 1978, Mason et al. 1971). Significant historical findings concerning recent benthic and drift macroinvertebate data from selected lower Ohio River pools are summarized

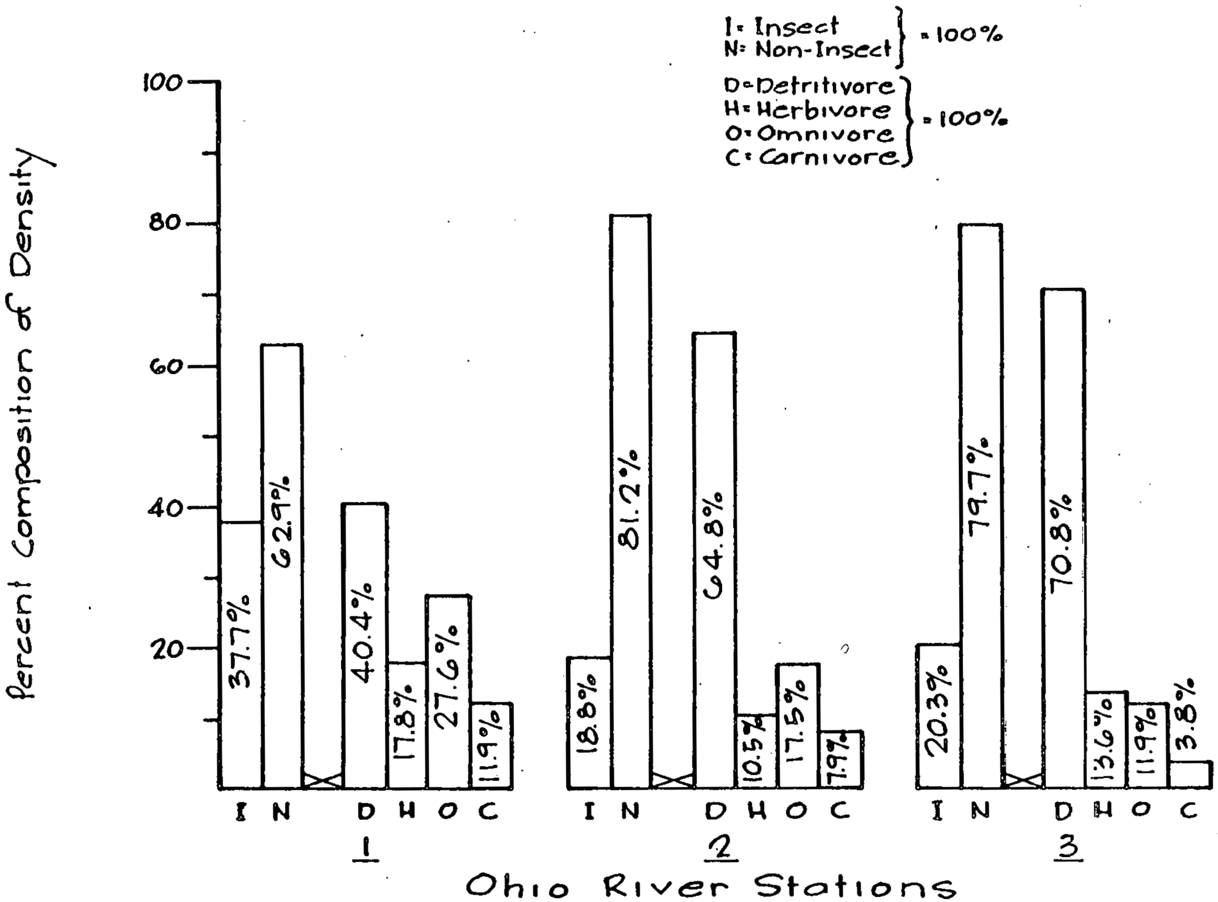

Figure 5.12 Longitudinal comparison of benthic macroinvertebrate functional feeding groups for Ohio River Stations (Composite Survey Data).

in Table 5.14. Most investigators using grab type collecting devices have observed moderately diverse communities comprised of primarily midge (Chironomidae) and tubificid (Tubificidae) taxa. Benthic communities are usually predominated by relatively high numbers or densities of tubificids and generally, to a lesser extent, midges. Additional zoobenthic organisms which are commonly collected from the lower Ohio River include many of the same insects collected at the Ashland site. These include representatives of Ephemeroptera Hexagenia spp., Caenis spp. Baetis spp., and numerous other genera of Plecoptera, Megaloptera and Odonata.

The non-insect organisms collected often included Corbicula, as well as many other taxa, too. These benthic invertebrates include primarily crustacean taxa from the major taxonomic groups, Amphipoda, Isopoda, and occasionally Decopoda.

Water quality evaluation was determined from interpretation of the benthic macroinvertebrate data. This procedure included the evaluation of taxonomic composition and structure in relation to the presence and/or absence of pollution tolerant organisms in the Ohio River. This information indicated moderate to good water quality during the four surveys in 1980-81 (Whipple 1947, U.S. EPA 1970, 1973a, Beck 1977, Lewis 1978, Saether 1975, Mason 1975, Roback 1974). Good water quality was further substantiated by chemical and physical analyses conducted during each field trip, and by results obtained from complete water analyses carried out by Howard Laboratories, Inc. (Section 10.5.17).

5.5.4.2 Town Creek

The benthic macroinvertebrates collected from Town Creek on May 16, July 16, October 9, 1980, and January 9, 1981 are defined in Section 5.5.4.1. In Town Creek benthic macroinvertebrates were collected with a

Table 5.14 Summary of benthic macroinvertebrate data collected from selected lower Ohio River pools.

Author/Client	Date of study	Pool and River mile	Predominant Benthic Macroinvertebrate groups/taxa	Number of taxa	Highest taxa density M^2	Collection method
Dames & Moore Ashland Synthetic Fuels (1981 Baseline)	1980-81	Cannelton RM 705-708.2 (Cross section of river)	Tubificidae	6		Ponar
			Limnodrilus hoffmeisteri		912	
			Immature tubificids		3808	
			Chironomidae	21		
			Stenochironomus sp.		427	
			Corbiculidae	1		
			Corbicula manilensis		383	
			Range in total benthic macroinvertabrate taxa (3-18) and density (31.9 - 4832.0/M^2) collected during study.			
Dames & Moore Southern Indiana Gas and Electric Co. (1979)	1978	Uniontown RM 814 - 815 (Indiana side)	Tubificidae	6		Ponar
			Limnodrilus spp.		4778	
			Chironomidae	16		
			Xenochironomus sp.		1021	
			Range in total benthic taxa (4-18) and density (194-4916 (M^2) collected during study.			
Dames & Moore Texas Gas Transmission Corporation (1975)	1974-75	Uniontown RM 842 (Kentucky side)	Tubificidae	2		Ponar
			Limnodrilus sp.		7032	
			Gammaridae	1		
			Synurella sp.		13	
			No range reported for taxa or density.			

Table 5.14 Continued.

Author/Client	Date of study	Pool and River mile	Predominant Benthic Macroinvertebrate groups/taxa	Number of taxa	Highest taxa density M^2	Collection method
Elbert (1978)	1975-76	Cannelton RM 720.7 (At the Cannelton Lock and Dam)	Oligochaeta	(not determined)	1796/2 baskets	Basket artificial substrate
			Gammaridae			
			Gammarus fasciatus		765/2 baskets	Petersen
			Chironomidae			
			Polypedilum illinoense		630/2 baskets	
			Dicrotendipes neomodestus		765/2 baskets	
			Range in total benthic macroinvertebrate taxa (4-23) and density (5-3592/2 baskets) during study.			
Kentucky Utilities Texas Instruments, Inc. (EIS Pending)	1979-80	Cannelton RM 705-722	Tubificidae	(not determined)	1801	Grab
			Undetermined spp.			
			Chironomidae	11		
			Polypedilum spp.		198	
			Range in total benthic macroinvertebrate taxa (3-11) and density (estimate 10-780) during study.			
Mason, Lewis and Anderson (1971)	1963-67	McAlpine RM [illegible]0.5 (Cr[illegible]s section)	Oligochaeta	(not determined)	3649	Petersen Ekman
			Chironomidae	14		
			Procladius sp.		226	
			Corbiculidae	1		
			Corbicula sp.		474	
			Range in total benthic macroinvertebrate taxa (7-24) and density (226-3951/M^2) collected during study.			
		Uni[illegible]wn RM [illegible].7 (Indi[illegible] and Kentucky sides)	Oligochaeta	(not determined)	1507	Petersen Ekman
			Chironomidae	15		
			Polypedilum halterale		474	
			Corbiculidae	1		
			Corbicula sp.		388	
			Range in total benthic macroinvertebrate taxa (6-17) and density (75-2250/M^2) collected during study.			

Surber sampler; those methods and procedures used to process these samples are described in Section 5.5.4.1. A discussion of the importance of zoobenthos and the methods for evaluating and interpreting these data is also in Section 5.5.4.1.

The findings of the quarterly benthological sampling program in Town Creek showed diverse macroinvertebrate communities. These communities consisted of non-insect and insect taxa which ranged from 22 in July to 43 in October, 1980. In all instances, insect taxa made up at least 91 percent of total zoobenthic densities (91.5% - 99.1%). Taxonomic composition of benthic insects during the Ashland study ranged from 17-33 and represented most of the major insect orders. These included Ephemeroptera, Plecoptera, Odonata, Megaloptera, Trichoptera, Coleoptera, Hemiptera, and Diptera. Those orders having the most diverse taxonomic fauna were Diptera (7-23 taxa/survey) and Ephemeroptera (3 - 5 taxa/survey). Diptera benthic fauna included such predominant taxa as, _Stictochironomus_ sp., _Paratendipes albimannus_, _Chironomus_ spp., _Dicrotendipes_ sp., _Polypedilum_ spp., _Cricotopus_ spp., and _Microtendipes aberrans_ (Chironomidae). The highest taxon density was $1758.3/M^2$ for _Stictochironomus_ sp. during the May survey. Additional insect taxa which were generally abundant in Town Creek consisted of the caddisflies, _Chematopsyche_ spp., which attained densities of $1119.5/M^2$, and _Hydropsyche_ spp. which showed a maximum density of $132.8/M^2$. Numerous other insect taxa were collected from Town Creek which ranged between 80 and 120 organisms per M^2. These included both immature and adult Elmidae (Coleoptera) consisting primarily of Stenelemis sp., the mayflies Caenis sp. and Leptophelbia sp. and other midges (Chironomidae).

Important non-insect organisms collected from Town Creek during the 1980-81 surveys consisted primarily of Crustaceans and Mollusks, and occasionally Oligochaets. The types of Crustaceans present at the site included the isopod Lirceus sp., the amphipod Hyalella sp., and Orconectes sp., (Decapoda) a crayfish. The highest density attained, $39.6/M^2$, was Lirceus sp. during the January, 1981 survey.

Four species of Mollusca were collected from Town Creek, one species of fingernail clam, Pisidium sp. (Sphaeriidae) a bivalve, and three species of Gastropoda (snails). The aquatic snails included Ferrissia sp., Helisomia sp., and Physa sp. The maximum density obtained by Mollusca was $35.9/M^2$ (Ferrissi sp.) during the October survey. Oligochaeta collected from Town Creek were most often immature tubificids, Limndrilus sp. and two taxa of Naididae, Dero sp. and Nais sp. Overall, the number of non-insect taxa collected from Town Creek ranged from 4 in May and July to 10 in October, 1980.

Total zoobenthic densities ranged from $1209.6/M^2$ in July to $2889.0/M^2$ in October, 1980. The quarterly survey trends in number of taxa and densities are summarized in Figure 5.13. Percent composition of total densities and numbers of taxa (annual composite) fluctuated in opposing "peaks and valleys"; during May and October the highest values were noted, while the lowest values were noted during July and January. Highest benthic macroinvertebrate densities were expected to occur during April since this is generally the temporal period for aquatic insects to overwinter. This has not been observed in Town Creek although the taxonomic

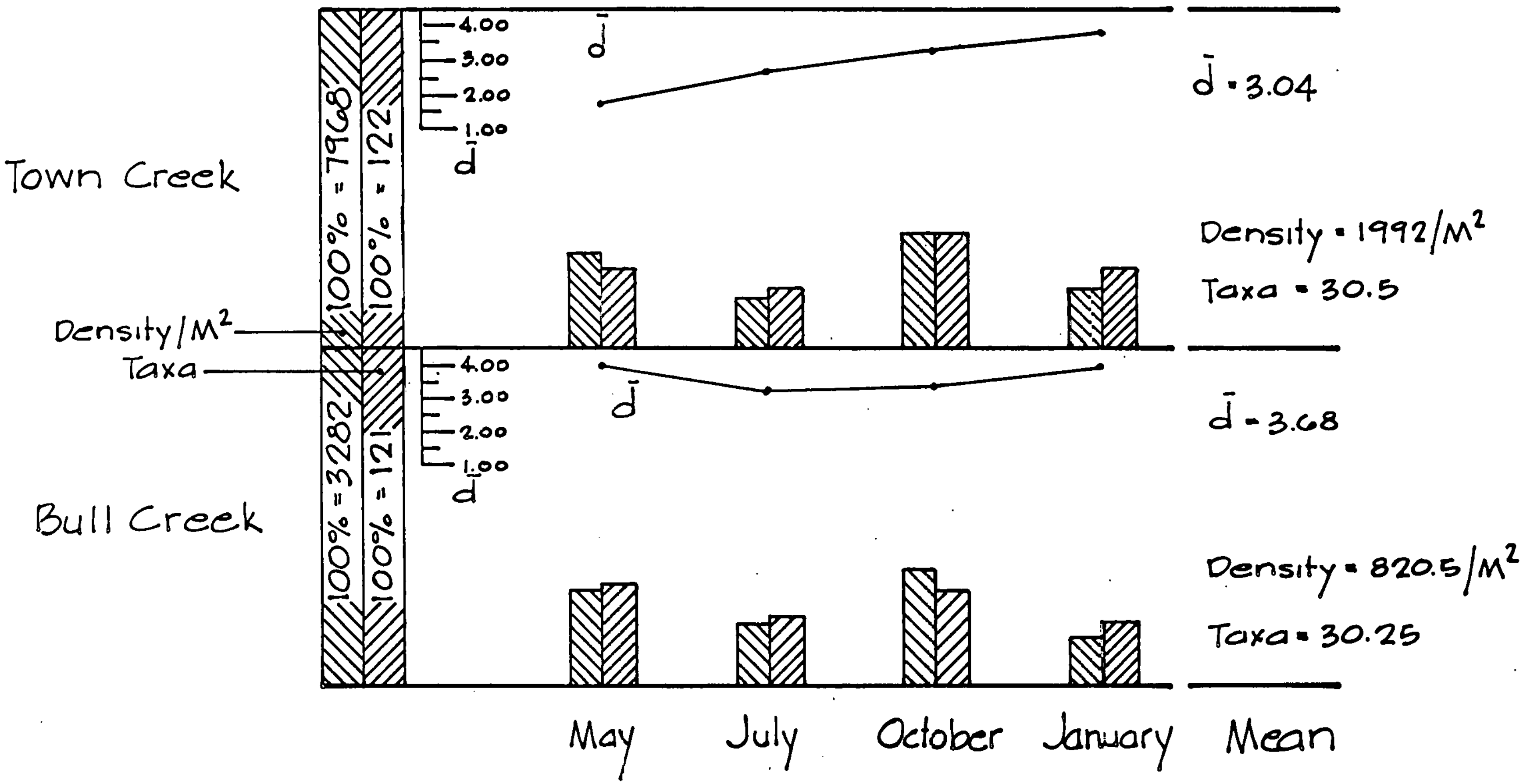

Figure 5.13 Comparison of benthic macroinvertebrate density, number of taxa and community diversity in Town Creek and Bull Creek during May, July, October and January.

make up of insects is high. At the present time no rational for explaining this phenomena is evident.

The zoobenthic community diversity trend did not fluctuate in a similar fashion during the quarterly surveys as indicated by density and taxonomic compositon. Community diversity increased during each successive survey during 1980-81, initially from 1.96 ($\bar{d}$), then gradually increasing to the maximum (3.92) during January. Equitability (e) followed the same trend as community diversity, and both statistics indicated a generally taxonomic rich, evenly structured macroinvertebrate community at the Town Creek station. (The higher diversity and equitability values during the last three surveys may be attributed, in part, to relocation of the Town Creek station to improve habitat). Although community diversity and equitability showed distincly taxonomically rich and diverse fauna in Town Creek; the pattern exhibited by invertebrate functional feeding groups generally did not.

The benthic macroinvertebrate community in Town Creek retained predominantly herbivorous habits throughout the survey. Percent composition of total zoobenthic densities (Figure 5.14) expressed for herbivores ranged from 78.4 percent during October to 94.1 percent during the May survey. The next highest densities for functional feeding groups of benthic organisms was 9.6 percent for omnivores (October), 9.5 percent and 6.5 percent for detritivores during January. The predominance of herbivorous zoobenthos in Town Creek probably results from the abundance of periphytic food items available. Numerous types of insect and non-insect collectors, gatherers and filters, scrapers, grazers and miners were collected from this site. Presence of generally low densities of benthic macroinverte-

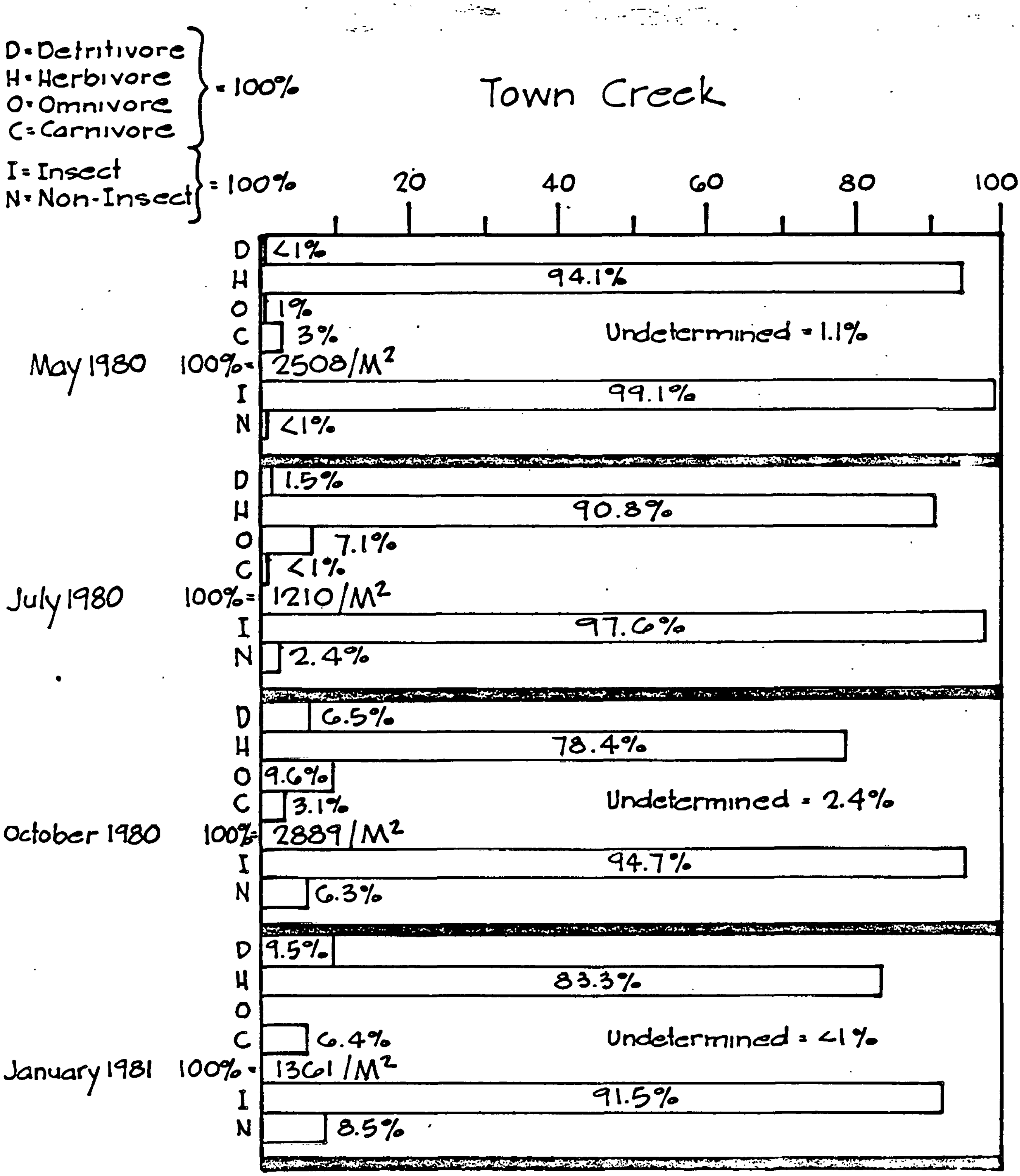

Figure 5.14 Comparison of benthic macroinvertebrate functional feeding groups in Town Creek during May, July, October and January.

brates utilizing other functional feeding habits is not typical. Picazzo and DeMoss (1980) conducted benthic fauna inventories of relatively small creek locations in Eastern Kentucky. Although their work excluded Diptera, many of the aquatic insect fauna they collected were similar to those found in Town Creek. Both sets of data indicate that typical ecological relationships exist, this is especially evident in comparisons of trophic patterns.

5.5.4.3 Bull Creek

Results of the quarterly sampling program in Bull Creek showed generally similar benthological characteristics as that sampling program for Town Creek. The purpose herein, will be to point-out the major, and most significant similarities and differences.

Benthic communities in Bull Creek did not show the high densities which were observed in Town Creek (Figure 5.13). The mean-annual benthic densities in Bull Creek were 820.5/M^2 compared to 1992.0/M^2 in Town Creek. The number of taxa reported from both areas was similar, approximately 30 for an average from all surveys although community diversity ($\bar{d}$) was consistently higher in Bull Creek (range 4.16 during May to 3.13 during July). All diversity values in Bull Creek, considering other ecological variables too, indicate a very rich and diverse benthic macroinvertebrate community. The pattern of fluctuations in densities during the course of the study was similar at both stations.

The predominant zoobenthic taxa collected from Bull Creek were very similar to those collected from Town Creek. Most of the predominant insect and non-insect taxa which occured at Town Creek also occured in Bull Creek. A few addition taxa of importance at the Bull Creek station would include;

Cladotanytarsus spp., *Thienemannemyia* group (Chironomidae), and biting midges (Ceratopogonidae). The fingernail clam, *Pisidium* sp., and in general, tubificids, were more abundant in Bull Creek. The gastropod, *Physa* sp. was not collected from Bull Creek, but the remaining taxa reported from Town Creek were.

Bull Creek consisted predominantly of benthic macroinvertebrates which were classified as herbivores (Figure 5.15). Herbivores typically made up lower densities than in Town Creek; herbivores ranged from 27.3 percent composition of densities to 85.1 percent. Omnivores, carnivors and detritivores consistently represented larger proportions of the zoobenthic densities in Bull Creek and were generally comprised of more non-insect taxa than Town Creek. This is perhaps an indication of why diversity was also consistently higher at the Bull Creek Station than at Town Creek. Overall, the benthic macroinvertebrate community at Bull Creek showed lower secondary production, but consistently had a richer and more equitable benthic community displaying complex functional (trophic) ecological relationships.

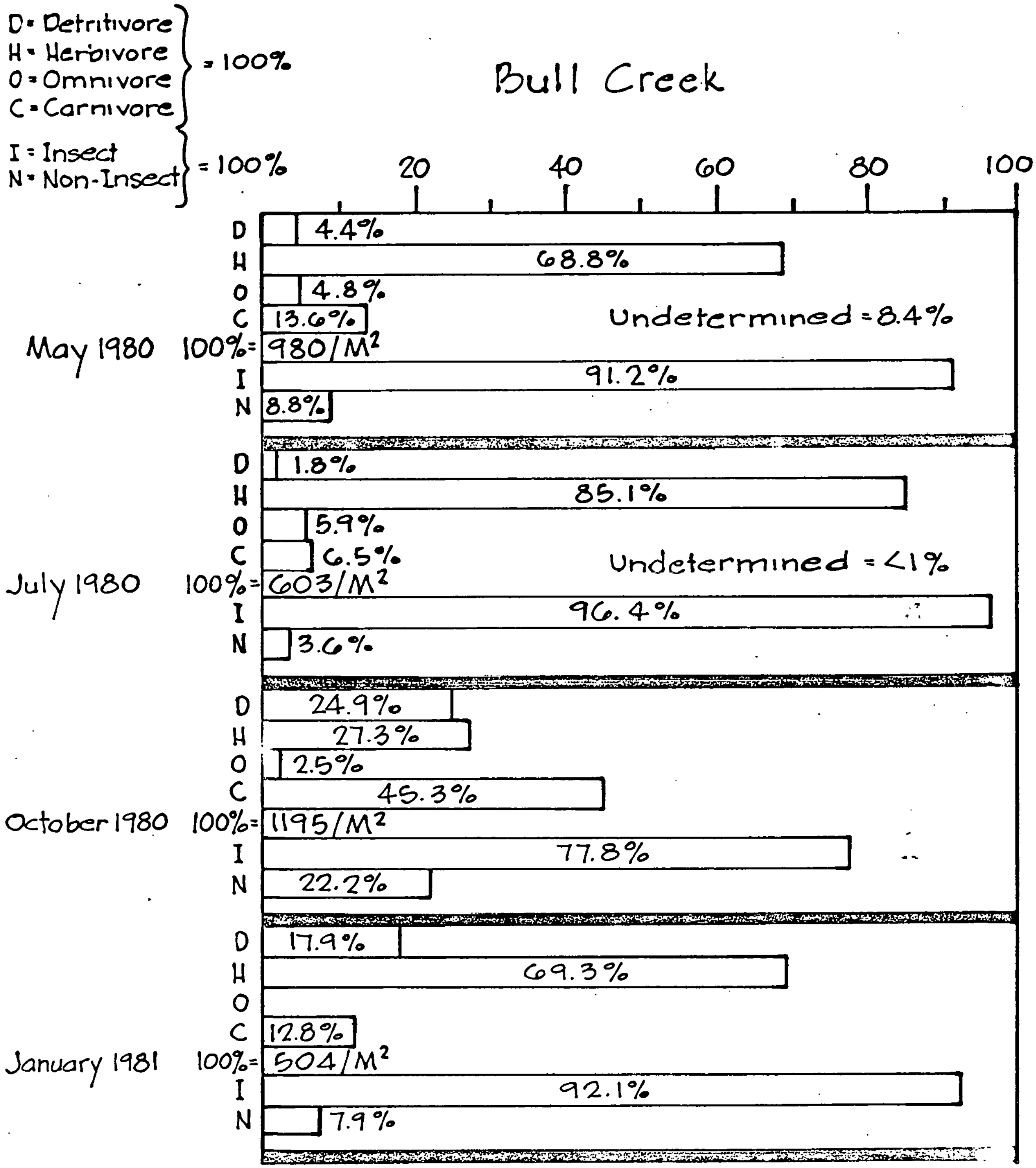

Figure 5.1 5 Comparison of benthic macroinvertebrate functional feeding groups in Bull Creek during May, July, October and January.

5.5.5 Mussels

Freshwater mussels, or naiades (Mollusca: Bivalvia: Unionidae), are bivalved invertebrates most of which rely on larval parasitism of host fish to complete their life cycle. The period of parasitic infestation of the glochidia (mussel larvae) on the gills of fish, specific species of fish utilized and the time of year infestation occurs is dependent on the mussel species (Pennak 1979, Fuller 1974). Naiad mussels occupy a wide range of aquatic habitats in the Ohio River, many of its tributaries, flood plain ponds, and backwater embayments (Dames & Moore 1979, 1980, Williams 1969, Taylor 1980). They are an important component of freshwater ecosystems because they filter minute particles and plantonic organisms from the water. Through this feeding process, and because they are basically sedentary, mussels may bioaccumulate contaminants such as heavy metals, pesticides and other trace elements in their tissue and, thus, are useful indicators of many types of contamination (Fuller 1974, 1978, Foster & Bates 1978). Mussels also provide aesthetic enrichment to the benthic community, they are utilized as a food source for fish, and occasionally other types of wildlife and waterfowl (Murray & Leonard 1962). The commercial value of mussels is presently restricted to generally regulated harvesting for the cultured pearl industry (Krumholz, et. al. 1970, Fuller 1978, Taylor 1980, Correspondence with State of Kentucky 1980). Mussel shells are cleaned and cut into small dice like cubes which make excellent seed material for the culturing of pearls within the adult clam. Ohio River bivalves collected for this purpose are usually the thick shelled varieties and include the ebony shell, Fusconaia ebena, and the pigtoe, Pleurobema cordatum. These mussels have been known to be harvested as recently as 1977 and 1978 from the Ohio River (Correspondence with State of Kentucky, 1980).

The importance of determining species composition, relative abundance and distribution of mussel fauna is further prompted by encouragement from numerous federal agencies to complete such investigations for government funded projects (Sanders,et al 1979). This policy provides protection of habitat and/or endangered and threatened species under the Endangered Species Act of 1973 (P.L. 93-205) when there is a direct and immediate threat against them. The importance of such investigations is enhanced by the occasional rediscovery, or a new find of presumed extinct or rare organisms (Isom, Gooch and Dennis 1979).

5.5.5.1 <u>Ohio River</u>

The general distribution and number of mussels collected from the Ohio River suggested only a locally sparse and non-diverse fauna. During the coarse of three brailing efforts designed to obtain presence/absence data, eighteen mussels comprising six species were collected (Table 5.15). Fifteen individuals were taken from a relatively firm mud substrate, grading downstream into a coarse-rock substrate, between the confluence of Bull Creek and Ohio River Station 3 which was located at the Ohio River mile (ORM) marker 708.2 (Figure 5.1). The remaining three naiad mussels were collected from the upstream control station at ORM 704.3 on the Indiana side of the river. Those species of mussels which were captured from the control station were also captured near Ohio River Station 3. Both areas had similar substrate type which were directly influenced by upstream tributary outlets.

Table 5.15 Freshwater mussels (bivalvia) collected by brail in the Ohio River during 1980 and 1981, in the vicinity of the proposed Ashland Synthetic Fuels site.

Species	Common Name	Ohio River Station 3	Control Station	Date	Total Number Collected
Bivalvia					
Unionidae					
Ambleminae					
Amblema plicata	Threeridge	6		7/80	6
Quadrula nodulata	Wartyback	1		10/80	1
Unioninae					
Plethobasus cyphyus	Bullhead	1		10/80	1
Liqumia recta	Black Sandshell	1		10/80	1
Proptera alata[a]	Pink Heelsplitter	1	1	10/80	2
Obliquaria reflexa[a]	Threehorn	5	2	7/80 10/80 1/81	7
TOTAL		15	3		18

[a] Used for tissue analysis.

Bivalves collected from the Ohio River consisted of six species, two Ambleminae and four Unioniae. Ambleminae included Amblema plicata, the threeridge, and Quadrula nodulata, the wartyback. The Unioniae included Plethobasus cyphyus, the bullhead, Ligumia recta, the black sandshell, Proptera alata, the pink heelsplitter and the threehorn, Obliquaria reflexa. Both the pink heelsplitter and threehorn were collected from the control station and along with similar species from Station 3, were subsequently used for tissue analyses. Both individuals of Proptera alata were parasitized by water-mites (Arachnoidae). Amblema plicata and Obliquaria reflexa were the most abundant mussels collected near Ohio River Station 3, making up 40 percent and 33 percent respectively. The remaining four species of mussels each made up approximately 7 percent of those collected. The mussel fauna collected from the relatively small-localized firm mud bottom between Bull Creek outlet and Ohio River Station 3 suggested strong ecological affinities.

Most of the mussels retrieved by brail where solitary, individuals exemplifying a scattered and sparse distribution pattern. The thin detritus covered mud substrate from which the bivalves were pulled was generally firm. Toward the downstream end of the localized mud deposit the substrate changed to predominantly coarse rock. Four small Obliquaria reflexa were collected from the mud-coarse rock interface; the additional eleven mussels were collected from the mud deposition. These results indicated that the firm mud substrate was more favorable or suitable as mussel habitat than other locations that were composed of substrate with different characteristics. For example, brailing over shifting-unstable sand and through relatively thick deposits of fine debris did not result in mussel captures.

Similar circumstances have been noted during previous Dames & Moore (1978, 1980) mussel investigations as well as by other mussel investigators (Fuller 1979, Taylor 1980, Starrett 1971 and Williams 1969). It should be noted too, that those mussels collected from the Ohio River control station were also located in a firm mud substrate down river from confluence of a small creek.

The ecological affinity between kinds of mussels and the more favorable localized mud substrate in the study area may be recognized too. As noted by Fuller (1979, 1980), Williams (1969), and during previous Dames & Moore studies (1979, 1980), certain species of bivalves appeared to adapt more successfully to firm mud substrates. The six species of mussels collected from the Ashland site do favor mud substrate habitat. Furthermore, the two predominant species, Amblema plicata and Obliquaria reflexa seem to adapt especially well to this type of environment (Fuller 1978, 1980). Collectively, all mussels obtained by brail from the study area have shown at least some favorable ecological affinity towards that habitat typically encountered near Ohio River Station 3. In addition to the substrate type which has been discussed above, this would include tolerance to potentially unfavorable water quality, favorable fish-host relationships, and relatively good adaptation to unfavorable effects of stream regulation (Fuller 1978, Taylor 1980, Williams 1969).

The fish-host relationship is very important since propagation of the species, improved population numbers, and distribution depends on its success. Amblema plicata has possibly benefited more than the other species of mussels collected in the Ohio River because it has nine "known or implicated host fish" (Fuller 1974) which occur in the vicinity of the proposed plant site. These include such predominant fish as white and black crappie, bluegill, the highfin carpsucker, channel, and flathead catfish and less frequent largemouth bass, sauger, white bass and the Shortnose Gar.

Obliquaria reflexa has no known fish-host but is likely facultative in its fish-host relationship (Murray & Leonard 1962). This may certainly enhance the possibilities for the Threehorn to gain wide distribution in areas of the Ohio River which offer suitable habitat. Those mussels which appear less abundant also have favorable fish-host relationships with numerous fishes which occur in this area. Although many mussel fish-host species occur in the vicinity of Ohio River Station 3, it is not presently known if the abundance of fishes are sufficient to sustain optimuim glochidial parasitism.

Historic information pertaining to the occurrance of mussel beds in the Ohio River in the general vicinity of the proposed Ashland site indicated that two beds existed. One bed was located upriver near the control station ORM 704.3, and the other bed was located approximately 305 meters (1000 feet) below ORM 708.2 (Williams 1969). Williams determined this mussel bed to be approximately 322 meters (1056 feet) long and assessed the mussel population as being quite diverse. Aquatic biological surveys by Texas Instruments, Inc., (U.S. EPA, in press) during 1979 and 1980 showed only occasional occurrences of unidentified bivalves near the Ashland site (Ohio River Mile 705 and 707). In overview based on the information obtained from the mussel surveys by brail, and from historic data, no sizeable or significant freshwater mussel population was apparent in the immediate vicinity of the proposed Ashland site on the Ohio River.

5.5.5.2 Town Creek

Live freshwater mussels were not collected from the main stem of Town Creek, its embayment area, or from the channel confluent with the Ohio River. One relic mussel, a species of Anodontinae (pond mussel) was collected from the upper embayment area. Although no live mussels were collected from the embayment portion of Town Creek, it is likely that live specimens do inhabit this area. Both physical and chemical characteristics, as well as respective fish-host are favorable for Anodontinae mussels in Town Creek. Anodonta imbecillis and Anodonta grandis have been collected from generally similar habitat at Floyd's Fork Creek in the Bullitt County area recently by Taylor (1980). Floyd's Fork Creek is a tributary to Salt Creek which drains into the Ohio River, Cannelton Pool, via Rolling Fork Creek near West Point, Kentucky.

5.5.5.3 Bull Creek

No freshwater mussels, living or dead, were collected from Bull Creek during the 1980 surveys. However, the aquatic environment, including physical, chemical and biological, in Bull Creek embayment is also conducive to inhabitation of Anodontinae and is likely to contain the two species cited in Section 5.5.5.2.

5.5.6 Fishes

5.5.6.1 Ohio River

A total of 17 species of adult fish were collected at three Cannelton Pool stations (Figure 5.1) during May, July and October of 1980 and January of 1981 (Table 5.16). White crappie were predominant, with bluegill and gizzard shad being second and third in abundance, respectively. Species diversity (Margelef, 1951) was moderate during all samplings (with the exception of the January effort during which a single fish was collected). Species diversity of 2.33, at Station 2 during July, was the highest for the study. Diversity at Station 3 in May was slightly lower at 2.27. Over the year, species diversity was lower at Station 1 than at Stations 2 and 3, which were similar. Total species diversity was highest during the Spring, 1980 sampling. Increasing day lengths and water temperatures seem to initiate greater feeding activity and also spawning behavior in a variety of fishes. Both of these phenomena result in increased movement (Hynes, 1970) and, perhaps, vulnerability to capture.

The total number of fish collected was highest in October. This is due at least partly to the increase from one to two in the number of hoopnets fished at each station. It should also be noted that occasionally during the spring and summer samplings, hoopnets appeared to have been opened and, perhaps, fish removed.

Electrofishing catch per unit effort (C/f) increased in October to compare favorably with those of the May sampling; although electrofishing success varied among stations for the two seasons (Table 5.16).

The January, 1981 sampling was conducted during relatively mild winter conditions with daytime air temperatures at just above 32° F (0° C). How-

Table 5.16 Summary of fish collections.[a] Ohio River Stations 1, 2, and 3.

Species by Family	May, 1980 Station 1	2	3	July, 1980 Station 1	2	3	October, 1980[c] Station 1	2(N)[b]	3	January, 1981[c] Station 1	2	3	Total Fish per Station 1	2	3	Total Fish 1980-1981	Mean Length[f] mm	Mean Weight[f] g
Clupeidae																		
Gizzard shad (Dorosoma cepedianum)	3	--	2	--	6	--	5	7	6	--	--	--	8	13	8	29	193.7	83.7
Cyprinidae																		
Carp (Cyprinus carpio)	1	--	2	1	--	--	--	1	1	--	--	--	2	1	3	6	557.7	2439.3
Bullhead minnow (Pimephales vigilax)	--	--	--	--	1	--	--	--	--	--	--	--	0	1	0	1	83.0	8.0
Catostomidae																		
Quillback (Carpoides cyprinus)	--	--	--	--	--	--	--	1	1	--	--	--	0	1	1	2	349.5	575.0
Smallmouth buffalo (Ictiobus bubalus)	--	--	--	--	1	--	--	--	--	--	--	--	0	1	0	1	349.0	640.0
Ictaluridae																		
Channel catfish (Ictalurus punctatus)	--	--	1	--	1	--	2	--(1)	3	--	--	--	2	2	4	8	371.4	430.9
Flathead catfish (Pylodictis olivaris)	4	3	2	6	1	1	--	--	--	--	--	--	10	4	3	17	355.8	500.1
Centrarchidae																		
Bluegill (Lepomis macrochirus)	12	3	4	--	3	11	7	24	2	--	--	--	19	30	17	66	162.1	82.7
Longear sunfish (Lepomis megalotis)	--	2	--	--	--	--	--	1	--	--	--	--	0	3	0	3	134.7	68.0
Largemouth bass (Micropterus salmoides)	--	--	1	--	--	--	--	--	--	--	--	--	0	0	1	1	264.0	210.0
White crappie (Pomoxis annularis	13	11	2	1	16	21	5	26	14	--	--	--	19	53	37	109	188.4	84.5
Black crappie (Pomoxis nigromaculatus)	1	3	--	--	1	1	--	--	6	--	--	--	1	4	7	12	225.3	165.2
Percidae																		
Sauger (Stizostedion canadense)	3	--	--	--	--	2	--	--	--	--	--	--	3	0	2	5	291.0	218.0
Sciaenidae																		
Freshwater drum (Aplodinotus grunniens)	--	--	--	2	1	--	--	4(1)	--	--	--	1	2	6	1	9	223.2	137.0
Total number of fish per station (N)	37	22	14	10	31	36	19	64(2)	32	0	0	1	56	119	84	269		
Total number of species per station (s)	7	5	7	4	9	5	4	8	7	0	0	1	9	12	11	14		
Species diversity (d)[e]	1.66	1.29	2.27	1.30	2.33	1.12	1.02	1.66	1.73	0	0	0	1.91	2.30	2.26	2.32		
Catch per unit effort (electroshocking)	0.42	0.16	0.46	0.08	0.18	0.00[t]	0.18	0.42	0.48	0	0	0	--	--	--	--		
Catch per unit effort (gillnetting)	--	--	--	--	--	--	--	0.59	0.02	--	--	--	--	--	--	--		

a. Electrofishing, hoopnetting and gillnetting. Effort for electrofishing is expressed in minutes; gillnetting in hours. Gillnetting conducted during the October, 1980 sampling only. Only Stations 2 and 3 were gillnetted.
b. Fish collected during a selective, night-electrofishing session of Station 2, October 10, 1980. All fish collected are included in listing. None are included in catch per unit effort figures.
c. Two hoopnets were fished at each river station during the fall sampling trip.
d. Two hoopnets were fished at each of Stations 2 and 3. One at Station 1.
e. According to Margelef (1951).
f. To convert from: mm to inches, multiply to 0.039
g to pounds, multiply by 0.002

Source: Dames & Moore field data, 1980 - 1981.

ever, water temperatures remained near 0° C, and this, in conjunction with fairly low water levels, seemed to adversely affect fish activity at all three Ohio River stations. As fish are temperature sensitive organisms capable of seeking-out preferred temperatures (Lagler, et al., 1962), the deeper waters of mid-channel may well provide a more suitable and stable environment during the winter months. Hynes (1970) discusses a variety of fishes which move into deeper water for the winter. Due to the lack of data for January, this sampling is not included in further discussions of the Ohio River.

In the summer of 1979 and spring of 1980, RM 704 and 707 were sampled for fish (U.S. EPA, Region IV [in press]). Species diversity was low to moderate during 1979, although a greater variety of species were collected during the 1979 portion of the U.S. EPA Region IV (in press) study than during the current Ashland Synthetic Fuels, Inc. (ASFI) study. However, the 1980 portion of the previous study resulted in a significant decrease in both numbers of fish and variety of species collected (Table 5.17). Differences in the variety of species collected during the two studies may be partially due to the use of gillnets and beach seining, as opposed to the hoopnetting conducted in the ASFI study. Electrofishing units were similar in design, however, and were fished in the same manner at each location--between the bank and the drop-off (Personal communication. February 5, 1981. Telephone conversation with James Boswell, Aquatic Section, Texas Instruments, Inc.). Another factor may be seasonal differences between the U.S. EPA Region IV (in press) 1979 study (conducted June through August) and the 1980 study (conducted April through early June) although one would expect greater numbers and species are normally collected

Table 5.17. Comparison of Ohio River species collected[a] during 1979, 1980, and 1981.

Common Name	U.S. EPA Region IV (in press) 1979 RM 705,707	U.S. Region IV (in press) 1980 RM 705,707	Jackson 1980 Cannelton Pool	ASFI 1980-81 RM 705,707, 708
Longnose gar	X	X	X	-
Skipjack herring	X	-	X	-
Gizzard shad	X	X	X	X
Goldeye	X	-	X	-
Mooneye	X	-	-	-
Carp	X	-	X	X
Silver chub	X	-	X	-
Emerald shiner	X	X	-	-
River shiner	X	-	-	-
Mimic shiner	X	-	-	-
Bullhead minnow	-	X	-	X
Unidentified minnows	X	-	-	-
River carpsucker	X	-	X	-
Quillback	-	-	-	X
Smallmouth buffalo	-	-	-	X
Golden redhorse	-	X	-	-
Unidentified suckers	X	-	-	-
Channel catfish	X	-	X	X
Flathead catfish	X	-	X	X
White bass	X	-	-	-
Bluegill	X	-	-	X
Longear sunfish	-	-	X	X
Largemouth bass	X	-	X	X

Table 5.17 Continued

Common Name	U.S. EPA Region IV (in press) 1979 RM 705,707	U.S. Region IV (in press) 1980 RM 705,707	Jackson 1980 Cannelton Pool	ASFI 1980-81 RM 705,707, 708
White crappie	X	-	X	X
Black crappie	-	-	-	X
Logperch	X	-	-	-
Sauger	X	X	X	X
Walleye	X	-	-	-
Freshwater Drum	X	X	X	X

[a] U.S. EPA Region IV (in press) study used electrofishing, gillnetting, and beach seining. Jackson (1980) study used electrofishing and gillnetting. ASFI study used electrofishing and hoop netting.

during the spring months. Reasons for the changes discussed above are not readily apparent (Personal communication. February 5, 1981. Telephone conversation with James Boswell, Aquatic Section, Texas Instrument, Inc.).

Additional literature on the species composition and relative abundance of fishes in the Cannelton Pool includes lock and dam studies conducted by the Ohio River Valley Water Sanitation Commission (ORSANCO) from 1968-1970, and again in 1975 and 1976, at the Cannelton Lock and Dam (RM 720.7). Table 5.18 details the numbers and sizes of fishes collected during the 1976 Cannelton Dam study. Of the 29 species collected, gizzard shad was predominant in both numbers and biomass. Only 12 of these 29 species were collected from RM 705, 707 and 708 during the ASFI 1980-81 study, along with bullhead minnow and quillback.

A June 1978 summary of Ohio River fish surveys categorized the Ohio River fishes into the following associations, based on phylogenetic relationships, ecologic and economic factors (U.S. EPA, 1978):

Category	Forms Included
Forage A	All minnows, shiners, and chubs.
Forage B	Shad and herrings.
Sport A	All sunfishes and basses.
Sport B	Walleye, sauger, and perches.
Commercial	Channel catfish, blue catfish, buffalofishes, freshwater drum.
Rough	Carp, bullhead catfish, and suckers.
Miscellaneous	All others.

From 1968-1976 Forage B species made up 48.5 percent of the total weight (based on Kg/ha) of fish collected at the Cannelton Dam. Rough fish constituted the next highest percentage (24.8). According to the U.S. EPA (1978) estimates of fish biomass in Kg/ha, between RM 700 and 800 have

TABLE 5.18
Ohio River Fish Population Study
CANNELTON LOCK AND DAM (M.P. 720.7)

October 4, 1976

Family Common Name (Scientific name)	No.	Wt. Kg.	Range Cm.
Suckers, (Catostomidae)			
Bigmouth buffalo, (Ictiobus cyprinellus)	3	10.773	52-67
Smallmouth Buffalo, (Ictiobus bubalus)	11	15.241	31-59
Carpsuckers, (Carpides carpio)	30	20.843	33-45
Shorthead redhorse, (Moxostoma macrolepidotum)	2	1.061	32-44
Minnows and Carps, (Cyprinidae)			
Carp, (Cyprinus carpio)	28	83.842	44-79
Silver chub, (Hybopis storeria)	61	1.678	9-15
Emerald Shinner, (Notropis atherinoides)	3	.045	9-12
Paddlefishes, (Polyodon tidues)			
Paddlefish, (Polydon spathula)	1	.227	50
Freshwater catfishes, (Ictaluridae)			
Channel Catfish, (Icthlurus punctatus)	224	19.482	6-59
Blue catfish, (Ictalurus furlatus)	1	.026	26-27
Flathead catfish, (Pylodictis olivaris)	9	.826	6-30
Herrings, (Clupeidae)			
Threadfin shad, (Dorosoma petenense)	55	.862	6-15
Gizzard shad, (Dorosoma cepedianum)	2,024	155.265	12-36
Skipjack herring, (Alosa chrysochlopis)	250	5.700	11-36
Mooneyes, (Hiodontidae)			
Mooneye, (Hiodon tergisus)	9	.798	9-24
Goldeye, (Hiodon alosoides)	1	.304	33
Freshwater eels, (Anguillidae)			
American eel, (Anguilla rostrata)	22	2.858	36-75
Perches, (Percidae)			
Walleye, (Stizostedion vitreum)	15	.948	12-23
Sauger, (Stizostedion canadense)	25	1.855	15-37
Sunfishes, (Centrarchidae)			
Warmouth sunfish, (Lepomius gulosus)	2	.014	6.5-10
Longear sunfish, (Lepomis megalotis)	7	.177	3-15
White crappie, (Pomoxis nigromaculatus)	41	2.313	12-27
Black crappie, (Pomoxis nigromaculatus)	5	.585	15-27
Bluegill, (Lepomis macrochirus)	62	1.374	3-21
Kentucky bass, (Micropterus punctulatus)	2	.354	13-27.5
Temperate basses, (Percichthyidae)			
Striped bass, (Morone saxatilis)	3	.064	12-15
White bass, (Morone chrysops)	18	.771	12-18
Gars, (Lepisosteidae)			
Longnose gar, (Lepisosteus osseus)	4	.880	33-62
Drums, (Sciaenidae)			
Freshwater drum, (Aplodinotus grunniens)	604	64.818	3-41
Totals	3,522	393.984	

Source: Table 53, ORSANCO Water Quality Assessment, 1977 decreased slightly between the periods 1968-1970 and 1975-1976. However, both the number of species and number of fish collected at the Cannelton Dam decreased by approximately 30 percent during that same period (U.S. EPA, 1978). This phenomena seems to be prevalent for most of the Ohio River despite substantially improved water quality over the years. ORSANCO (1977) finds the overall decline in number and weight of fishes lacking ready explanation.

Although gizzard shad and carp were not predominant species taken during the ASFI study (Table 5.16), it is felt that the backwaters to both Town and Bull Creeks are heavy producers of clupeids (herring and shad family) and very likely contribute to the river population. These findings are discussed in later paragraphs.

The prevalence of white crappie and bluegill among species taken during this study would seem to indicate that more desirable conditions, in view of habitat and water quality, are to be found at RM 705, 707 and 708 than in the Cannelton Pool as a whole. However, gizzard shad, skipjack herring, and minnows were predominant in the U.S. EPA Region IV (in press) study. (Again, differences in gear type probably play a role here.) In addition, gizzard shad and emerald shiner, the two species found to be the most abundant in the Ohio River from 1968-1976 (U.S. EPA, 1978) are considered to be wide-ranging river species (Dames & Moore, 1975) more vulnerable to lock and dam studies. Crappies and bluegill tend to be more restricted in movement (Hynes, 1970).

Electrofishing efforts, conducted by the Kentucky Fisheries Division, in the Cannelton Pool during 1979 produced six different species of fish (Jackson, 1980). Of these, gizzard shad was predominant with a catch-per-unit-effort (c/f) of 135 fish per hour (intermediate and havestable sizes combined). Longnose gar and longear sunfish were next in abundance, with C/f's of 21 fish per hour each. Largemouth bass were collected at a rate of 18 per hour, however, only three per hour were of legally havestable size (12 inches in length or greater).

Gillnetting in the Cannelton Pool during the same study produced 13 species (Table 5.17 includes combined electrofishing and gillnetting species list). These were dominated by sauger, with 2.4 fish per net-day (2.0 of these were of harvestable size; $\geq$ 12 inches). Silver chub were next in abundance at 2.2 fish per net-day. Gizzard shad were gillnetted at a rate of 0.8 fish per net-day which was intermediate among the 13 species collected.

During 1979, six pools of the Ohio River were investigated by Jackson (1980) in a similar manner as described above. Of these, the Cannelton Pool produced the most game fish per unit of effort. This was primarily due to the large electrofishing catch of largemouth bass; termed "excellent" by Jackson (1980). The Cannelton Pool also produced the most diverse gillnetting collection of the six pools studied.

The prevalence of game fish in the previously described study tends to support findings of the ASFI study, in which game fish (white crappie, black crappie, largemouth bass, and sauger) made up 47 percent of the total Ohio River catch. Mean lengths of these four species indicate that all but black crappie are below suggested, or legal, minimum size limits. White crappie, the most abundant species in this study, averaged 188.4 mm or 7.4 inches in length--just below the 8 inch suggested size limit (Table 5.16).

Fourteen different species were taken during the Jackson (1980) study and also during the ASFI 1980-81 study. Sport A and B species combined

(U.S. EPA, 1978) dominated both studies. Forage B species were more prevalent in the previous study. This is due to the collection of goldeye and skipjack herring, in addition to gizzard shad--the only Forage B species observed during the ASFI study. Gizzard shad appear to have been more numerous during the previous study, as 135 fish per hour were taken by electrofishing only, compared to a total of 29 gizzard shad taken during the entire ASFI 1980-81 study. However, it should be kept in mind that the Jackson (1980) study encompassed selected areas of the entire Cannelton Pool.

Each of the near-shore areas sampled at RM 705, 707 and 708 offered relatively shallow water during the ASFI study. Bottom types were similar (bare sand) at Stations 1 and 2; however, Station 1 has slightly more cover in its upper reaches. This cover is in the nature of downed trees and stumps. Station 1 is where the greatest number (31) of white crappie were taken during any single sampling (May, 1980), although over the course of the study the total number of white crappie taken at Station 2 was approximately 43 percent greater than at either Station 1 or 3 (Table 5.16). This is difficult to explain in view of the lack of cover to be found at Station 2--especially when compared to Station 3, the length of which provides numerous downed trees and brush in the near-shore area. The same overall situation existed for bluegills, but with the greatest number (24) for any single sampling being taken at Station 3. Perhaps periodic, or even daily, movements of these two species through the relatively barren habitat of the Station 2 area best explains their prevalence here.

The Ohio River backwaters of Town Creek and Bull Creek are very similar in physical appearance and are located between Ohio River miles 707 and 708 (Figure 5.1). Both of these water bodies were created with the installation of the Ohio River highlift dam system and are the result of flooding by the Ohio River. Sand bars at the mouths of both systems insure the existence of these backwaters even during extremely low river flow. However, water levels in the backwaters are dependent upon elevation of the Cannelton Pool. According to area residents, backwaters in the Cloverport area of this pool are used extensively for bass tournament fishing.

Neither of these backwaters are included on the Ohio River Basin Commission's (ORBC) 'Priority Wetland List,' but they do appear on ORBC's 'Recommended for Study' list. Town Creek and Bull Creek are described as 25 and 30-35 acre embayments, respectively. They are classified as Type 5 Wetlands (inland open fresh water), according to Shaw and Fredine (1956). In their upper reaches, these systems are characterized by willow bottoms with cropland adjacent. The shorelines are wooded and produce Type 1 Wetlands (seasonally flooded basins or flats) during flooding (Personal communication. February 11, 1981 telephone conversation with Lauren Schaaf, Environmental Section, Kentucky Department of Fish and Wildlife Resources).

During both high and low waters, these backwater areas would appear to provide excellent refuge and habitat for fish reproductive activity. Several ripe and gravid fishes were collected during the May, 1980 sampling, including bluegill, warmouth, longear sunfish, river carpsucker, and largemouth bass. During the July, 1980 sampling, shore seining efforts in these water bodies produced numerous young-of-the-year (YOY) sunfish, along with one YOY largemouth bass from both Town and Bull Creeks.

Both backwater areas were sampled for ichthyoplankton on May 21, 1980. Relative densities of various species taken during both day and night sampling are detailed in Table 5.19. These data reflect adult fish collections made in these areas with members of the herring and shad family dominating the catch. Catostomids (suckers) were also prevalent, especially in the Bull Creek night samples. Stizostedion spp. also appeared in the Bull Creek night samples. While no fish of this genus were collected in Bull Creek, one YOY sauger (Trautman, 1957) was collected during a qualitative night electrofishing effort on Town Creek during October. Also, both sauger and walleye were captured during the summer, 1979 EPA Region IV (in press) study. Six sauger were collected during the Kinman (1979) study of Bull Creek (discussed in later paragraphs). Centrarchids taken during the ASFI ichthyoplankton sampling consisted of Pomoxis spp. only. This may be associated with preference of white and black crappie for cooler water temperature (Hansen, 1957), and so earlier spawning activity than other centrarchids. These data, in conjunction with the spawning conditions and YOY fishes observed, suggest the importance of these backwaters as nursery and spawning areas for a variety of fishes.

The EPA Region IV (in press) study sampled ichthyoplankton in the vicinity of RM 705 and 707. Taxonomic family composition of these collections compare favorably with those of the backwaters (Table 5.20). Those families collected in the previous study, but not in the ASFI study, includ the paddlefishes, the gars and the drums, all of which are considered to be more wide-ranging, river types.

Jackson (1980) conducted adult fish studies on the backwater to both Town and Bull Creeks, along with Clover Creek (RM 711) during 1979. Re-

Table 5.19. Ichthyoplankton Densities (No/100m^3)[e], Bull and Town Creek backwaters, May 21, 1980[a].

Day Samples	Bull Creek							Town Creek						
Station	1		2		3		Mean	1		2		3		Mean
Duplicate	A	B	A	B	A	B	No/100m^3	A	B	A	B	A	B	No/100m^3
Clupeidae	657	689	203	69	128	139	314.2	170	108	41	56	91	126	98.7
Catostomidae														
Ictiobinae	7	3	--	--	--	--	--	5.0	--	--	--	--	--	--
Centrarchidae														
Pomoxis spp.	4	2	2	3	5	5	3.5	33	27	8	14	55	53	31.7
Percidae														
Logperch type	54	34	< 1	--	2	2	18.6	1	2	--	--	2	3	2.0
Night Samples														
Clupeidae	490[c]	724[c]	107[c]	213[c]	86[c]	107[c]	287.8	85[c]	93[c]	76[c]	139[c]	46[c]	72[c]	85.2
Dorosoma spp.	--	2[b]	--	3[b]	--	1[b]	2.0	--	6[b]	--	--	1[b]	7[b]	4.7
Alosa spp.	--	--	--	--	--	--	--	--	--	--	1[c]	--	--	1.0
Hiodontidae														
Hiodon tergisus	3[b]	3[b]	--	--	--	--	3.0	--	--	--	--	--	--	--
" "	2	--	--	--	--	--	2.0	--	--	--	--	--	--	--
Cyprinidae	3	--	--	1[c]	--	--	2.0	--	--	--	1[c]	--	--	1.0
Notropis atherinoides	2[d]	2[d]	--	--	--	--	2.0	--	--	--	--	--	--	--
Catostomidae	--	--	--	--	--	--	--	--	--	1[c]	1	--	--	1.0
Ictiobinae	234	247	1[c]	--	4[c]	2[c]	97.6	1[c]	2[c]	2[c]	1	--	2	1.6
Catostominae	8	6	--	--	--	2.0	5.0	--	--	--	--	--	--	--

Table 5.19. Continued.

	Bull Creek							Town Creek						
	1		2		3		Mean	1		2		3		Mean
	A	B	A	B	A	B	No/100m^3	A	B	A	B	A	B	No/100m3
Night Samples														
Percichthidae														
Morone spp.	--	2[c]	--	--	--	--	2.0	--	--	--	--	--	--	--
Centrarchidae *Pomoxis* spp.	2	2	3	10	1[c]	3	3.5	17[c]	27	9[c]	16[c]	20	26	19.2
Percidae														
Logperch type	11[b]	2[b]	1[b]	1[c]	1[b]	1[b]	2.8	--	1[b]	--	--	1	1	1.0
Stizostedion spp.	53	53	35	--	--	--	44.0	--	--	--	--	--	--	--

[a]Used 505_u nets

[b]Prolarvae

[c]Postlarvae

[d]Adult

[e]To convert from m^3 to gallons multiply by 264.17

Source: Dames & Moore field data, 1980.

Table 5.20 . Comparison of Ohio River Mile 705 and 707[a], Town Creek backwater[b], and Bull Creek backwater[b] ichthyoplankton catches; by taxonomic family. 1979-1980.

Taxonomic Family[c]	Summer, 1979 Ohio River RM 705 & 707	Spring, 1980 Ohio River RM 705 & 707	Spring, 1980 Town Creek backwater	Spring, 1980 Bull Creek backwater
Polyodontidae (paddlefishes)	--	X	--	--
Lepisosteidae (gars)	X	--	--	--
Clupeidae (herrings)	X	X	X	X
Hiodontidae (mooneyes)	X	X	X	X
Cyprinidae (minnows & carps)	X	X	X	X
Catostomidae (suckers)	X	X	X	X
Percichthyidae (temperate basses)	X	X	--	X
Centrarchidae (sunfishes)	X	--	X	X
Percidae (perches)	--	X	X	X
Sciaenidae (drums)	X	X	--	--

[a]Field collections made during EPA Region IV (in press) study.

[b]Field collections made during ASFI study.

[c]This listing not necessarily inclusive, as some fish eggs and larvae could not be identified to family.

Source: EPA Region IV (in press) and Dames & Moore 1980 field data.

sults of electrofishing and gillnetting efforts are reported as combined "Cannelton Pool backwater areas" for these three water bodies. Electrofishing produced 11 species of fish from the three backwaters which were dominated by gizzard shad. Bluegill and largemouth bass were second and third in abundance, respectively. Catch per unit effort of largemouth bass was greater for the backwaters (22.9 fish per hour) than the river (18 fish per hour), for the Jackson (1980) study. Also, 39.3 percent of the backwater largemouth bass were of legal size while only 20 percent of those taken in the river were 12 inches in length or greater. Gillnetting in the same three areas produced 10 species, of which gizzard shad was overwhelmingly dominant. This is in contrast with the dominance of sauger in Ohio River gillnetting catches for the same study. No sauger were collected by gillnetting in the backwaters. Gillnet catches of other sport fish, such as white crappie, bluegill and longear sunfish, were also relatively low.

ASFI adult fish collections by electrofishing in the Town Creek backwater are summarized in Table 5.21. These data tend to agree with those of Jackson (1980), for electrofishing, in both species composition and C/f. Actual collections were dominated by centrarchids (sunfish and basses) during each of the quarterly samplings. However, gizzard shad were observed to be extremely numerous during each sampling except January, 1981 (during which ice cover restricted sampling to the channel areas in both backwaters. Due to the great numbers of 200-300 mm gizzard shad present, only a few were collected and processed. Mean length for largemouth bass collected in Town Creek was just under the legal size limit at 242.5 mm or 9.5 inches, but was greater than that for the Ohio River (264.6 mm or 10.4 inches).

Table 5.21 Summary of fish collections. Town Creek (T) and Bull Creek (B) backwaters.

Species by Family	May, 1980 T	May, 1980 B	July, 1980 T	July, 1980 B	October, 1980 T(N)[e]	October, 1980 B	January, 1981 T	January, 1981 B	1980 - 81 Town Creek[h] No.	x̄mm	x̄g	1980 - 81 Bull Creek[h] No.	x̄mm	x̄g
Clupeidae														
Gizzard shad (Dorosoma cepedianum)	--[b]	--[b]	5[b]	3[b]	10[b]	4[b]	--	--	15	180.5	72.1	7	156.9	41.3
Cyprinidae														
Goldfish (Carrassius auratus)	1	--	--	1	--	--								
Carp (Cyprinus carpio)	3	--	3	1	2	3	--	--	1	310.0	590.0	1	330.0	700.0
Emerald shiner (Notropis atherinoides)	--	--	--	--	3	1	--	--	8	516.0	1858.1	4	498.8	1624.5
Catostomidae							--	--	3	63.3	1.3	1	67.0	2.0
River carpsucker (Carpoides carpio)	1	--	1	--	--(1)	--								
Ictaluridae							--	--	3	422.7	946.0	0	--	--
Yellow bullhead (Ictalurus natalis)	--	1	--	--	--	--	--	--	0	--	--	1	245.0	170.0
Channel catfish (Ictalurus punctatus)	1	--	--	--	--	3	--	--	1	390.0	400.0	3	342.3	369.3
Flathead catfish (Pylodictis olivaris)	1	1	--	--	--	--	--	--	1	430.0	750	1	340.0	405.0
Centrarchidae[c]														
Warmouth (Lepomis gulosus)	1	1	1	2	--	1	1	4	3	115.3	32.7	8	120.8	47.1
Bluegill (Lepomis macrochirus)	9	8	12	9	24(2)	21	9	--	56	129.3	54.1	38	135.8	54.6
Longear sunfish (Lepomis megalotis)	2	--	4	-	2(1)	3	1	--	10	122.5	37.1	3	118.3	34.0
Largemouth bass (Micropterus salmoides)	3	2	2[d]	2[d]	8(3)	2	--	--	16	299.8	449.8	6	242.4	306.0
White crappie (Pomoxis annularis)	--	3	1	1	5(1)	11	--	--	7	227.3	138.6	15	232.5	191.5
Black crappie (Pomoxis nigromaculatus)	--	--	--	--	1	--	--	--	1	216.0	116.0	0	--	--
Percidae														
Sauger (Stizostedion canadense)	--	--	--	--	--(1)	--	--	--	1	158.0	15.0	0	--	--
Sciaenidae														
Freshwater Drum (Aplodinotus grunniens)	--	--	--	--	--(1)	1	--	--	1	245.0	140.0	1	117.0	18.0
Total number of fish per creek (N)	22	16	29	19	55(10)	50	11	4	127			89		
Total number of species per creek (S)	9	6	8	7	11	10	3	1	15			13		
Species diversity (d)[g]	2.59	1.80	2.08	2.04	2.50	2.30	0.83	0	2.31			2.67		
Catch per unit effort[a]	1.15	0.80	1.57	1.04	3.47[f]	2.73[f]	1.34	0.43	--			--		

a Fish collected by electrofishing in backwaters. Effort expressed in minutes.
b numerous gizzard shad; unable to shock.
c Numerous young-of-the-year sunfish taken while seining backwaters during July sampling.
d Includes one young-of-the-year from each backwater.
e Fish collected during a selective, night electrofishing session in Town Creek on October 10, 1980. Not included in catch per unit effort figures and or species diversity values.
f Based on estimated electrofishing time--counter malfunctioned.
g Margelef (1951)
h To convert from: mm to inches multiply by 0.039
g to pounds multiply by 0.002

Source: Dames & Moore field data, 1980-81.

Domination of the Town Creek catch by centrarchids and gizzard shad agree with ichthyoplankton collections discussed earlier (Table 5.19).

Table 5.22 compares electrofishing collections made in Town Creek during the EPA Region IV (in press) study with those of the ASFI study. The relatively low numbers of fish collected during 1980, for both studies, was characteristic and follows with seemingly reduced numbers of fish present. Summer, 1979 data for this previous study compare more favorably with summer, 1980 data for this study with gizzard shad and centrarchids being predominant. (It should be noted that differences in numbers of fish taken is a reflection of six sampling dates for the EPA Region IV (in press) summer study, as opposed to one sampling date for the summer sampling of the ASFI study).

The Kentucky Fisheries Division conducted a rotenone study on the Bull Creek backwater during 1978 (Kinman, 1979) (Table 5.23). Forage fish comprised the largest percentage (49.2) of the total catch, with gizzard shad as the dominant species. Panfish comprised 34.8 percent of the total with bluegill being predominant among these.

Compared to backwater areas in other pools studied during 1978, Bull Creek was a greater producer of centrarchids. The others seemed to produce more commercial, or rough, fishes such as carp, species of buffalo, and suckers. Because of this, Bull Creek rated lower in standing crop estimates (Kinman, 1979). However, Bull Creek's importance as a recreational fishery is emphasized by this finding.

The ASFI study agrees with Kinman (1979), and details of Bull Creek collections may be found in Table 5.21. Again, gizzard shad were extremely numerous so only a few were collected and processed. Second in abundance

Table 5.22 . Comparison of adult fish species from Town Creek backwater. Electrofishing.[a] EPA Region IV (in press) study and ASFI study.

Species by Family	EPA Reg. IV Spring, 1980	ASFI Spring, 1980	EPA Reg. IV Summer, 1979	ASFI Summer, 1980
Clupeidae				
Gizzard shad	12	--[b]	24	5[b]
Cyprinidae				
Goldfish	--	1	1	--
Carp	--	3	3	3
Emerald shiner	--	--	8	--
Golden shiner	--	--	1	--
Catostomidae				
River carpsucker	1	1	3	1
Ictaluridae				
Channel catfish	--	1	--	--
Flathead catfish	--	1	1	--
Percichthyidae				
White bass	--	--	1	--
Centrarchidae				
Green sunfish	--	--	1	--
Warmouth	--	1	--	1
Bluegill	--	9	9	12
Longear sunfish	--	2	3	4
Smallmouth bass	--	--	2	--
Largemouth bass	--	3	--	1
White crappie	--	--	--	1
Black crappie	--	--	--	--
Sciaenidae				
Freshwater Drum	2	--	7	--
Total number of fish	15	22[b]	64	29[b]
Total number of species	3	10	13	8

[a]Electrofishing efforts vary between studies.
[b]Gizzard shad extremely numerous.
Source: EPA Region IV (in press) and Dames & Moore 1980 field data.

Table 5.23. Species composition and relative abundance of the fish population in the backwater of the Ohio River in Bull Creek (Cannelton Pool) in 1978.

GROUP/species	Fingerling size (per acre)*		Intermediate size (per acre)		Harvestable size (per acre)		Total (per acre)		Percent of total population	
	Number	Pounds*	Number	Pounds	Number	Pounds	Number	Pounds	Number	Biomass
GAME FISHES										
Largemouth bass	54	0.26	20	4.15	5	8.67	79	13.08	1.4	6.3
Black crappie	2	0.01	3	0.45	-	-	5	0.46	0.1	0.2
White crappie	659	2.05	2	0.20	1	0.20	662	2.45	11.8	1.2
Sauger	-	-	6	1.13	-	-	6	1.13	0.1	0.5
Total	715	2.32	31	5.93	6	8.87	752	17.12	13.4	8.2
FOOD FISHES										
Channel catfish	-	-	1	0.08	2	0.97	3	1.05	0.1	0.5
Total	-	-	1	0.08	2	0.97	3	1.05	0.1	0.5
PREDATORY FISHES										
Longnose gar	2	t	2	t	-	-	4	t	0.1	t
Total	2	t	2	t	-	-	4	t	0.1	t
PISCIVOROUS TOTAL	718	2.32	34	6.01	8	9.84	759	18.17	13.5	8.7
PANFISHES										
Bluegill	796	0.93	682	32.09	234	38.04	1,712	71.06	30.4	34.2
Longear sunfish	2	t	121	4.17	2	0.22	125	4.39	2.2	2.1
Redear sunfish	-	-	7	0.38	-	-	7	0.38	0.1	0.2
Warmouth	-	-	97	3.79	17	2.18	114	5.97	2.0	2.9
Total	798	0.93	907	40.43	252	40.44	1,957	81.80	34.8	39.4
COMMERCIAL FISHES										
Smallmouth buffalo	2	t	24	8.08	-	-	26	8.08	0.5	3.9
River carpsucker	-	-	-	-	4	6.55	4	6.55	0.1	3.2
Golden redhorse	1	t	1	0.14	-	-	2	0.14	t	t
Goldfish	-	-	-	-	2	2.27	2	2.27	t	1.1
Spotted sucker	-	-	-	-	1	1.20	1	1.20	t	0.6

Table 5.23. Continued.

GROUP/species	Fingerling size (per acre)		Intermediate size (per acre)		Harvestable size (per acre)		Total (per acre)		Percent of total population	
	Number	Pounds	Number	Pounds	Number	Pounds	Number	Pounds	Number	Biomass
COMMERCIAL FISHES (concluded)										
Carp	-	-	2	0.22	2	5.98	4	6.12	0.1	2.9
Yellow bullhead	2	t	14	2.30	-	-	16	2.30	0.3	1.1
Freshwater drum	14	0.03	73	9.12	3	2.27	90	11.42	1.6	5.5
Total	19	0.03	114	19.86	12	18.27	145	38.16	2.6	18.4
FORAGE FISHES										
Gizzard shad	2,325	23.08	253	19.86	150	26.30	2,728	69.24	48.5	33.3
Emerald shiner	1	t	-	-	-	-	1	t	t	t
Golden shiner	2	0.05	-	-	-	-	2	0.05	t	t
Misc. cyprinids	2	t	-	-	-	-	2	t	t	t
Tadpole madtom	2	0.01	1	0.01	-	-	3	0.02	t	t
Blackstrip top-minnow	16	0.06	-	-	-	-	16	0.06	0.3	t
Logperch	1	t	-	-	-	-	1	t	t	t
Orangespotted sunfish	-	-	1	0.06	1	0.09	2	0.15	t	0.1
Gambizio	14	0.02	-	-	-	-	14	0.02	0.2	t
Total	2,363	23.22	255	19.93	151	26.39	2,769	69.54	49.2	33.5
NON-PISCIVOROUS TOTAL	3,180	24.18	1,276	80.22	415	85.10	4,871	189.50	86.6	91.2
GRAND TOTAL	3,897	26.50	1,309	86.23	422	94.94	5,628	207.67	100.0	100.0

t < .005 lb/a and .05%

Y/C = 2.49.

Source: Kinman (1979)
*To convert from acres to hectares, divide by 2.47.
*To convert from pounds to kilograms, multiply by 0.45.

were the centrarchids with bluegill dominating these. Mean length for bluegill collected in Bull Creek was 135.8 mm (5.3 inches) which is just below the suggested harvestable size of 6 inches (Jackson, 1980). Forty percent of the bluegill taken in 1978 ranged from 76.2 to 127 mm (3-5 inches) and the population was described as having sufficient numbers of YOY and intermediate size fish to continue it for several years (Kinman, 1979). Mean length for largemouth bass taken in Bull Creek during the ASFI study was 242.4 mm (9.5 inches) which is below the legal minimum size limit of 12 inches and less than mean length for the same species taken from Town Creek (264.6 mm or 11.8 inches).

Approximately half as many species were collected from the Bull Creek during the ASFI study as during the Kinman (1979) study. This is a reflection of the effectiveness of rotenone as a fish sampling agent. The quantity of various suckers, minnows and longnose gar was insignificant in the Kinman (1979) study, although this method of sampling provides a more complete picture of the fish community present.

Adult fish studies in the Town Creek and Bull Creek backwaters suggest these areas to be more productive than the Ohio River stations studied. Species diversities in these backwaters were moderate, but generally higher than those of the river stations (Tables 5.21 and 5.16). Total numbers of species collected were similar, but catch-per-unit-effort for electrofishing averaged six times greater in the backwaters than the river. The importance of these areas for spawning and rearing of young was illustrated by ichthyoplankton and young-of-the-year fish collections. Most of the recreational fishing pressure along the Ohio River is confined to the backwater areas (Kinman, 1979), and observed fish communities in Bull and Town Creeks seem to warrant this type of use. The prevalence of game and panfish in these waters would seem to make them excellent sport fisheries. In fact, the Cannelton Pool, and its backwater areas, was noted as providing more game and panfish than any of the other pools studied during 1978 and 1979 (Kinman, 1979 and Jackson, 1980).

5.5.6.2 Town Creek

Town Creek was sampled approximately two miles upstream from its confluence with the Ohio River, during July, October, and January (Figure 5.1). When water levels were low, upstream movement of fish was made impossible by a small concrete dam, equipped with a six inch flowthrough pipe. Due to its placement, this pipe restricts upstream fish movement when water depths below the dam are less than three feet.

The station is a series of riffles and pools with water depths ranging from 1-2 inches in the riffles to 2-3 feet in some pools. The large pool directly below the dam was 3-4 feet deep in some places. Substrate varied from clay and silt in the large pool to gravel/cobble further downstream. A fairly steep bank with undercut tree roots offer a variety of habitat in a relatively short distance. Growths of herbacios plants and mature trees caused the station to be mostly shaded. Waters were generally clear with temperatures ranging from 1° C in January to 25° C in July. Dissolved oxygen levels of 5.2 to 11.2 mg/l adequately supported fish year round (Table 10.3 through 10.6).

The entire station, approximately 45 meters (150 feet) in length, was seined during the summer and fall. Additional seining, upstream of the dam, was conducted during the July mussel survey and produced a few male redfin shiners in spawning condition. Seining in January of 1981 was restricted to portions of the large pool below the dam and two downstream riffles, due to heavy ice cover. Only a few darters were taken during this effort.

A total of 213 fish of 16 species were collected at Town Creek during the course of this study (Table 5.24).

Table 5.24 Summary of fish collections.[a] Town Creek (T) and Bull Creek (B), upper stations.

Species by Family	May, 1980 T	May, 1980 B	July, 1980 T	July, 1980 B	October, 1980 T	October, 1980 B	January, 1981 T	January, 1981 B	1980-81 Town Creek[d] No.	x̄mm	x̄g	1980-81 Bull Creek[d] No.	x̄mm	x̄g
Esocidae														
Grass pickerel (Esox americanus vermiculatus)	1	--	1	--	5[a]	4[a]	--	--	7	93.3	4.7	4	144.5	16.0
Cyprinidae														
Emerald shiner (Notropis atherinoides)	--	--	1	--			--	--	1	61.0	2.0	0	--	--
Ghost shiner (Notropis buchanani)	--	1	--	--	--	--	--	--	0	--	--	1	43.0	1.0
Striped shiner (Notropis chrysocephalus)	--	--	--	1	--	3[a]	--	--	0	--	--	4	67.0	2.0
Redfin shiner (Notropis umbratilis)	--	--	3	--	57	--	--	--	60	50.0[b]	2.5[b]	0	--	--
Mimic shiner (Notropis volucellus)	--	--	5	--	--	--	--	--	5	39.2	1.0	0	--	--
Bluntnose minnow (Pimephales notatus)	2	--	5	--	33	--	--	--	40	65.0[b]	3.0[b]	0	--	--
Fathead minnow (Pimephales promelas)	1	--	--	--	--	--	--	--	1	42.0	2.0	0	--	--
Creek chub (Semotilus atromaculatus)	8	--	1	2	--	18[a]	--	--	9	53.8	4.6	20	77.0[b]	5.5[b]
Unidentified shiner (Notropis spp.)	--	--	--	1	5[a]	--	--	--	5	--	--	1	32.0	1.0
Unidentified cyprinid	--	--	--	--	--	1[a]	--	--	0	--	--	1	--	--
Catostomidae														
Creek chubsucker (Erimyzon oblongus)	--	--	--	--	2[a]	1[a]	--	--	2	--	--	1	--	--
Ictaluridae														
Yellow bullhead (Ictalurus natalis)	--	--	--	--	--	1[a]	--	--	0	--	--	1	--	--
Cyprinodontidae														
Blackstripe topminnow (Fundulus notatus)	--	7	1	--	8	5	2	--	11	46.5	1.7	12	45.0	1.5
Poeciliidae														
Mosquitofish (Gambusia affinis)	--	--	--	--	1	7	--	--	1	30.0	1.0	7	30.4	1.0
Centrarchidae														
Green sunfish (Lepomis cyanellus)	4	--	--	1	3[a]	4	--	--	7	86.0	17.0	5	59.6	3.0
Warmouth (Lepomis gulosus)	--	--	--	--	--	1	--	--	0	--	--	1	143.0	50.0
Bluegill (Lepomis macrochirus)	--	15	2	7	4	1	--	--	6	91.5	15.7	23	125.9	46.4
Longear sunfish (Lepomis megalotis)	--	7	2	--	3	6	--	--	5	102.0	22.8	13	80.0	40.2
Spotted sunfish (Lepomis punctatus)	--	1	--	--	--	--	--	--	0	--	--	1	138.0	54.0
Largemouth bass (Micropterus salmoides)	--	--	--	--	--	1	--	--	0	--	--	1	81.0	8.0
Percidae														
Fantail darter (Etheostoma flabellare)	5	3	1	1	2	2	9	--	17	49.0[b]	1.5[b]	6	39.7	1.0
Johnny darter (Etheostoma nigrum)	14	--	4	--	6	1	12	--	36	41.0[b]	1.1	1	35.0	1.0
Blackside darter (Percina maculata)	--	--	--	--	--	1[a]	--	--	0	--	--	1	--	--
Total number of fish per creek (N)	35	34	26	13	129	57	23	0	213			104		
Total number of species per creek (S)	7	6	11	6	12	16	3	0	16			19		
Species diversity (d)[c]	1.69	1.42	3.07	1.95	2.09	2.68	0.64	0	2.63			2.90		

[a]Includes fish taken during a qualitative seining effort on October 25, 1980. These fish not included in species diversity values. No length or weight measurements.
[b]This figure represents the average of a range of lengths or weights for: 60 redfin shiners; 40 bluntnose minnows; 17 fantail darters; 36 johnny darters; 20 creek chubs.
[c]Margelef (1951)
[d]To convert from: mm to inches multiply by 0.039
g to pounds multiply by 0.07

Greatest numbers of fish (129) were collected in October, 1980. Nearly half of these were redfin shiners ranging between 25 and 65 mm in length. This increase in numbers may be associated with young-of-the-year (YOY) redfins utilizing the sluggish riffles (Trautman, 1957) common to this portion of Town Creek. Trautman (1957) mentions YOY redfin shiners as ranging from 0.7 to 2.0 inches (18 to 51 mm) in length during October, which compares favorably with these data. Also, adult redfin shiners in spawning condition were observed in July.

Another factor that may be reflected in the increased catch during October is the lack of creek flow during this sampling. Lower water tends to reduce the amount of cover available, causing more fish to become vulnerable to the seine.

During May, 1980, Town Creek was sampled approximately 8.0 kilometer (1/2 mile) upstream of the previously described station. This location provided fewer types of habitat and had deeper, slower moving waters. The lower species diversity observed at this location seems to reflect these conditions (Table 5.24).

Of the 16 species colected in upper Town Creek during this study, it seems that all but three were also collected during the U.S. EPA Region IV (in press) study of Town Creek. Those three additional species include redfin shiner, mimic shiner, and fathead minnow. It should be noted, however, that upstream and backwater seining data were lumped together in the U.S. EPA Region IV (in press) study. As a result of this, it is possible that some of the species mentioned above may have been collected in the backwater area of Town Creek rather than the upstream area.

Published literature on the fish community of upper Town Creek seems to be non-existent. The Kentucky Division of Fisheries has not yet been able to include the creek in its schedule of stream inventories (Personal, Communication. February 9, 1981 telephone conversation with David Bell, Kentucky Department of Fish and Wildlife Resources). The Kentucky Nature Preserve Commission has not yet investigated Town Creek for endangered species (Personal Communication. February 10. 1981 telephone conversation with Mel Warren, Kentucky Nature Preserve Commission).

This portion of Town Creek seems to support a healthy and fairly diverse fish community in which a variety of forage species are complimented by the presence of a few predatory types, such as the centrarchids and the grass pickeral.

5.5.6.3 Bull Creek

The upper creek station on Bull Creek was located just upstream from where Route 144 crosses the creek (Figure 5.1). Upstream influences were severely hampered during low water because of the placement of three large culverts facilitating a private road. Unless a moderate flow existed in Bull Creek, upstream fish movement was impossible due to the height of the culverts above the water surface.

The Bull Creek Station is a series of riffles and pools. Substrate generally consisted of gravel and rubble with a covering of silt, periphyton and debri. Stream banks were quite steep on either side with a fairly dense growth of trees and vegetation causing the station to be shaded most of the time. Water temperatures ranged from 0.5° in January to 28° C in July and dissolved oxygen levels of 5.0-11.4 mg/l were more than adequate to support fish (Tables 10.3 through 10.6). Waters were always clear for the entire depth, which ranged from 1-2 inches at the riffles to 2-3 feet in some pools.

The entire station, from the culverts to approximately 45 meters (150 feet) downstream, was seined quarterly. During the course of the study, a total of 19 species of fish were collected at Bull Creek; including three species unique to the study, and one unidentified cyprinid, which were taken during a qualitative seining effort in October. These were dominated by creek chub, bluegill, longear sunfish and blackstripe topminnow with bluegill being the most prevalent (Table 5.24). No fish were taken in Bull Creek during the January, 1981 sampling due to heavy ice conditions, although one small riffle remained open and was seined.

Published literature on the fish community of upper Bull Creek seems to be non-existent. The Kentucky Division of Fisheries has not yet been able to include the creek in its schedule of stream inventories (Personal communication. February 9, 1981 telephone conversation with David Bell, Kentucky Department of Fish and Wildlife Resources). The Kentucky Nature Preserves Commission has not yet investigated Bull Creek for endangered species (Personal communication. February 10, 1981 with Mel Warren, Kentucky Nature Preserves Commission).

The apparent fish community in this section of Bull Creek seems to be fairly well balanced. A diverse population of predatory species, dominated by a variety of centrarchids, is seemingly well complimented by forage types. Diversities remained moderate throughout the study, with the exception of January. Both numbers of fish and species diversity increased during the October, 1980 sampling. The reason for this is not readily apparent, however, increases in diversities from May through October correspond with decreases in creek flow during this same period (Table

5.24). It may be that lack of water, and thus cover, causes more fish to become vulnerable to capture.

Overall, Bull Creek appears to be a moderately healthy system which most likely supplies a reasonable panfish fishery to area residents.

5.5.7 Tissue Analysis

5.5.7.1 Ohio River

Tissue analysis of white crappie and carp from the river showed low levels of organic compounds and most heavy metals (Tables 5.26, 5.27). Data for several heavy metals, selected for closer inspection due to their presence in the fishes, are summarized in Table 5.25.

By utilizing one-way analyses of variance, it was found that there were significant ($P < 0.05$) differences between white crappie and carp for none of the metals but zinc. That is, species differences in most metal accumulations were not found, but carp contained significantly more zinc.

In comparison to other data for heavy metals in fishes, copper appeared to be the only one that evidenced a concentration higher than in fish from unpolluted environments. Most values in the literature for copper in fish muscle ranged from about 0.1 to 2.5 ppm dry weight (Mathis and Cummings 1973; ORSANCO, 1977, Wiener and Giesy 1979, U.S. EPA, in press). Although levels were low in the spring, average values for copper in both carp and white crappie in the fall were greater than 5 ppm. Copper levels from muscle tissue of fishes from the same area in 1979-80 were reported to range fom 0.66 ppm for walleye and channel catfish to 2.17 ppm for river carpsuckers (U.S. EPA in press). The same study found that carp contained 0.78 ppm. Other data from the Ohio River at Cannelton Lock and Dam reported 0.38 ppm in the muscle of several catfish (ORSANCO, 1977). Only the data of Goodyear and Boyd (1972), with a grand mean of 6.2 ppm in largemouth bass from five localities in the southeastern U.S., show values as high as those found in the fall in the present study. Because it is a belief of Wiener and Giesy (1979) and others that copper, as an essential body element, is under homeostatic control, the ambient levels of

Table 5.25 Means and (ranges) for selected heavy metals in fish muscle and whole body from the Ohio River, Town Creek, and Bull Creek, 1980.

METAL	OHIO RIVER	Stations TOWN CREEK	BULL CREEK
	White Crappie - Muscle	Green Sunfish-White Body	Bluegill-Muscle and Whole Body
N[b]	6	6	7
Al	4.42 (0.49 - 13.6	2.54 (0.88 - 4.70)	2.46 (0.34 - 3.30)
Ba	- (<0.02 - 1.65)	0.71 (0.58 - 0.95)	0.99 (0.23 - 1.54)
Br	0.49 (0.10 - 2.10)	0.62 (0.19 - 1.10)	0.70 (0.15 - 1.25)
Cd	- (0.02 - 0.05)	- (< 0.05 - 0.09)	0.18 (0.04 - 0.27)
Co	- (< 0.043 -2.32)	- (< 0.04 - 9.31)	- (0.04 - 1.00)
Cr	0.51 (0.15 - 1.80)	1.37 (0.82 - 2.06)	1.67 (0.20 - 2.69)
Cu	(< 0.04 - 14.80)	2.18 (0.33 - 4.67)	- (0.065 - 6.84)
Fe	18.35 (3.84 -33.3)	24.3 (20.9 - 29.4)	53.1 (21.3 - 75.3)
La	0.71 (0.33 - 1.21)	- (<0.16 - 0.93)	0.92 (0.22 - 1.75)
Mg	280.2 (224-333)	337.5 (247 - 552)	379.5 (262 - 384)
Mn	- (< 0.041 - 10.90)	5.97 (1.09 - 11.80)	1.88 (0.797 - 2.02)
Hg	- (< 0.001 - 0.015)	- (< 0.002-0.18)	- (< 0.001 - 0.07)
Ni	- (< 0.05 - 10.42)	0.43 (0.19 - 0.64)	1.53 (0.19 - 6.84)
Sn	6.95 (4.3 - 11.5)	- (< 0.05 - 15.9)	8.99 (0.25 - 27.3)
Zn	5.97 (4.81 - 8.57)	14.24 (6.33 - 28.40)	11.52 (7.16 - 13.42)
	Carp - Muscle	Creek Chubs	Whole Body
N	6	3	3
Al	2.34 (0.30 - 5.82)	0.43 (0.37 - 0.49)	4.99 (4.23 - 6.18)
Ba	0.36 (0.04 - 0.95)	0.42 (0.39 - 0.44)	0.91 (0.89 - 0.94)
Br	0.50 (0.10 - 1.80)	0.62 (0.55 - 0.70)	0.25 (0.21 - 0.28)
Cd	- (0.02 - 0.04)	0.05 (0.03 - 0.06)	0.47 (0.43 - 0.49)
Co	- (< 0.05 - 2.03)	- (<0.06 - 0.08)	- (< 0.06 - 0.65)
Cr	0.29 (0.18 - 0.38)	0.63 (0.51 - 0.73)	2.04 (1.88 - 2.30)
Cu	3.31 (0.24 - 7.61)	0.30 (0.29 - 0.34)	8.32 (6.20 - 12.50)
Fe	29.01 (10.78 - 56.6)	20.10 (18.2 - 21.4)	29.83 (23.70 - 33.60)
La	0.70 (0.28 - 1.40)	0.62 (0.58 - 0.67)	0.89 (0.86 - 0.92)
Mg	294.8 (238 - 328)	343.0 (322 367)	362.7 (351 - 384)
Mn	3.42 (0.646 - 14.23)	1.03 (0.97 - 1.11)	5.45 (3.78 - 6.39)
Hg	- (< 0.002 - 0.027)	- (< 0.002 - 0.003)	0.04 (0.02 - 0.05)
Ni	0.87 (0.29 - 2.07)	0.78 (0.69 - 0.89)	2.78 (1.25 - 3.90)
Sn	6.87 (2.90 - 11.4)	10.3 (8.7 - 11.2)	(< 0.05)
Zn	9.14 (5.04 - 13.60)	7.46 (7.15 - 7.99)	45.20 (40.30 -53.90
		Bluntnose Minnow - Whole Body	Longear Sunfish - Whole Body
N		3	2
Al		2.36 (2.28 - 2.45)	2.18; 0.62
Ba		6.47 (6.21 - 6.69)	0.44; 0.37
Br		0.32 (0.28 - 0.35)	1.01; 0.30
Cd		- (< 0.07 - 0.09)	<0.01; 0.92
Co		5.69 (5.21 - 6.26)	0.21; 0.15
Cr		2.50 (2.29 - 2.67)	0.16; 1.10
Cu		7.14 (6.38 - 7.63)	<0.077; 0.256
Fe		429.7 (411 - 441)	23.9; 14.4
La		1.38 (1.32 - 1.44)	0.98; 0.74
Mg		359.0 (345 - 383)	257; 307
Mn		62.0 (59.3 - 67.4)	0.933; 1.260
Hg		0.05 (0.04 - 0.06)	<0.001: 0.001
Ni		0.86 (0.82 - 0.91)	<0.01; 0.24
Si		(<0.05)	16.2; 9.4
Zn		35.97 (35.40 - 37.00)	6.57; 6.21

[a] Results in mg/kg wet weight

[b] Number of observations

Table 5.26. Fish Tissue Data, Spring 1980.

	Station 1	Station 2	Station 3			
	1T	2T	3T	4T	5T	6T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	0.30	7.26	1.07	5.82	0.49	0.95
Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	<0.02	<0.02	<0.02	0.04	<0.02	<0.02
Barium	0.95	1.65	0.51	0.24	0.23	1.20
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	0.10	2.10	0.42	1.80	0.18	0.26
Cadmium	0.02	0.05	0.04	0.04	0.04	0.03
Cobalt	0.08	0.14	0.07	<0.05	<0.04	<0.04
Chromium	0.21	0.18	0.18	0.37	0.37	0.20
Copper	1.080	<0.043	0.240	0.703	0.350	0.106
Iron	35.1	33.3	31.4	56.6	12.1	23.0
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Mercury	<0.002	<0.001	<0.002	<0.002	<0.001	<0.001
Lanthanum	0.64	1.21	0.82	1.40	0.33	0.46
Magnesium	238	273	324	277	224	288
Manganese	0.905	1.680	0.646	1.260	<0.041	0.190
Molybdenum	0.20	0.09	0.04	0.04	0.01	0.02
Nickel	0.29	0.30	0.40	0.29	0.24	0.51
Lead	<0.041	<0.043	<0.039	<0.051	<0.040	<0.037
Rubidium	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Antimony	<0.011	<0.008	<0.010	<0.010	<0.020	<0.016
Selenium	<0.003	<0.002	<0.003	<0.004	<0.005	<0.003
Tin	11.4	6.0	8.0	10.8	11.5	5.0
Strontium	<0.031	<0.030	<0.034	<0.028	<0.027	<0.026
Titanium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Uranium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Table 5.26. Continued

	Station 1	Station 2	Station 3			
	1T	2T	3T	4T	5T	6T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tungsten	<0.10	<0.11	<0.14	<0.09	<0.08	<0.08
Zinc	11.66	5.90	5.04	7.54	4.81	4.94
Zirconium	<0.06	<0.07	<0.09	<0.05	<0.05	<0.05
Silver	<0.01	<0.01	0.02	0.09	0.03	<0.01
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<7	<10	<7	<10	<10	<10
Aliphatic Hydrocarbons (2)	<20	<10	<20	<10	<10	<10
Arylamines	26	<3	32	<2	<2	<2
Mono & polycyclic hydrocarbons: (3)						
Benzo(a)pyrene	ND	ND	Trace	ND	ND	ND
Benzo(c)phenathrene	24	ND	18	ND	ND	ND
Pyrene	Trace	ND	Trace	ND	ND	ND
Sulfur compounds: (4)						
Thiophenes	<2	<5	<2	<5	<5	<5
Mercaptans	<2	<5	<2	<5	<5	<5
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<10	<25	<10	<25	<25	<25

Table 5.26. Continued

	Station B					
	7T	8T	9T	10T	11T	12T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	3.30	2.84	0.34	1.83	2.18	0.62
Arsenic	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron	<0.02	0.04	<0.02	<0.02	<0.02	<0.02
Barium	0.43	0.31	0.64	0.23	0.44	0.37
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	1.25	1.16	0.15	0.95	1.01	0.30
Cadmium	0.05	0.04	0.05	0.27	<0.01	0.92
Cobalt	<0.05	<0.06	<0.05	<0.04	0.21	0.15
Chromium	0.20	1.10	0.82	0.37	0.16	1.10
Copper	3.910	<0.065	0.178	0.339	<0.077	0.256
Iron	41.5	75.3	24.4	21.3	23.9	14.4
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lanthanum	1.75	1.16	0.22	0.95	0.98	0.74
Magnesium	297	262	268	307	257	307
Manganese	1.890	1.190	0.797	1.600	0.933	1.260
Molybdenum	0.03	<0.01	0.05	0.05	0.02	0.07
Nickel	0.19	0.19	0.23	6.84	<0.01	0.24
Lead	<0.053	<0.071	<0.052	<0.035	<0.076	<0.058
Rhubidium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	<0.013	<0.022	<0.019	<0.017	<0.013	<0.009
Selenium	<0.002	<0.005	<0.004	<0.003	<0.002	<0.002
Tin	4.1	27.3	13.4	8.3	16.2	9.4
Strontium	<0.019	<0.033	<0.037	<0.021	<0.011	<0.014
Titanium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Uranium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Table 5.26. Contined

	Station B					
	7T	8T	9T	10T	11T	12T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tungsten	<0.09	<0.08	<0.11	<0.10	<0.09	<0.09
Zinc	13.42	9.65	8.97	7.16	6.57	6.21
Zirconium	<0.05	<0.05	<0.06	<0.06	<0.05	<0.05
Silver	0.08	0.06	<0.01	<0.01	<0.01	<0.01
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<10	<10	<10	<10	<10	<10
Aliphatic Hydrocarbons (2)	<10	<10	<10	<10	<10	<10
Arylamines	<2	<2	<2	<2	<2	<2
Mono & polycyclic hydrocarbons: (3)						
Benzo(a)pyrene	ND	ND	ND	ND	Trace	Trace
Sulfur compounds (4)	<5	<5	<5	<5	<5	<5
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<25	<25	<25	<25	<25	<25

Table 5.26. Continued

	Station T					
	13W	14W	15W	16W	17W	18W
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	0.43	0.49	0.37	0.88	0.97	0.94
Arsenic	<0.02	<0.02	<0.03	<0.02	<0.02	<0.03
Boron	<0.04	<0.04	<0.08	<0.04	<0.04	<0.08
Barium	0.43	0.39	0.44	0.63	0.58	0.67
Beryllium	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02
Bismuth	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02
Bromine	0.61	0.70	0.55	0.93	1.10	1.09
Cadmium	0.06	0.05	0.03	0.09	0.09	0.07
Cobalt	<0.06	<0.06	<0.08	<0.05	<0.04	<0.07
Chromium	0.66	0.73	0.51	0.84	0.82	0.91
Copper	0.34	0.29	0.28	0.33	0.40	0.36
Iron	18.2	21.4	20.7	26.2	24.0	23.5
Gallium	<0.03	<0.03	<0.04	<0.03	<0.03	<0.04
Germanium	<0.05	<0.05	<0.07	<0.05	<0.05	<0.07
Mercury	<0.002	<0.002	<0.003	<0.002	<0.002	<0.003
Lanthanum	0.58	0.62	0.67	0.84	0.93	0.86
Magnesium	340	322	367	247	265	283
Manganese	0.97	1.11	1.02	1.34	1.20	1.09
Molybdenum	<0.02	<0.02	<0.03	0.06	0.05	<0.03
Nickel	0.77	0.89	0.69	0.58	0.51	0.64
Lead	<0.068	<0.072	<0.088	<0.041	<0.039	<0.076
Rubidium	<0.04	<0.04	<0.06	<0.03	<0.03	<0.05
Antimony	<0.011	<0.014	<0.019	<0.019	<0.018	<0.08
Selenium	<0.004	<0.004	<0.006	<0.004	<0.004	<0.006
Tin	11.2	10.9	8.7	14.3	14.8	15.9
Strontium	<0.038	<0.041	<0.066	<0.035	<0.041	<0.076
Titanium	<0.06	<0.06	<0.08	<0.05	<0.05	<0.07
Uranium	<0.10	<0.10	<0.15	<0.10	<0.10	<0.18

Table 5.26. Continued

	Station T					
	13W	14W	15W	16W	17W	18W
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.05	<0.05	<0.08	<0.05	<0.05	<0.08
Tungsten	<0.13	<0.14	<0.19	<0.11	<0.10	<0.16
Zinc	7.24	7.99	7.15	6.33	6.47	7.01
Zirconium	<0.08	<0.08	<0.11	<0.08	<0.08	<0.12
Silver	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<10	<10	<10	<10	<10	<10
Aliphatic Hydrocarbons (2)	<10	<10	<10	<10	<10	<10
Arylamines	<3	<3	<3	<3	<3	<3
Mono & polycyclic hydrocarbons: (3)						
Benzo(a)pyrene	Trace	Trace	Trace	ND	ND	ND
Sulfur compounds (4)	<8	<8	<8	<8	<8	<8
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<25	<25	<25	<25	<25	<25

Table 5.26. Continued

Description of Fish is as follows:

T - Tissue
W - Whole Fish

Station 1		
1T	-	Carp - Shock - 6 lbs. 4 oz. - 565gr - 5-14-80
Station 2		
2T	-	White Crappie - Hoop Net - 300mm - 260gr - 5-16-80
Station 3		
3T	-	Carp - Hoop Net - 4 lbs. 14 oz. - 5-14-80
4T	-	Carp - Shock - 7 lbs. 4oz. - 5-14-80
5T	-	White Crappie - Hoop Net - 335mm - 310gr - 5-16-80
6T	-	White Crappie - Hoop Net - 230mm - 160gr - 5-16-80
Station B - Bull Creek		
7T	-	Bluegill - Seine - 175mm - 98gr - 5-15-80
8T	-	Bluegill - Seine - 160mm - 78gr - 5-15-80
9T	-	Bluegill - Seine - 175mm - 92gr - 5-15-80
10T	-	Bluegill - Seine - 152mm - 68gr - 5-15-80
11T	-	Longear Sunfish - Seine - 135mm - 58gr - 5-15-80
		Longear Sunfish - Seine - 117mm - 32gr - 5-15-80
12T	-	Longear Sunfish - Seine - 124mm - 44gr - 5-15-80
	-	Longear Sunfish - Seine - 115mm - 38gr - 5-15-80
Station T - Town Creek		
13W	-	Creek Chub - Seine - 20mm - 1gr - 5-16-80
	-	Creek Chub - Seine - 80mm -10gr - 5-16-80
14W	-	Creek Chub - Seine - 52mm - 4gr - 5-16-80
	-	Creek Chub - Seine - 45mm - 6gr - 5-16-80
	-	Creek Chub - Seine - 14mm - 2.5gr - 5-16-80
15W	-	Creek Chub - Seine - 30mm - 2gr - 5-16-80
	-	Creek Chub - Seine - 55mm - 5.5gr - 5-16.80
	-	Creek Chub - Seine - 65mm - 6gr - 5-16-80
16W	-	Green Sunfish - Seine - 90mm - 20gr - 5-16-80
17W	-	Green Sunfish - Seine - 75mm - 16gr - 5-16-80
18W	-	Green Sunfish - Seine - 48mm - 8gr - 5-16-80
	-	Green Sunfish - Seine - 55mm - 10gr - 5-16-80

Table 5.27. Fish Tissue Data, Fall, 1980.

Station	1-A	2B	2A	Lower Town Ck.	2	3
	1T	2T	3T	4T	5T	6T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	13.6	2.43	1.79	0.43	4.79	1.63
Arsenic	<0.52	<0.55	<0.50	<0.53	<0.52	<0.53
Boron	11.59	<1.10	<0.99	<1.06	<1.03	<1.05
Barium	<0.02	0.07	<0.02	0.10	0.32	0.04
Beryllium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	0.15	0.12	0.10	0.22	0.19	0.24
Cadmium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cobalt	1.03	2.32	1.99	2.08	1.66	1.90
Chromium	0.15	1.80	0.37	0.24	0.35	0.38
Copper	14.80	4.68	1.48	7.61	5.62	4.61
Iron	8.28	29.60	3.84	10.78	22.02	18.15
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mercury	0.013	0.011	0.015	0.027	0.016	0.013
Lanthanum	0.98	0.76	0.54	0.73	0.28	0.33
Magnesium	263.00	333.00	300.00	328.00	303.00	299.00
Manganese	0.98	10.90	1.34	1.65	14.23	1.80
Molybdenum	<0.05	0.06	<0.04	<0.05	<0.05	<0.05
Nickel	7.05	10.42	<0.05	2.07	1.34	0.82
Lead	<0.25	<0.25	<0.05	<0.05	<0.05	<0.05
Rubidium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	<0.52	<0.55	<0.50	<0.53	<0.52	<0.53
Tin	6.70	8.20	4.30	3.70	2.90	4.40
Strontium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Titanium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.50
Uranium	<0.07	<0.07	<0.07	<0.07	<0.07	<0.07

Table 5.27. Continued

Station	Town Creek			Bull Creek		
	7C	8C	9C	10C	11C	12C
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	2.45	2.28	2.35	2.23	2.14	2.07
Arsenic	<0.64	<0.96	<0.82	<0.67	<0.59	<0.51
Boron	<1.59	<1.92	<1.64	<1.06	<1.18	<1.01
Barium	6.21	6.69	6.51	1.36	1.54	1.44
Beryllium	<0.09	<0.09	<0.05	<0.05	<0.05	<0.05
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	0.32	0.28	0.35	0.22	0.18	0.29
Cadmium	<0.09	<0.09	<0.07	0.23	0.22	0.24
Cobalt	5.61	5.21	6.26	1.00	0.83	0.94
Chromium	2.67	2.29	2.55	2.69	2.32	2.54
Copper	7.41	7.63	6.38	6.63	6.71	6.84
Iron	441.00	437.00	411.00	54.60	48.50	52.70
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mercury	0.06	0.04	0.04	0.07	0.06	0.06
Lanthanum	1.32	1.44	1.38	0.47	0.42	0.55
Magnesium	349.00	383.00	345.00	384.00	383.00	376.00
Manganese	59.30	67.40	59.40	2.02	1.89	1.87
Molybdenum	0.06	0.06	<0.05	0.07	<0.05	0.09
Nickel	0.82	0.86	0.91	0.60	0.55	0.57
Lead	<0.09	<0.09	<0.07	<0.06	<0.05	<0.06
Rubidium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	<0.64	<0.96	<0.82	<0.67	<0.59	<0.51
Tin	<0.05	<0.05	<0.05	0.25	0.31	0.30
Strontium	0.72	0.67	0.58	<0.25	<0.22	<0.09
Titanium	<0.90	<0.70	<0.70	<0.60	<0.50	<0.60
Uranium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Table 5.27. Continued

Station	Town Creek			Bull Creek		
	7C	8C	9C	10C	11C	12C
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.09	<0.09	<0.07	<0.06	<0.05	<0.06
Tungsten	<0.10	<0.08	<0.09	<0.11	<0.12	<0.12
Zinc	35.50	37.00	35.40	13.00	9.60	7.30
Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	<0.01	<0.01	<0.01	0.03	0.03	0.05
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<10	<8	<9	<10	<12	<12
Aliphatic Hycrocarbons (2)	24	22	18	<10	<10	<10
Arylamines	<3	<4	<3	<6	<6	<6
Mono & polycyclic hydrocarbons: (3)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfur compounds: (4)						
Thiophenes	<3	<3	<3	<3	<3	<3
Mercaptans	<3	<3	<3	<3	<3	<3
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<10	<10	<10	<10	<10	<10

Table 5.27. Continued

Station	Bull Creek			Town Creek		
	13C	14C	15C	16W	17W	18W
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	4.23	6.18	4.55	4.14	3.62	4.70
Arsenic	<0.55	<0.62	<0.73	<0.52	<1.23	<0.52
Boron	18.59	13.88	18.33	<1.03	2.45	<1.03
Barium	0.89	0.94	0.91	0.70	0.95	0.70
Beryllium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	0.28	0.21	0.27	0.19	0.23	0.19
Cadmium	0.43	0.49	0.48	<0.05	<0.08	<0.05
Cobalt	0.47	<0.06	0.65	<0.05	9.31	0.31
Chromium	1.93	2.30	1.88	1.93	2.06	1.63
Copper	6.25	12.50	6.20	4.02	4.67	3.31
Iron	33.60	23.70	32.20	20.90	21.80	29.40
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mercury	0.02	0.05	0.04	0.09	0.10	0.18
Lanthanum	0.92	0.86	0.88	<0.20	<0.18	<0.16
Magnesium	351.00	353.00	384.00	333.00	552.00	345.00
Manganese	6.39	3.78	6.19	11.80	11.20	9.21
Molybdenum	<0.04	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	3.20	1.25	3.90	0.33	0.35	0.19
Lead	<0.08	<0.08	<0.05	<0.08	<0.05	<0.05
Rubidium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	<0.55	<0.62	<0.73	<0.52	<1.23	<0.52
Tin	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Strontium	0.76	0.48	0.68	<0.21	<0.15	<0.24
Titanium	<0.06	<0.08	<0.07	<0.10	<0.10	<0.10
Uranium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Table 5.27. Continued

Station	Bull Creek			Town Creek		
	13C	14C	15C	16W	17W	18W
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.07	<0.08	<0.08	<0.05	<0.08	<0.05
Tungsten	<0.10	<0.14	<0.16	<0.14	<0.12	<0.19
Zinc	41.40	40.30	53.90	21.40	28.40	15.80
Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	0.03	0.02	0.02	<0.01	<0.01	0.28
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<8	<6	<7	<10	<11	<10
Aliphatic Hycrocarbons (2)	15	22	26	<10	<10	<10
Arylamines	31	15	12	<8	<6	<8
Mono & polycyclic hydrocarbons: (3)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfur compounds: (4)						
Thiophenes	<3	<3	<3	<3	<3	<3
Mercaptans	<3	<3	<3	<3	<3	<3
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<10	<10	<10	<10	<10	<10

Table 5.27. Continued

Station	Control Station			River Station		
	19M	20M	21M	22M	23M	24M
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Aluminum	75.60	53.70	75.70	101.00	52.60	49.40
Arsenic	<0.53	<0.87	<1.50	<0.52	<1.97	<0.74
Boron	<1.06	<1.74	<1.72	2.99	<0.39	<1.47
Barium	15.50	6.53	5.01	1.59	6.57	6.32
Beryllium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bismuth	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bromine	0.31	0.22	0.19	<0.20	0.48	0.21
Cadmium	0.46	0.78	0.82	0.41	0.37	0.21
Cobalt	2.73	1.57	1.41	0.10	4.93	8.84
Chromium	2.41	8.13	6.80	3.96	13.10	6.82
Copper	4.49	5.38	4.32	3.50	13.80	13.40
Iron	226.00	183.00	188.00	163.00	583.00	954.00
Gallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Germanium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Mercury	0.21	0.14	0.19	0.10	0.06	0.12
Lanthanum	0.76	0.42	0.54	0.30	0.32	0.19
Magnesium	279.00	196.00	176.00	240.00	384.00	316.00
Manganese	73.50	45.30	80.80	15.20	39.70	60.40
Molybdenum	<0.05	<0.05	<0.06	<0.05	<0.05	<0.05
Nickel	<0.05	0.16	0.37	0.31	0.72	0.87
Lead	0.83	2.09	1.35	<0.33	1.18	0.89
Rubidium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Selenium	<0.53	<0.87	<1.50	<0.52	<1.97	<0.74
Tin	<0.05	<0.05	<0.05	3.20	3.10	3.00
Strontium	0.56	0.74	0.62	<0.21	<0.18	0.36
Titanium	<0.40	<0.30	<0.35	<0.28	<0.25	<0.28
Uranium	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Table 5.27. Continued

Station	1-A	2B	2A	Lower Town Ck.	2	3
	1T	2T	3T	4T	5T	6T
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tungsten	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Zinc	8.57	6.76	4.82	9.10	13.60	7.87
Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<8	<6	<5	<7	<5	<4
Aliphatic Hycrocarbons (2)	<10	<10	<10	<10	<10	<10
Arylamines	<4	<6	12	<8	<6	<7
Mono & polycyclic hydrocarbons:(3)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfur compounds: (4)						
Thiophenes	<3	<3	<3	<3	<3	<3
Mercaptans	<3	<3	<3	<3	<3	<3
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<10	<10	<10	<10	<10	<10

Table 5.27. Continued

Description of Fish is as follows:

T - Tissue
W - Whole Fish
C - Composite
M - Mussel
MC - Mussel Composite

1-A / 1T	- White Crappie - 272mm, 249 g, 10-10-80
2B / 2T	- White Crappie - 270mm, 244 g, 10-10-80
2A / 3T	- White Crappie - 248mm, 198 g, 10-9-80
Lower Town Ck. / 4T	- Carp - 530 mm, 68 oz., 10-10-80
2 / 5T	- Carp - 455 mm, 3 lb. 4 oz., 10-10-80
3 / 6T	- Carp - 517 mm, 68 oz., 10-8-80
Town Creek	
7C) 8C) 9C)	- Pimephales spp. (23 fish) - 44 -75 mm, <1 -4 g, 10-9-80
Bull Creek	
10C) 11C) 12C)	- Bluegill (62 fish) 60 g, 10-9-80
13C	- Creek Chubs - 104 mm, 10g, 10-25-80
14C) 15C)	- Creek Chubs (12 fish) 20 g, Total Rec;d 10-9-80 & (5 fish) 8 g, Rec'd 10-25-80
Town Creek	
16W	- Green Sunfish - 122 mm, 32 g, 10-9-80
17W	- Green Sunfish - 80 mm, 12 g, 10-9-80
18W	- Green Sunfish - 117 mm, 32 g, 10-25-80

copper in the environment must have been greater in the fall. This was found to be true in both water and sediments (see Chapter 10).

A comparison below of the present data with other data from the same area (U.S. EPA, in press) shows that cadmium and mercury were higher in the latter and copper, chromium and manganese higher in the former. It should be noted that the high cadmium and mercury values were from the muscle of largemouth bass, a fish at the top of the food chain.

	Cadmium	Chromium	Copper	Lead
U.S. EPA, (1981)	0.03-0.46	<0.03-0.65	0.66-2.17	<0.01-0.48
Dames & Moore (1981)	0.02-0.05	0.15-1.8	0.04-14.8	<0.037-<0.25

	Manganese	Mercury	Zinc
U.S. EPA, (1981)	0.12-0.85	<0.02-1.16	1.2-13.0
Dames & Moore (1981)	<0.04-14.2	<0.001-027	4.8-13.6

ORSANCO (1980) reported the results of analysis made by the FDA of fish muscle from the Ohio River for certain pesticides and other trace organic chemicals and a few heavy metals. Carp and minnows contained low levels of all constituents, while several catfish contained excessive amounts of chlordane and PCB's. However, most of the problems were from the Upper Ohio River.

Analyses of mussels from Station 3A show that many constituents, including cadmium, mercury, manganese and organic compounds, were lower in the fall than in the winter (Table 5.28 - 5.30). However, due to the difference in species between dates and the low number of observations, the significance of this finding is not known.

Table 5.28 Mussel Tissue Analyis from the Ohio River. [a,b,c]

Parameter	Station 3[d] (7 Observations)	Upstream Control[ef] (3 Observations)
Aluminum	43.14(12.5-101.0)	(53.7-75.7)
Arsenic	<1.6 (<0.52-<2.7)	(<0.53-<1.50)
Boron	<14.33(<0.39-27.34)	(<1.06-<1.72)
Barium	25.6 (1.59-43.2)	(5.01-15.50)
Beryllium	<0.07(<0.05-<0.14)	(<0.05)
Bismuth	<0.05(<0.01-<0.09)	(<0.01)
Bromine	<7.16(<0.20-<13.67)	(0.19-0.31)
Cadmium	0.58 (0.21-0.902)	(0.46-0.82)
Cobalt	3.93 (0.10-8.84)	(1.41-2.73)
Chromium	11.20 (3.96-34.0)	(2.41-8.13)
Copper	13.06 (3.50-41.40)	(4.32-5.38)
Iron	427.6 (163-954)	(183-226)
Gallium	<1.3 (<0.02-<2.2)	(<0.02)
Germanium	<0.09(<0.02-<0.18)	(<0.02)
Mercury	2.19 (0.06-9.57)	(0.14-0.21)
Lanthanum	<0.5 (0.19-<0.9)	(0.42-0.76)
Magnesium	276.9(239-384)	(176-279)
Manganese	412.0(15.2-941)	(45.3-80.8)
Molybedunum	<0.06(<0.05-0.28)	(<0.05-<0.06)
Nickel	0.31(<0.05-9.16)	(<0.05-0.37)
Lead	0.72(<0.33-2.32)	(0.83-2.09)
Rubidium	<0.07(<0.02-<0.14)	(<0.02)
Antimony	<0.02(<0.01-<0.02)	(<0.01)
Selenium	<1.6 (<0.52-<2.7)	(<0.53-<1.50)
Tin	1.49(<0.5-4.4)	(<0.05)
Strontium	0.23(<0.18-0.46)	(0.56-0.74)
Titanium	<0.3(<0.25-<0.3)	(<0.30-<0.40)
Uranium	<0.08(0.03-0.09)	(<0.08)
Vanadium	<0.08(<0.07-<0.20)	(<0.05-<0.15)
Tungsten	<0.22(<0.19-<0.38)	(<0.07-<0.12)
Zinc	24.59(13.90-37.20)	(39.90-46.60)
Zirconium	<0.14(<0.05-<0.25)	(<0.05)
Silver	0.03(<0.01-0.09)	(<0.01)
Phenols	<10 (<10-<11)	(<7-<8)
Aliphatic Hydrocarbons	160 (<10-590)	(<10-27)
Arylamines	<0.5(<0.5-<6)	(<3-<4)
Mono- and Polycyclic Hydrocarbons	<3.0(<0.01-<3.0)	(<0.01)
Sulfur Compounds	12 (<6-22)	(<6)
Chlororganics	<3 (<1-<4)	(<1)
Chloramines	<10 (<10-<100)	(<10)

Table 5.28 Continued.

Parameters	Station 3[d] (7 Observations)	Upstream Control[ef] (3 Observations)

[a]Results in ppm wet weight
[b]Means and (ranges); medians and (ranges) when one or more observations reported as a less than (<) value
[c]See Section 5.4.7 for description of mussels
[d]Collected October 1980 and January 1981
[e]Collected October 1980
[f]Ohio River Mile 704.3, Indiana side.

Table 5.29. Mussel Tissue Data, Ohio River, Fall, 1980.

Station	Control Station			River Station		
	*19M	20M	21M	22M	23MC	24M
	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg	As Is mg/Kg
Vanadium	<0.05	<0.09	<0.15	<0.07	<0.20	<0.07
Tungsten	<0.10	<0.07	<0.12	<0.30	<0.28	<0.19
Zinc	45.60	41.15	39.90	13.90	37.20	28.70
Zirconium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Silver	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Phenols (1)	<8	<7	<8	<10	<11	<11
Aliphatic Hycrocarbons (2)	27	22	<10	28	15	<10
Arylamines	<3	<4	<3	<6	<6	<6
Mono & polycyclic hydrocarbons: (3)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfur compounds: (4)						
Thiophenes	<3	<3	<3	<3	<3	<3
Mercaptans	<3	<3	<3	<3	<3	<3
Chlororganics (5)	<1	<1	<1	<1	<1	<1
Chloramines	<10	<10	<10	<10	<10	<10

* 19M - Pink Heelsplitter
20M - Threehorn
21M - Threehorn
22M - Pink Heelsplitter
23MC - Composite of 3 Asiatic clams
24M - Threehorn

Table 5.30. Mussel Tissue Data, Ohio River, Winter, 1981.[a]

	1 mg/Kg As Is	2 mg/Kg As Is	3 mg/Kg As Is	4 mg/Kg As Is
Aluminum	12.5	45.6	16.6	24.3
Arsenic	<1.6	<1.7	<2.7	<1.4
Boron	<15.92	<17.16	<27.34	<14.33
Barium	42.7	41.6	37.2	43.2
Beryllium	<0.08	<0.09	<0.14	<0.07
Bismuth	<0.06	<0.07	<0.09	<0.05
Bromide	<7.96	<8.58	<13.67	<7.16
Cadmium	0.732	0.901	0.902	0.566
Cobalt	4.22	2.06	3.15	4.23
Chromium	6.77	4.82	34.00	8.95
Copper	4.04	5.07	41.40	10.20
Iron	362.0	316.0	298.0	317.0
Gallium	<1.4	<1.5	<2.2	<1.3
Germanium	<0.10	<0.11	<0.18	<0.09
Mercury	1.38	0.86	9.57	3.26
Lanthanum	<0.6	<0.7	<0.9	<0.5
Magnesium	242.0	255.0	262.0	239.0
Manganese	741.0	714.0	373.0	941.0
Molybedunum	<0.06	0.15	0.28	0.10
Nickel	<0.05	<0.05	9.16	1.63
Lead	<0.40	0.43	2.32	0.72
Rubidium	<0.08	<0.09	<0.14	<0.07
Antimony	<0.02	<0.02	<0.02	<0.02
Selenium	<1.6	<1.7	<2.7	<1.4
Tin	3.6	<0.5	4.4	2.9
Strontium	0.19	0.23	0.28	0.46
Titanium	<0.3	<0.3	<0.3	<0.3
Uranium	<1.8	<1.9	<2.4	<1.6
Vanadium	<0.08	<0.09	<0.14	<0.07
Tungsten	<0.22	<0.24	<0.38	<0.20
Zinc	20.2	22.2	30.9	19.0
Zirconium	<0.15	<0.18	<0.25	<0.14
Silver	0.09	0.03	0.07	0.06

Table 5.30. Continued

	1 ug/Kg As Is	2 ug/Kg As Is	3 ug/Kg As Is	4 ug/Kg As Is
Phenols (1)	<10	<10	<10	<10
Aliphatic Hydrocarbons (2)	450	590	380	160
Arylamines	<0.5	<0.5	<0.5	<0.5
Mono & polycyclic hydrocarbons (3)	<3.0	<3.0	<3.0	<3.0
Sulfur Compounds (4)	12	18	22	14
Chlororganics (5)	<4	<3	<4	<4
Chloramines	<100	<100	<100	<100

[a] Four Threehorned wartybacks collected at St. 3A.

Of the toxic trace elements, cadmium and lead in bivalves sometimes exceeded levels found in the sediments collected in the spring. Most constituents in bivalves were present in greater amounts than in the fish but were lower than in the fall sediments samples. Mercury, however, was generally more concentrated in the mussels than in the sediments from either date. In fish it has been found that mercury, unlike other trace metals, is not regulated in muscle tissue but accumulates with time (Wiener and Giesy 1979). If this is also true for mussels, mercury may accumulate to greater amounts than are present in the sediments. Several other metals have been found to reach a maximum in mussel tissue during sexual maturation in juveniles and then to decrease with later life stages (Boyden, 1977, Foster and Bates, 1978).

5.5.7.2 Town Creek

Fish tissue data from the creeks are difficult to compare to that of the Ohio River due to the differences in species and tissue type between stations. They can, however, be compared to values in the literature. One trend that was evident and similar to results from the river was the greater amount of metals in the fall (Tables 5.26 and 5.27). Most metal concentrations were lower than those found in fish tissue from the river and thus, in line with those from uncontaminated environments cited in the literature. Zinc and chromium were higher in tissue from both creeks but still within the ranges reported from whole fish from uncontaminated environments (Uthe and Bligh, 1971, Giesy and Wiener, 1977, Murphy et al., 1978, Wiener and Giesy, 1979).

5.5.7.3 Bull Creek

Fish from Bull Creek contained low levels of most constituments. Several of the metals, including barium, cadmium, chromium, copper, and mercury were again considerably higher in the fall (Tables 5.26 and 5.27). Cadmium was higher in the creek chubs than most values in the literature from unpolluted environments (Uthe and Bligh, 1971, Giesy and Wiener, 1977, Lucas et al., 1978, Van Hassel et al., 1980).

5.6 QUALITY CONTROL

As required by the Dames and Moore Lexington "Quality Control Plan," principal aquatic ecology personnel met and discussed important goals and objectives, pertaining to fish studies for the ASFI baseline study, at the onset of the project. Potential problems were designated according to site morphology and plant operational plans.

Field collections followed EPA approved methods as indicated in Section 5.4. Field logs are maintained to document daily progress. Records of all sampling parameters, client, location, data, time, collector(s) name, sampler types, preservative volume and other observations are made. Every attempt is made to assure that the field collections are of high quality, and will produce useful data.

After each field trip the project manager reviews the field memo. This review process is a check on difficulties which occurred in the field and what, if any, methods or procedures were aborted/modified. All alterations, if any, are recorded and placed in the respective job files.

The Dames & Moore biological laboratory is organized so that the QC plan may easily be integrated into its routine filing system. Qualified laboratory personnel acknowledge receipt of samples by recording each sample in the laboratory log book. The information recorded must include: sample number or ID, number of samples, client, data, time, type of sample, collecting device, collector, preservative and volume and other pertinent data. This serves as a complete inventory, and a check for proper identification or labeling of all samples arriving in the lab. It also is a check to verify that correct methods and procedures were used to obtain the sample.

After the samples are logged into the laboratory they are placed in storage until they can be processed. Once sample processing begins, it is carried out in an expedient manner by qualified personnel. Laboratory records such as sorting logs, bench sheets, certifications and calibration sheets pertaining to each set and type of sample is maintained and kept on file throughout the duration of the project.

Specific QC procedures are carried out by reviewing all lab records to determine overall quality. The review would include reanlayzing 10% of the samples to determine efficiency of proposed lab evaluations, and a check of calculation procedures to determine accuracy. This is done to insure the quality of laboratory work being performed, and in turn enhances the overall reliability of the data produced.

When difficulties in taxonomic identification arise or potential rare or endangered species are encountered outside experts in the respective field, discipline or speciality are called upon to confirm identifications.

Data analysis includes tabulation, enumeration, general mathematical evaluations and statistical evaluation. During the course of applying data analysis records are maintained for documenting all calculations, equations and formulae and other statistics. These documents are kept in the respective job files and reviewed by qualified professionals to assure that proper scientific rationale and resultant evaluations have been made.

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Vegetation

6.0 VEGETATION

6.1 INTRODUCTION

During the summer, fall, and winter of 1980 and spring of 1981, five field trips, each of approximately five days duration, were made to the project site. The purpose of these field trips was to assess the existing composition and condition of the plant communities and associated wildlife upon which prediction of site development impacts can be based.

This chapter is divided into the following sections: background and objectives, threatened and endangered species, sampling methodology and frequency, sampling location and rationale, results and discussion, quality assurance, and references. The vegetation data are discussed by overstory, understory, and ground cover as they relate to the habitat types which include bottomland, midslope, and upland hardwood forests, and oldfield communities. Other plant communities treated in this chapter include riparian areas, roadsides, fencerows, railroad rights-of-way, and wetlands.

6.2 BACKGROUND AND OBJECTIVES

The project vicinity lies in the Interior Low Plateau physiographic province (Hunt, 1967). Topographically it is characterized by moderate to steeply rolling hills ending abruptly at the Ohio River floodplain. Drainage patterns are dendritic with headwater areas of streams entrenched in rather narrow ravines. Lower sections of streams are sluggish with wider floodplains and are subject to inundation from Ohio River backwater. The region is underlain by both sandstones and limestones. Small springs and seepages are common where the limestones outcrop.

The topography, surface water drainage, and variety of parent material have allowed the development of a variety of plant communities. Braun (1950) included the area in the Western Mesophytic Forest region. This is a transition region from the mixed mesophytic forest communities in the east and the oak and oak-hickory forests farther west. Mixed mesophytic forest is characterized by a single climax type usually with 20 to 25 species as co-dominants. The most indicative trees of this type are basswood (_Tilia heterophylla_) and sweet buckeye (_Aseculus octandra_). The species composition of the mixed mesophytic forest is primarily controlled by climate, but as one moves westward climatic control lessens and other factors such as ground water, soil fertility and topography exert a greater influence on vegetational development. These transition forests are generally dominated by fewer species, but there is a greater variety of forest types.

Braun (1950) identified six sections of the Western Mesophytic Forest region. The project area lies in the Hill Section, which is distinguished by the large component of mixed mesophytic forest on slopes. More specifically, the project area is in the Shawnee physiographic subsection which is vegetationally very similar to the Knobs of Kentucky. Forest communities range from mixed mesophytic on ravines and lower slopes to very xerophytic communities on uplands, ridge crests and limestone ledges. See Table 6.1 for forested acreage in the project area.

Agricultural development, cultivated and pasture land, accounts for approximately 1000 hectares (2470 acres) or 23 percent of the project area, defined as site and both waste disposal areas (Table 6.1 and Figure 6.1). Approximately 84 percent (815 hectares or 2013 acres) of this land is on the plant site. The cultivated land is in row crops (corn, soybeans and some tobacco) and pasture land is used for cattle grazing. The majority of the agricultural land on the plant site is prime farmland. For a more detailed discussion of prime farmland, see Section 9.5.

The major plant communities in the project area, based on acreage, are forests, cultivated lands, pasture, and oldfields. Of these, only the forests could be considered natural communities although the oldfields are generally in mid-successional stages developing toward a forest community.

The objective of this study is to assess the existing condition of the plant communities in the project vicinity in order to be able to predict, as accuratley as possible, the potential effects of site development on those communities.

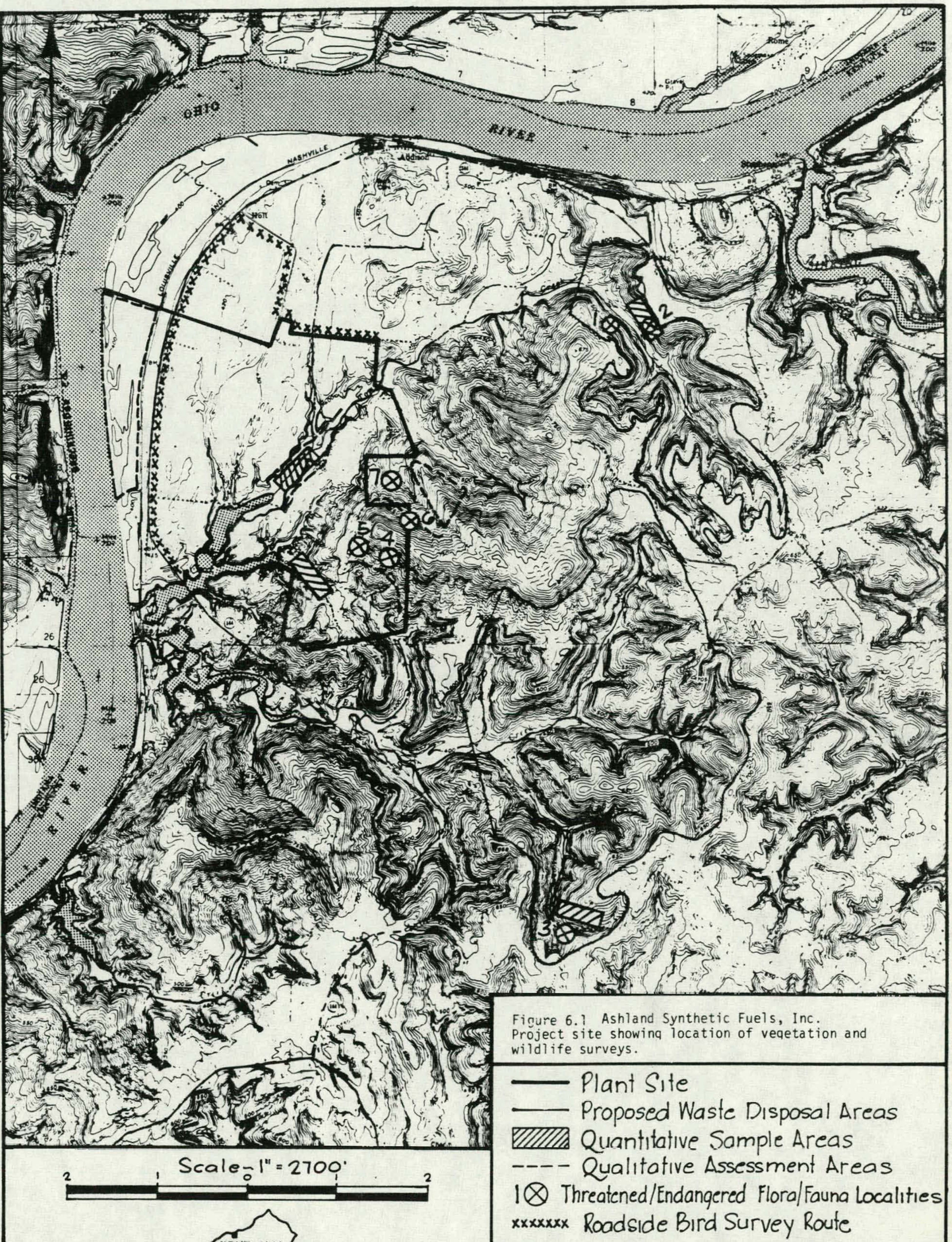

Figure 6.1 Ashland Synthetic Fuels, Inc.
Project site showing location of vegetation and wildlife surveys.

6.3 THREATENED AND ENDANGERED SPECIES

Summer, fall and winter sampling have not revealed the presence of any federally threatened or endangered plants. However, the Kentucky Nature Preserves Commission has recently completed their Natural Areas Plan (Harker et al., 1980) which includes extensive data on plants considered rare, threatened or endangered in Kentucky. Nine species, for which suitable habitat appears to exist on or near the site, are either known from Breckinridge County or occur in nearby counties. These species are listed in Table 6.2.

The definitions of the state status categories listed in Table 6.2 are as follows:

> Endangered: A species which is in danger of extirpation and/or extinction throughout all or a significant portion of its range in Kentucky, including those species proposed or recognized as federally endangered that occur in Kentucky. For plants, this includes those species occurring in Kentucky that are listed as endangered in the 1978 Smithsonian Report or published in the Federal Register. Species listed as threatened Federally may be listed as endangered for Kentucky.
>
> Threatened: A species which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range in Kentucky, including those species proposed or recognized as Federally threatened that occur in Kentucky. For plants, this includes those species occurring in Kentucky that are listed as threatened in the 1978 Smithsonian Report.
>
> Special Concern: A species about which sufficient information exists that indicates it should be continually monitored because (a) it exists in a limited geographic area, (b) its existence may become threatened or endangered due to modification or destruction of its habitat, (c) certain characteristics or requirements make it especially vulnerable to specific pressures, or (d) ot other reasons identifiable by experienced researchers.

During field work in August, 1980 two small colonies of Hydrastis canadensis (goldenseal) were found in the northern waste disposal area. These are noted as localities one and two shown on Figure 6.1. Also during that survey, a colony of Veratrum woodii (false hellebore) was found in the southern waste disposal area (locality three on Figure 6.1). At that time both species were listed as threatened on the U.S. Department of Interior Fish and Wildlife Service's rare plant list, 40 FR, 27823, July 1, 1975. Consequently this prompted a special field trip in early September to more extensively survey the project area and vicinity to gain some insight into the distributional status of these plants in the area. No other colonies of false hellebore were found. However, localities four, five, and seven on Figure 6.1 had small colonies of goldenseal. Also, localities three, six, and seven had small colonies of ginseng (Panax quinquefolium). This species was also listed as threatened on both state and federal lists.

Subsequent to these surveys, false hellebore was dropped from both state and federal lists; goldenseal was dropped from the federal list and given special concern status by the KNPC; and ginseng was dropped from the federal list and remained in the threatened category on the KNPC Natural Areas Plan (Harker et al., 1980).

6.4 SAMPLING METHODOLOGY AND FREQUENCY

6.4.1 Overstory and Understory

The bottomland, midslope, and upland hardwood vegetation types were sampled by the point-centered-quarter (PCQ) method (Cottam and Curtis, 1956; Phillips, 1959). This method provides quantitative information about relative density, relative frequency, relative dominance, species frequency, and total basal area. A total of 40 points for overstory and 40 points for understory was run. The distance between points was 15.2 m (50 ft). Each point was divided into four 90° segments, and the closest tree to the point was tallied. This tally included distance from the point, species, and the diameter at breast height (dbh) or 1.4 m (4.5 ft). Distance and dbh were used to estimate the basal area per acre for each species. In each PCQ survey, 40 points were utilized, providing data on 160 trees. Overstory strata were limited to trees greater than 20.3 cm (8.0 in) dbh, whereas understory strata included woody species less than 20.3 cm dbh and greater than 6.4 cm (2.5 in) dbh. The following calculations were performed on the overstory and understory data:

1. Distance = distance from point-center to species.
2. Mean distance = sum of distances divided by number of measurements.
3. Total density (plants/hectare) = 10,000 m^2 (1 hectare) divided by mean area (m^2) of plants.
4. Relative density = quotient of number of individuals of one species divided by number of individuals of all species, multiplied by 100.
5. Frequency of species = number of points at which species

occur divided by total points (40).

6. Relative frequency = quotient of frequency of individual species divided by sum of frequency values of all species, multiplied by 100.
7. Basal area per tree = total basal area divided by number of trees.
8. Relative dominance (cover[a]) = quotient of total basal area of one species divided by total basal area of all species, multiplied by 100.
9. Total basal area = mean area times density.
10. Importance value = relative density plus relative dominance plus relative frequency.

[a]Relative dominance applies to overstory and understory species; relative cover applies to ground cover.

(After Cottam and Curtis, 1956)

The overstory and understory were sampled in the fall. Sampling locations and rationale for selection are presented in Section 6.5.

6.4.2 Herbaceous Ground Cover

Ground cover and grassland vegetation were sampled by the microplot-quadrat method (Kershaw, 1964; Daubenmire, 1968), which employs uniformly spaced sampling points. The size of the microplot-quadrat frame was 0.1 m^2 (1.07 ft^2). In the oldfield vegetation (consisting primarily of graminoid species), 40 sampling points were established at 7.6 m (25 ft) intervals. In the forested sample areas ground cover was sampled at every fourth point yielding 10 sample points. Calculations for the microplot-quadrat method included stems per acre (computer program set up for English instead of metric), absolute frequency, relative frequency, absolute density, relative density, absolute percentage cover, and relative percentage cover. Importance values were based on the summation of relative percentage cover, relative density, and relative frequency.

These communities were sampled during spring, summer and fall. Sampling locations and rationale for selection are presented in Section 6.5.

6.4.3 Qualitative Assessment

In addition to quantitative sampling, several areas on the plant site, in the waste disposal areas, and in the project vicinity were walked over (Figure 6.1). The purposes of these surveys were to: 1) make an overall assessment of species composition and condition of the plant communities (logging frequency, fire damage, successional trends, etc.); 2) provide some ground truthing information for the false color infrared photographs, from which the vegetation maps were made; and, 3) search for unique, threatened, or endangered species or suitable habitats.

6.5 SAMPLING LOCATION AND RATIONALE

In mid May, 1980, a half day preliminary site reconnaissance was made to familiarize investigators with the topography, drainage systems, vehicular access, and general plant community types. At this time it was decided that, due to the size of the project (approximately 8465 hectares [3500 acres]), false color infrared aerial photographs would be necessary before vegetation sampling locations could be chosen. After examination of the aerial photos, 7.5 minute topographic maps, and field notes from the site reconnaissance, four plant community types were selected for quantitative sampling. These are bottomland hardwoods, midslope hardwoods, upland hardwoods, and oldfields. These sampling locations are shown on Figure 6.1.

The bottomland forest along Town Creek was selected because it is a distinct plant community and is located on the proposed plant site. Also the preliminary site reconnaissance revealed that this is a mature bottomland forest and is excellent wildlife habitat, especially for whitetailed deer and woodcock.

The northern waste disposal area was selected for the midslope woodland sampling area, because a section of relatively undisturbed mature woodland surrounded by highgraded woodland is found along the southwest facing slope. The southern waste disposal area was selected for the upland hardwoods sampling site mainly because this was the only area under consideration for development that contained any appreciable acreage of this plant community. Upland hardwoods were sampled because they are vegetationally distinct from the other two forest types and also provide wildlife habitat and especially food (mast) producing trees such as oaks and hickories, which are important to whitetailed deer and squirrels.

By selecting quantitative vegetation sampling sites for woodland in all three potential development areas, a good area-wide data base for this vegetation type can be obtained, thus helping to minimize sampling bias, with respect to the vegetation types, that would have been present had only the plant site itself been sampled for these three woodland types.

The southeastern corner of the plant site was selected for oldfield sampling because: 1) it contained suitable acreage of this plant community, 2) it appeared representative of oldfields in the general area, and 3) access was better compared to some other oldfield areas noted on the aerial photographs.

An additional, but equally important, rationale for the vegetation sampling locations was their suitability as wildlife sampling areas (note Section 7.5).

6.6 RESULTS AND DISCUSSION

Quantitative sampling and qualitative assessments of the vegetation on the plant site and waste disposal areas were done on four field trips, totaling approximately 20 days in 1980 and 1981. Table 6.3 is a master list of 310 species by plant form and habitat type of the vascular plants observed during these field trips. This is not intended as a complete list of the flora of these areas. Figures 6.2 a, b, and c show the major vegetation cover patterns for the plant site, southern and northern waste disosal areas, respectively.

6.6.1 Bottomland Hardwood Forest

This forest type is located in the floodplains of Town and Bull Creeks, primarily along the lower 4,000 feet of Town Creek. The Town Creek bottomland forest encompasses about 25 acres of seasonally inundated land. This woodland was sampled for overstory and understory trees in Fall, 1980 and ground cover was sampled in Summer and Fall, 1980 and Spring, 1981. Results of sampling are shown in Table 6.4 overstory, Table 6.5 understory and Tables 6.6, 6.7, and 6.8 ground cover. A graphic presentation of the overstory and understory data is found in Figures 6.3 and 6.4, respectively.

As seen in Table 6.4 and Figure 6.3, the dominant canopy trees are silver maple, sycamore, box elder, hackberry, slippery elm, white ash, and cottonwood. The understory composition shown in Table 6.5 and Figure 6.4 indicates that the canopy structure is fairly stable and successional trends are not readily evident. Figure 6.4 shows the understory composed of approximately the same species as the canopy which indicates that any replacement of canopy trees will be by those already represented in the canopy. Thus a stable, climax community is indicated.

The ground cover data are presented in Table 6.6 for spring, Table 6.7 for summer, and Table 6.8 for fall. As can be seen from these data, the overall herbaceous species composition changed little during one growing season. Also, the number of species occurring in the sample plots was not significantly different from season to season; spring, 13 species, summer, 16 species, and fall, 12 species.

Based on the above data and on observations spanning approximately one year, this bottomland forest appears rather typical of the area. Hosner and Minckler (1963) sampled 62 bottomland hardwood forests in southern Illinois, mainly along the Mississippi River. Their extensive data indicate that a cottonwood-willow community develops on new alluvium. This community develops into a box elder, silver maple, elm, and ash community which eventually develops into a mixed soft-hardwood association. This association consists primarily of silver maple, ash, elm, sweet gum, willow, sycamore, and box elder (based on basal area data). Their data indicate that these stands generally reproduce to the same species with a tendency toward an increase in hackberry. Results of the present study are quite similar in species composition with some variations in frequency of occurrence and basal area among the species. The variations can likely be attributed to differences in micro-climate and water table levels and frequency and duration of surface and ground water fluctuations.

This Town Creek bottomland forest is not a virgin stand; there is ample evidence of past disturbance. Small areas have been cleared within the past 30 years, but have been abandoned and are now rapidly developing to the mixed soft-hardwood stand previously described. During the fall, winter, and early Spring of 1980-1981 the steep northwest facing slope of Town Creek was extensively logged. This was but a small portion of approximately 1,600 acres of timber on and adjacent to the site and the southern waste disposal area that was logged by high-grading. A more detailed discussion of this can be found in the following section. The effects of logging this slope on the bottomland forest are uncertain, but the increased light intensity to the bottomland adjacent to the slope may alter species composition and frequency somewhat. It is not anticipated that this perturbation will have significant long term impacts on the bottomland forest.

Although this forest type is not unique in the area or in the state, it is becoming much rarer due to increased floodplain industrial development and continued clearing for farmland. This area is classified as a palustrine forested wetland and will be discussed in the wetland section.

In addition to being an important habitat for a variety of plants that are restricted to moist areas, this forest is a very important and highly productive wildlife habitat and will be discussed in that section.

6.6.2 Midslope Hardwood Forest

The midslope and upland forests comprise approximately 99 percent of the forested acreage in the project area. The midslope forest sampled is on a southwest facing mesic slope in the northern waste disposal area (see Figure 6.1). Nineteen species of canopy trees were sampled. Table 6.9 shows frequencies, dominance, densities and importance values for these species and, Figure 6.5 shows the density-size class dendrograph. These data show beech, sugar maple, shumard oak, white oak, white ash, pignut hickory, tulip tree, black oak, and shagbark hickory as the dominant canopy species. The average age of this forest was estimated using the growth rate data of Fowells (1965). The average ages of oaks, hickories, sugar maple and beech were calculated, omitting the unusually large trees, because they were undoubtedly passed over when the woodland was first cut and their inclusion would bias the estimate. The average age of beech was 194 years (12 trees measured). Almost all of these large beech trees were hollow at the hole and thus were unmarketable. This is a common occurrence in this species, since they are susceptible to fire damage and subsequent disease. As with the other unusually large trees, they were probably passed over in previous logging operations. Average age of oaks was 103 years (36 trees sampled), hickories, 65 years (13 trees sampled), and sugar maple, 96 years (36 trees sampled).

Results of understory sampling are found in Table 6.10 and Figure 6.6. Sugar maple is the most important understory canopy species with shagbark hickory, beech, slippery elm, and white ash appearing in descending order. These are the species most likely to replace old canopy trees as they are removed from the stand. Based on these data, it appears that the stand is in a climax condition meaning that significant changes in the present composition are not expected except as a result of climatic or geologic changes. Vankat, Blackwell, and Hopkins (1975) studied a beech-maple forest in the southern portion of the range of this forest type in southwestern Ohio and did an extensive search and evaluation of the pertinent literature. It has long been hypothesized that the southern beech-maple forest is successional and is undergoing directional change in structure and composition toward western mesophytic or mixed mesophytic forest (Sears, 1926; Braun, 1941, 1950). Vankat, et al. have concluded that "since there is no firm factual evidence of successional change, we propose that Heuston Woods, as an example of the southern portion of the beech-maple forest, is probably in a state of dynamic equilibrium, with no apparent successional trend toward a western or mixed mesophytic forest." Results of the present study support those conclusions.

Results of ground cover sampling are found in Table 6.11, 6.12, and 6.13. This herbaceous ground cover is typical of mature mesic slope woodlands. In addition to those species sampled, several other uncommon plants were found here Goldenseal (Hydrastis canadensis) occurs in several large colonies on this slope, and ginseng (Panax quinquefoliam) was found sporadically on the opposite slope. These two plants are on the Kentucky Nature Preserves Commission's list of rara plants (see Section 6.3). The northern fragile fern (Cystopteris fragilis var. mackayi was found on the moist sandstone ledges that form an almost unbroken cliff line in this woodland. Cranfill (1980) considers this a very rare plant in Kentucky, having been positively identified only from Hardin and Crittenden Counties. These localities appear to be near the southern terminus of its range.

This mature beech-maple forest, (see Figure 6.1, northern waste disposal area sample site) approximately 30 acres, is uncommon in Kentucky and is of scientific and educational interest. The woodland surrounding this site has been logged within the past five years (Paul Dowell, land owner, personal communication, August, 1980) and the woodlands throughout the area either have recently been, or are now being logged. Only one other mature to old growth midslope woodland was found in the area. This was on the steep northwest facing slope of Town Creek and was logged in the Fall and Winter of 1980.

In general, the midslope woodlands of the project area re second and third growth and are typical in composition to western mesophytic forests (Braun, 1950).

6.6.3 Upland Hardwood Forest

The upland hardwood sample area is located in the southern waste disposal area (Figure 6.1). This forest type occupies the drier upper slopes and ridges of the project area. Results of overstory sampling are in Table 6.14 and Figure 6.7 and understory results are in Table 6.15 and Figure 6.8. Dominant canopy species here are black oak, post oak, white oak, shagbark hickory, red cedar, and pignut hickory. As Table 6.7, the density-size class dendrograph, shows the canopy trees are rather small in average basal area but are fairly dense. This is indicative of a young woodland. There is ample evidence of recent logging in all upland woodlands in the project area, and the data shows this. Especially indicative of this is the occurrence of significant numbers and sizes of red cedar in both the overstory and understory. Red cedar is a typical invader of oldfields and other disturbed areas. It is also a major component of the eastern red cedar-hardwood type, which is a mixture of white and red oaks, hickories, black walnut, and other hardwood (Fowells, 1965).

The composition of the understory is indicative of the successional trends of the woodland. Dominant understory species are sugar maple, red cedar, chestnut oak, black oak, slippery elm, post oak, and dogwood (rarely a canopy species). From these data, it appears that the canopy composition will change slightly with a probable increase in occurrence of sugar maple and chestnut oak and the continued presence of red cedar in the stand.

Results of ground cover sampling are in Tables 6.16, 6.17, and 6.18. This species composition is typical of that found throughout the area.

6.6.4 Oldfield Communities

The oldfield community was sampled first in Summer, 1980 (see Figure 6.1 for location), and those results are in Table 6.19. Subsequent to that sample the area was subjected to heavy grazing by cattle in the fall, and winter of 1980, and spring of 1981. This made further sampling of this area useless, since results would not be comparable. The summer sample yielded 33 species the most important of which were Korean lespedeza, broom-sedge, meadow fescue, mistflower, and three-awned grass.

Woody invader species in this community are red cedar, sycamore, black cherry, white ash, sassafras, sweet gum, winged sumac, smooth sumac, coral-berry, usage orange, winged elm, greenbrier and multiflora rose.

Although this community does not occupy a large percentage of the project area (less than five percent) it is an important wildlife habitat.

6.6.5 Qualitative Assessment Areas

Riparian areas (river and stream banks), roadsides, fencerows, railroad right-of-way, and wetlands on the plant site were investigated by walking over the areas and identifying major components of the plant communities.

6.6.5.1. Riparian areas

Woody vegetation along the Ohio River consisted of silver maple, box elder, black willow, cottonwood, and sycamore. Hosner and Minckler (1963) found the same species composition on newly formed land along the Mississippi River in southern Illinois. These trees were in the sapling growth stage and formed a very narrow band along the edge of the high cut-bank between the river and cultivated land. Based on field observation, it appears unlikely that this community will reach maturity, since lateral bank erosion destroys portions of this community as fast as it is formed. Herbaceous species found here are typical of those found on disturbed sites such as roadsides and fencerows discussed in the next section.

6.6.5.2 Roadsides, fencerous, and railroad right-of-way

These areas support a similar variety of woody invader species as that found in oldfield communities discussed in the previous section. Additional woody species that commonly occur here are bittersweet, honey locust, shingle oak, hackberry, and abundant poison ivy.

Some typical herbaceous species found here are yellow horse-gentian, poke, giant ragweed, common ragweed, blackberries, wormwood, ironweed, trumpet-vine, foxtail, common milkweed, johnson-grass, jimson-weed, horse-nettle, and thistles.

This type of plant community is common in any disturbed area throughout the region, and its primary significance is as wildlife habitat.

6.6.5.3 Wetlands

Based on the United States Department of the Interior Fish and Wildlife Service classification system (Cowardin et al., 1979), there are two types of wetlands on the site. Both types are in the Palustrine System; one is classed as Emergent Wetland and the other as Forested Wetland (see Figure 6.2a for locations on the plant site). The Palustrine System includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below five percent. It includes small, shallow, permanent or intermittent water bodies often called ponds. These wetlands may be situated shoreward of lakes, river channels, or estuaries; on river floodplains; in isolated catchments; or on slopes (Cowardin et al., 1979).

The small ponds with a border of emergent vegetation are Emergent Wetlands and are collectively about 10 acres in size (Figure 6.2a). Also considered Emergent Wetland is the shoreline of the Town Creek embayment, especially the upper reaches, and is approximaely 10 acres in size (Figure 6.2a).

The bottomland hardwood forest along Twon Creek is Forested Wetland and is about 20 acres in size.

6.7 QUALITY ASSURANCE

This vegetation study, from planning of sampling strategy and locations to technical report editing, has been systematically subjected to a quality assurance program. During the planning phase, sampling detail, methodology, and transect locations were developed by two plant ecologists and a wildlife biologist. The wildlife biologist was included to insure that the vegetation and wildlife programs were compatible.

During field work, a specimen of all plants not identifiable in the field, was collected. Identifications were made using standard references (Fernald, eight edition, 1970; Hitchcock, 1950; Gleason and Cronquist, 1963; Radford, Ahles, and Bell, 1964), comparison with specimens at the University of Kentucky Hebarium, and consultations with its curator, Mr. Ray Cranfill. Close cooperation with the Kentucky Nature Preserves Commission was also maintained, especially on matters concerning rare, threatened or endangered species, and any unusual or unique communities.

The plant community acreages for the vegetation maps were independently calculated for consistency. Also, the field sampling data, gathered by one plant ecologist, was checked by another and subjected to computer analysis. These computer data were also checked by both ecologists, and their interpretations concurred upon.

Finally, copies of all field notes, photographs, and records of correspondence, and literature search data were retained in the project files.

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Table 6.1 Land Usage in Hectares (acres) and Percent of Totals for Plant Site and Waste Disposal Areas. Composite Column Represents Project Area Tools.[a]

Land	Plant Site		Northern Waste Area		Southern Waste Area		Composite	
	Area	% of Total	Area	% of Total	Area	% of Total	Area	% of Total
Forested	407(1005)	29	536(1324)	87	1118(2761)	79	2061(5091)	58.1
Cultivated	682(1685)	49	0	0	43(106)	30	725(1791)	23.2
Pasture	133(329)	10	35(86)	6	107(264)	8	275(629)	8.2
Oldfield	92(227)	7	42(101)	7	149(358)	10	282(697)	8.1
Developed	32(79)	2	0	0	0	0	32(79)	1.0
Water	45(111)	3	0	0	0	0	45(111)	1.4
Totals	1391(3436)	100	612(1512)	100	1417(3500)	100	3420(8448)	100

[a]Sums are not exact due to rounding error.

Table 6.2 Threatened or Endangered Plants Occurring in or Near Breckinridge County.[a]

Scientific Name Common Name	Location	State Status	Habitat in Kentucky
Chelone obliqua var. speciosa Pink turtlehead	Ohio, McLean, Henderson Counties	Threatened	Floodplain forests and wooded sloughs.
Dodecatheon frenchii French's shooting star	Breckinridge County	Threatened	Sandstone rockhouses behind dripline in most counties within the dripping springs escarpment.
Heteranthera limosa Mud plantain	Meade County	Threatened	Edges of small ponds and sloughs.
Hydrastis canadensis Goldenseal	Onsite Records	Special concern	Rich mesophytic and alluvial woods.
Limnobium spongia Frog's bit	McLean County	Threatened	Muddy edges of sloughs.
Oenothera linifolia Sundrops	Breckinridge County	Special Concern	Thin soil over tar springs sandstone.
Panax quinquefolius Ginseng	Onsite Records	Threatened	Rich wooded slopes. Probably occurs in every Kentucky county.
Sedum telephioides Live forever	Hancock County	Threatened	Shaded sandstone cliffs and ledges.
Synandra hispidula Synandra	Breckinridge County	Threatened	Mesic woodlands. Known from 25 Kentucky counties.

[a]Source: Harker, D. F. Jr. et al., 1980. Kentucky Natural Areas Plan. Kentucky Nature Preserves Commission.

Table 6.3 Master List of Plants Observed on the Plant Site and Waste Disposal Areas During 1980 and 1981.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Acer negundo L. Box elder	A,B[a]			B	A,B
Acer rubrum L. Red maple	B				A,B
Acer saccharinum L. Silver maple	A,B			B	A,B
Acer saccharum Marsh. Sugar maple		A,B	A,B		
Achillea millefolium L. Yarrow				C	
Actaea pachypoda Ell. White baneberry		C			
Actinomeris alternifolia (L). D.C. Wingstem	C			C	C
Adiantum pedatum L. Maidenhair fern		C			
Agrimonia pubescens Wallr. Agrimony		C	C	C	
Agrostis alba L. Redtop				C	
Agrostemma githago L. Cork cockle				C	
Ailanthus altissima (Mill.) Swingle Tree-of-heaven				B	B

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Allium canadense L. Wild garlic		C		C	C
Allium cernuum Roth Wild onion		C		C	C
Amaranthus hydribus L. Pigweed					
Ambrosia artemissifolia L. Common ragweed				C	C
Ambrosia trifida L. Giant ragweed				C	C
Ampelamus albidus (Nutt.) Britt. Honeyvine	C			B	B
Andropogon virginicus L. Broomsedge				C	
Anemone virginiana L. Thimbleweed			C	C	
Antennaria plantaginifolia (L.) Hook. Pussytoes			C		
Aralia spinosa L. Hercules' - club	B	B	B	B	
Arisaema atrorubens (Ait.) Blume Jack-in-the-pulpit		C			
Arisaema dracontium (L.) Schott Green dragon	C	C			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Aristida longespica Poir. Long-awned grass				C	
Artemisia absinthium L. Wormwood				C	C
Artemisia annua L. Wormwood				C	C
Arundinaria gigantea (Walt.) Chapn. Wild cane	B				B
Asarum canadense L. Wild ginger		C			
Asclepias syriaca L. Common milkweed				C	C
Asclepias verticillata L. Whorled milkweed				C	
Ascyrum hypericoides L. St. Andrew's cross			C	C	
Asimina triloba (L.) Dunal. Paw-paw		B			
Asplenium pinnatifidum Nutt. Pinnatifid spleenwort		C			
Asplenium platyneuron (L.) Dakes Ebony spleenwort			C	C	
Aster ericoides L. Heath aster	C				C
Aster oblongifolius Nutt. Aromatic aster			C	C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Aster pilosus Willd.					
Frostweed aster	C			C	C
Athyrium asplenioides (Michx.) A.A Eaton Tidestrom					
Glade fern		C			
Athyrium pycnocarpon (Spreng.) Tidestrom					
Glade fern		C			
Barbarea vulgaris R. Br.					
Winter-cress				C	C
Bidens frondosa L.					
Beggar-ticks				C	C
Blephilia ciliata (L.) Benth.					
Downy woodmint		C	C	C	
Bomeria cylindrica (L.) Sw.					
Bog hemp				C	C
Botrychium virginianum					
Rattlesnake fern		C			
Brachyelytrum erectum (schreb.) Beauv.					
Grass		C			
Cacalia atriplicifolia L.					
Indian plantain		C			
Campanula americana L.					
Tall bellflower		C			
Campsis radicans (L.) Seem.					
Trumpet creeper				B,C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Camptosorus rhizophyllus (L.) Link Walking fern		C			
Cardamine bulbosa (Schreb.) BSP. Spring-cress		C			
Cardamine pensylvanica Muhl. Spring-cress				C	C
Carex Bushii Mackenz. Bush's sedge	C			C	
Carex grisea Sedge	C			C	
Carex platyphylla Carey Broad-leaved sedge		C			
Carex vulpinoidea Michx. Drooping sedge	C				
Carpinus caroliniana Walt. Ironwood	B	B			B
Carya cordiformis (Wang.) K. Koch Bitternut hickory	A	A			
Carya glabra (Mill.) Sweet Pignut hickory		A	A		
Carya laciniosa (Michx. f.) Lord Big shagbark hickory	A	A			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Carya ovalis (Wang.) Sarg. Sweet pignut hickory		A	A		
Carya ovata (Mill.) K. Koch Shagbark hickory	A	A	A		
Carya tomentosa Nutt. Mockernut		A			
Cassia fasciculata Michx. Partridge-pea			C	C	
Cassia marilandica L. Wild senna			C	C	
Catalpa speciosa Warder. Catalpa			A		
Celastrus scandens L. Bittersweet			B,C		
Celtis occidentalis L. Hackberry	A			A	A
Cercis canadensis L. Redbud		B	B		
Chelone glabra L. Turtlehead	C				
Chenopodium album L. Lamb's quarters				C	C
Chrysanthemum leucanthemum L. Ox-eye daisy				C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Cichorium intybus L. Chicory				C	
Circium discolor (Muhl.) Spreng. Field thistle				C	
Circium vulgare (Savi) Tenore Bull thistle				C	
Clematis virginiana L. Virgin's bower				C	
Collinsonia canadensis L. Citronella		C			
Commelina communis L. Dayflower				C	C
Conopholis americana Squaw-root		C			
Corallorhiza sp. Coral-root		C			
Coreopsis tripteris L. Tall coreopsis				C	
Cornus florida L. Dogwood		B	B		
Cryptotaenia canadensis (L.) D.C. Honewort		C			
Cunila origanoides (L.) Britt. Dittany			C		

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Cuscuta gronovii Willd. Dodder	C			C	C
Cyperus refractus Engelm. Sedge					C
Cyperus esculentus L. Yellow nut-sedge					C
Cystopteris fragilis (L.) Bernh. var. *mackayi* Lawson Fragile fern		C			
Cystopteris protrusa (Weatherby) Blasdell Southern fragile fern		C			
Dactylis glomerata L. Orchard grass				C	
Datura stramonium L. Jimsonweed				C	
Daucus carota L. Wild carrot				C	
Desmodium ciliare (Muhl.) D.C. Tick-trefoil			C	C	
Desmodium nudiflorum (L.) D.C. Naked-flowered tick-trefoil		C	C		
Desmodium perplexum Schub. Tick-trefoil			C		

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Desmodium rotundifolium D.C. Round-leaved tick-trefoil		C	C		
Diarrhena americana Beauv. Grass		C			
Digitaria sanguinalis (L.) Scop. Crabgrass				C	
Diodia teres Walt. Buttonweed				C	
Dioscorea quaternata (Walt.) J. F. Gmel. Wildyam	C	C			
Diospyros virginiana L. Persimmon	B	B	B		
Dipsacus sylvestris Huds. Teasel				C	
Dodecatheon meadia L. Shooting star		C			
Echinocloa crus-galli (L.) Beauv. Barnyardgrass				C	C
Elephantopus carolinianus Willd. Elephants-foot	C				
Elymus riparius Wild rye					C
Epifagus virginianus (L.) Bart. Beech-drops		C			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Erigeron annus (L.) Pero. Whitetop				C	
Erigeron canadensis L. Horse-weed				C	
Euonymus americanus L. Strawberry-bush		C			
Eupatorium coelestinum L. Mistflower					
Eupatorium fistulosum Barratt Joe-pye weed				C	C
Eupatorium purpureum L. Sweet joe-pye weed			C	C	C
Eupatorium rugosum Houtt. White snake root	C				
Euphorbia corrolata L. Flowering spurge		C	C		
Euphorbia maculata L. Eyebone				C	
Fagus grandifolia Ehrn. Beech		A			
Festuca elatoir L. Meadow fescue				C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Fraxinus quadrangulata Michx. Blue ash	B				
Galium aparine L. Cleavers		C			
Galium circaezans Michx. Wild licorice		C			
Galium sp. Bedstraw		C			
Geranium carolinianum L. Cranesbill				C	
Geranium maculatum L. Wild geranium		C			
Geum canadense Jacq. White avens	C			C	C
Glechoma hederacea L. Ground ivy	C			C	C
Gleditsia triacanthos L. Honey locust			B		A,B
Gnaphalium obtusifolium L. Catfoot			C	C	
Helianthus sp. False sunflower				C	
Hepatica acutiloba D.C. Hepatica		C			

Table 6.3 Continued.

Scientific Name / Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Heuchera americana L.					
Alum-root		C			
Hieracium venosum L.					
Rattlesnake-weed			C		
Hybanthus concolor (T.F. Forst.) Spreng.					
Green violet		C			
Hydrangea arborescens L.					
Wild hydrangea				B	
Hydrastis canadensis L.					
Goldenseal		C			
Hydrophyllum sp.					
Waterleaf		C			
Hypericum punctatum Lam.					
St. John's wort			C	C	
Hystrix patula Moencho					
Bottlebrush grass		C	C	C	
Impatiens capensis Meerb.					
Jewelweed	C				C
Impatiens pallida Nutt.					
Pale jewelweed	C				C
Ipomoea pandurata (L.) G.F.W. Mey.					
Wild potato vine				C	
Iresine rhizomatosa Standl.					
Bloodleaf	C				

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Iris cristata Ait.					
Crested dwarf iris		C			
Isopyrum biternatum (Raf.) T. & G.					
False rue anemonl		C			
Jeffersonia diphylla (L.) Pers.					
Twin-leaf		C			
Juglans nigra L.					
Black walnut	A	A			
Juniperus virginiana L.					
Red cedar			B	A	
Lactuca scariola L.					
Prickly lettuce				C	
Lamium amplexicaule L.					
Hen-bit				C	C
Lamium purpureum L.					
Purple deadnettle				C	
Laportea canadensis (L.) Wedd.					
Wood nettle		C			
Lemna minor L.					
Duckweed					
Leonurus cardiaca L.					
Motherwort				C	
Lepidium campestre L.					
Peppergrass				C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Old-ields	Riparian Areas
Lespedeza stipulacea Maxim. Korean lespedeza				C	
Liatris spicata (L.) Willd. Blazing star				C	
Liatris squarrosa (L.) Michx. Blazing star				C	
Lindera benzoin (L.) Blume Spicebush		B			
Linum sp. Flax				C	
Liparis lilifolia (L.) Richard Lily-leaved twayblade		C	C		
Liquidambar styraciflua L. Sweet gum	A			A	A
Liriodendron tulipifera L. Tulip tree		A		B	
Lobelia cardinalis L. Cardinal flower	C				C
Lobelia inflata L. Indian tobacco				C	C
Lobelia siphilitica L. Great blue lobelia					

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Lonicera japonica Thunb. Honeysuckle		C		C	C
Lycopus sp. Bugleweed				C	C
Maclura pomifera (Raf.) Schneid. Osage orange				A	A
Medicago sativa L. Alfalfa				C	
Melilotus alba L. White sweet clover				C	
Melilotus officinalis (L.) Desr. Yellow sweet clover				C	
Menispermum canadense L. Moonseed				C	
Mimulus alatus Ait. Monkeyflower	C				C
Morus rubra L. Red mulberry	A,B				A,B
Muehlenbergia sobolifera (Muhl.) Trin. Grass				C	
Nyssa sylvatica Marsh. Sour gum	A,B		A,B		
Oenothera biennis L. Sundrops				C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Onoclea sensibilis L. Sensitive fern	C				
Ornithogallum umbellatum L. Star-of-Bethelem				C	
Osmorhiza claytoni (Michx.) C. B. Clarke Sweet cicely		C			
Ostrya virginiana Hop hornbeam		B			
Oxalis grandis Small Large wood-sorrel		C			
Oxalis europea Jordan. Yellow wood-sorrel				C	
Panax quinquefolium L. Ginseng		C			
Panicum anceps Michx. Panic grass				C	C
Panicum boscii Poir. Panic grass			C	C	
Panicum capillare L. Witch-grass				C	
Parthenocissus quinquefolia (L.) Planch. Virginia creeper	C	C	C		
Paspalum distichum L. Knot grass					

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Pastinaca sativa L. Wild parsnip				C	
Pellaea atropurpurea (L.) Link Purple cliff-brake		C			
Penstemon sp. Beard-tongue			C	C	
Penthorum sedoides L. Ditch stonecrop					C
Phegopteris hexagonoptera (Michx.) Fee Broad beech fern			C C		
Phlox divaricata L. Blue phlox					
Phryma leptostachya L. Lopseed		C		C	
Physalis subglabrata L. Smooth ground-cherry				C	C
Phytolacca americana L. Poke				C	
Pilea pumila (L.) Gray Clearweed	C				C
Plantago lanceolata L. Buckhorn plantain				C	
Plantago major L. Common plantain				C	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Platanus occidentalis L. Sycamore	A,B			B	A,B
Poa pratensis L. Kentucky bluegrass				C	C
Podophyllum peltatum L. Mayapple		C			
Polemonium reptans L. Jacob's ladder		C			
Polygonatum biflorum (Walt.) Ell. Solomon's-seal		C		C	
Polygonum cespitosum L. Long-bristled smartweed				C	C
Polygonum pensylvanicum L. Pennsylvania smartweed				C	C
Polypodium virginianum L. Rock-cap fern		C			
Polystichum acrostichoides (Michx.) Schott Christmas Fern		C			
Populus deltoides Marsh. Cottonwood	A				A,B
Portulaca oleracea L. Purslane				C	
Potamogeton crispus L. Pondweed					D

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Potentilla simplex Michx.					
Oldfield cinquefoil			C	C	
Prenanthes sp.					
Rattlesnake-root		C			
Prunella vulgaris L.					
Self-heal			C	C	
Prunus serotina					
Black cherry		A,B		B	
Ptelea trifoliata L.					
Stinking ash	B				B
Pycnanthemum flexuosum (Walt.) BSP.					
Slender mountain-mint				C	
Pyrularia pubera Michx.					
Buffalo-nut		B			
Quercus alba L.					
White oak		A,B	A,B		
Quercus borealis Michx. f. var. *maxima* (Marsh.) Ashe.					
Northern red oak		A	A		
Quercus coccinea Muench.					
Scarlet oak			A		
Quercus imbricaria Michx.					
Shingle oak		A			
Quercus prinus L.					
Chestnut oak			A,B		

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Quercus shumardi Buckl. Shumard oak		A,B	A,B		
Quercus stellata Wang. Post oak			A,B		
Quercus velutina Lam. Black oak		A,B	A		
Ranunculus abortivus L. Kidneyleaf buttercup				C	
Rhamnus caroliniana Walt. Carolina buckthorn				A	
Rhus copallina L. Winged sumac				A,B	
Rhus glabra L. Smooth sumac			B	A,B	
Robinia pseudo-acacia L. Black locust				A,B	
Ribes cynosbati L. Prickly gooseberry			B		B
Rosa carolina L. Carolina rose			C	C	
Rosa multiflora Thunb. Multiflora rose				B	

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Rubus sp. Blackberry				C	
Rubus occidentalis L. Black raspberry				C	
Rudbeckia hirta L. Black-eyed susan				C	
Rumex acetosella L. Sheep-sorred				C	
Rumex crispus L. Curly dock				C	C
Rumex orbiculatus Gray Water dock					C
Sabatia angularis (L.) Pursh Rose-pink				C	
Sagittaria latifolia Willd. Arrowhead					D
Salix nigra Marsh. Black willow	B				B
Salvia lyrata L. Lyre-leaved sage			C	C	
Sambucus canadensis L. Elderberry				B	B
Sanguinaria canadensis L. Bloodroot		C			

Table 6.3 Continued.

Scientific Name / Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Sanicula gregaria Bickn.					
Black snakeroot		C			
Saponaria officinalis L.					
Soapwort				C	
Sassafras albidum (Nutt.) Nees					
Sassafras	B	B	B	A,B	B
Saururus cernuus L.					
Lizards's-tail					D
Saxifraga caroliniana Gray					
Saxifrage		C			
Scirpus atrovirens Willd.					
Small bullrush					D
Scutellaria incana Biehler					
Downy skullcap		C			
Sedum ternatum Michx.					
White stonecrop		C			
Senecio aureus L.					
Golden ragwort		C	C		
Senecio glabellus Poir					
Butterweed				C	C
Setaria viridis (L.) Beauv.					
Green foxtail				C	
Seymeria macrophylla Nutt.					
Mullien-foxglove	C	C			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Silene virnigica L. Red catch-fly		C	C		
Smilacina racemosa (L.) Desf. False solomon's -eal		C			
Smilax bona-nox L. Bristly greenbrier		C	C	C	
Smilax glauca Walt. Sawbrier			C	C	
Smilax rotundifolia L. Greenbrier		C	C	C	
Solanum carolinense L. Horse-nettle				C	
Solidago altissima L. Tall goldenrod			C	C	
Solidago caesia L. Blue-stem goldenrod			C		
Sorgum halpense Johnson-grass				C	
Specularia perfoliata (L.) A. D.C. Venus' looking-glass				C	
Stachys tenuifolia Willd. Hedge-nettle				C	
Staphylea trifolia L. Bladdernut	B				

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Stellaria media (L.) Cyrillo Common chickweed		C			
Stylophorum diphyllum (Michx.) Nutt. Wood poppy		C			
Swertia caroliniensis (Walt.) Ktze. Columbo			C		
Symphoricarpos orbiculatus Moench. Coral-berry			C	C	
Taenidia integerimma (L.) Drude Yellow pimpernel		C	C		
Taraxacum officinale weber Dandelion				C	
Tiarella cordifolia L. Foam flower		C			
Tilia sp. Basswood		A			
Tipularia discolor (Pursh) Nutt. Crane-fly orchid		C			
Tovara virginiana (L.) Raf. Jumpseed		C			
Toxicodendron radicans Ktze. Poison ivy	B,C	B,C	B,C	B,C	B,C
Tradescantia subaspera Ker. Spiderwort		C			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Trifolium pratense L.					
Red clover				C	
Trifolium repens L.					
White clover				C	
Trillium luteum (Muhl.) Harbison					
Yellow trillium					
Trillium sessile L.					
Sessile trillium		C			
Triosteum angustifolium L.					
Horse-gentian			C	C	
Typha latifolia L.					
Cat-tail					D
Ulmus alata Michx.					
Winged elm			B	B	
Ulmus americana L.					
American elm	A,B	A,B		B	
Ulmus rubra Muht.					
Slippery elm	B	B	B	B	
Uniola latifolia Michx.					
Spangle-grass	C	C			
Urtica dioica L.					
Stinging nettle	C	C			
Uvularia perfoliata L.					
Perfoliate bellwort		C			

Table 6.3 Continued.

Scientific Name Common Name	Bottomland Forest	Midslope Forest	Upland Forest	Fencerows Oldfields	Riparian Areas
Veratrum woodii Robbins					
False hellebore		C			
Verbascum thapsus L.					
Wolly mullien				C	
Vernonia altissima Nutt.					
Ironweed				C	
Veronica sp.					
Speedwell				C	
Viburnum prunifolium L.					
Black-haw	B	B			
Viola canadensis L.					
Canada violet		C			
Viola papilionacea Pursh.					
Meadow violet	C	C	C		
Viola triloba Schwein.					
Three-lobed violet			C	C	
Woodsia obtusa (Spreng.) Torrey					
Blunt-lobed woodsia		C			
Xanthium pensylvanicum					
Cocklebur				C	

[a]A - Overstory, B - Understory, C - Ground Cover, D - Aquatic - Emergent.

Table 6.4 Frequencies, densities, dominance, and importance values of overstory tree species at the bottomland hardwood sample location, Fall, 1980.

Scientific Name Common Name	Frequency	Percent Relative Frequency	 Relative Density	 Relative Dominance	 Importance[a] Value
Acer saccharinum L. Silver maple	60.0	26.1	36.4	37.1	99.6
Platanus occidentalis L. Sycamore	27.5	12.0	8.6	18.5	39.1
Acer negundo L. Box elder	30.0	13.0	12.8	9.2	35.0
Celtis occidentalis L. Hackberry	27.5	12.0	11.4	9.7	33.1
Ulmus rubra Muhl. Slippery Elm	30.0	13.0	9.9	8.6	31.5
Fraxinus americana L. White ash	25.0	10.9	9.2	9.5	29.6
Populus deltoides Marsh. Cottonwood	20.0	8.7	9.2	6.3	24.2
Carya ovata (Mill.) K. Koch. Shagbark hickory	2.5	1.1	0.7	0.4	2.1
Carpinus caroliniana Walt. Ironwood	2.5	1.1	0.7	0.3	2.1
Morus rubra L. Red mulberry	2.5	1.1	0.7	0.3	2.1
Liquidambar styraciflua L. Sweet gum	2.5	1.1	0.7	0.2	2.0
Totals[b]	230.0	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.5 Frequencies, densities, dominance, and importance values of understory tree species at the bottomland hardwood sample location, Fall, 1980.

		Percent			
Scientific Name Common Name	Frequency	Relative Frequency	Relative Density	Relative Dominance	Importance[a] Value
Ulmus rubra Muhl. Slippery elm	65.0	32.9	32.7	33.7	99.3
Acer saccharinum L. Silver maple	32.5	16.5	19.9	23.9	60.3
Celtis occidentalis L. Hackberry	32.5	16.5	18.9	17.0	52.4
Fraxinus americana L. White ash	30.0	15.2	13.8	9.6	38.6
Platanus occidentalis L. Sycamore	10.0	5.1	4.3	4.9	14.3
Acer negundo L. Box elder	10.0	5.1	3.5	3.4	12.0
Populus deltoides Cottonwood	7.5	3.8	2.6	3.6	10.0
Carya ovata (Mill.) K. Koch Shagbark hickory	5.0	2.5	2.6	2.5	7.6
Juglans nigra L. Black walnut	2.5	1.3	0.8	1.0	3.1
Liquidambar styraciflua L. Sweet gum	2.5	1.3	0.8	0.5	2.6
Totals[b]	197.5	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.6 Cover, frequencies, densities, and importance values of ground cover species at the bottomland hardwood sample location, Spring, 1981.

Scientific Name / Common Name	Relative Frequency (Percent)	Relative Density (Percent)	Relative Dominance (Percent)	Importance[a] Value (Percent)
Aster ericoides L. / Heath aster	59.0	35.6	63.4	158.6
Carex grayii Carey / Gray's sedge	12.0	14.3	8.5	34.8
Urtica dioica L. / Stinging nettle	6.0	7.1	6.4	19.5
Desmodium sp. / Tick-trefoil	1.5	7.1	3.2	11.8
Uniola ratifolia Michx. / Spangle-grass	0.2	7.1	2.2	9.5
Impatiens sp. / Jewelweed	0.5	3.6	5.3	9.4
Campsis ladicans (L.) Seem. / Trumpet-vine	2.0	3.6	2.2	7.8
Eupatorium fistulosum Barratt / Joe-pye weed	2.0	3.6	2.2	7.8
Toxicodendron radicans Ktze. / Poison ivy	0.5	3.6	2.2	6.3
Arisaema dracontium / Green dragon	1.0	3.6	1.1	5.7
Carex vulpinoidea Michx. / Drooping sedge	1.0	3.6	1.1	5.7
Cryptotaenia canadensis (L.) DC. / Honewort	1.0	3.6	1.1	5.7
Galium aparine L. / Cleavers	1.0	3.6	1.1	5.7
Leaf litter	12.3			12.3
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.7 Cover, frequencies, densities, and importance values of ground cover species at the bottomland hardwood sample location, Summer, 1980.

Scientific Name Common Name	Percent Relative Frequency	 Relative Density	 Relative Dominance	 Importance[a] Value
Aster ericoides L. Heath aster	23.0	15.8	23.5	62.3
Laportea canadensis (L.) Wedd. Wood nettle	17.0	13.1	17.3	47.4
Uniola latifolia Michx. Spangle-grass	8.0	10.5	13.4	31.9
Desmodium sp. Tick-trefoil	3.5	7.9	7.1	18.5
Tovora virginiana (L.) Raf. Jumpseed	5.0	5.3	6.1	16.4
Toxicodendron radicans (L.) Ktze. Poison Ivy	2.5	7.9	5.1	15.5
Eupatorium fistulosum Barratt Joe-pye weed	4.0	5.3	4.1	13.4
Mimulus alatus Ait. Monkeyflower	4.0	5.3	4.1	13.4
Carex grayii Carey Gray's sedge	2.0	5.3	4.1	11.4
Viola sp. Violet	2.0	5.3	4.1	11.4
Tradescantia subaspera Ker Spiderwort	4.0	2.6	4.1	10.7
Fraxinus americana L. White ash	1.0	5.3	2.0	8.3
Campsis radicans Trumpet creeper	1.0	2.6	2.0	5.6
Cuscuta sp. Dodder	1.0	2.6	1.0	4.6
Vernonia altissima Nutt. Ironweed	1.0	2.6	1.0	4.6
Acer saccharinum L. Silver maple seedling	0.5	2.6	1.0	4.1
Totals[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.8 Cover, frequencies, densities, and importance values of ground cover species at the bottomland hardwood sample location, Fall, 1980.

Scientific Name / Common Name	Percent			
	Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Aster ericoides L. Heath aster	23.2	29.0	50.4	102.6
Laportea canadensis (L.) Wedd Wood-nettle	11.0	22.6	21.5	55.1
Irisine rhizomatosa Standl. Bloodleaf	5.7	9.7	12.4	27.8
Uniola latifolia Michx. Spangle grass	1.9	6.5	4.1	12.5
Toxicodendron radicans (L.) Ktze Poison ivy	3.4	6.5	2.5	12.3
Carex grayii Carey Gray's sedge	1.5	3.2	1.7	6.4
Tovara virginiana (L.) Raf. Jumpseed	0.8	3.2	1.7	5.6
Viola sp. Violet	0.8	3.2	1.7	5.6
Tradescantia subuspera Ker Spiderwort	1.5	3.2	0.8	5.6
Acer saccharum L. Sugar maple	0.4	3.2	0.8	4.4
Campsis radicans (L.) Seem. Trumpet creeper	0.4	3.2	0.8	4.4
Desmodium sp. Tick-Trefoil	0.4	3.2	0.8	4.4
Bareground and litter	48.7			48.7
Totals[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.9 Frequencies, densities, dominance, and importance values of overstory trees on the mid-slope hardwood sample location, Fall, 1980.

Scientific Name Common Name	Frequency	Percent Relative Frequency	Relative Density	Relative Dominance	Importance[a] Value
Fagus grandifolia Ehrh. Beech	45.0	15.5	20.8	38.8	75.1
Acer saccharum L. Sugar maple	62.5	21.6	24.7	14.6	60.9
Quercus shumardi Buckl. Shumard oak	35.0	12.1	9.3	13.0	34.4
Quercus alba L. White oak	25.0	8.6	8.7	6.5	23.8
Fraxinus americana L. White ash	20.0	6.9	7.4	4.4	18.7
Carya glabra (Mill.) Sweet. Pignut hickory	17.5	6.0	5.4	4.0	15.4
Liriodendron tulipifera L. Tulip tree	12.5	4.3	3.3	4.1	11.7
Quercus velutina Lam. Black oak	12.5	4.3	4.0	3.4	11.7
Carya ovata (Mill.) K. Koch. Shagbark hickory	15.0	5.2	4.0	2.3	11.5
Ulmus rubra Muhl. Slippery elm	12.5	4.3	3.3	1.5	9.1
Juglans nigra L. Black walnut	5.0	1.7	2.0	1.6	5.3
Unidentified	5.0	1.7	1.3	1.9	4.9
Ouercus muehlenbergii Engelm Chinquapin oak	5.0	1.7	1.3	1.3	4.3
Prunus serotina Ehrh. Wild cherry	5.0	1.7	1.3	0.6	3.6
Gleditsia triacanthos L. Honey locust	2.5	0.9	0.6	1.0	2.5
Morus rubra L. Red mulberry	2.5	0.9	0.6	0.5	2.0
Celtis occidentalis Hackberry					

Table 6.9 Continued.

Scientific Name Common Name	Frequency	Percent Relative Frequency	 Relative Density	 Relative Dominance	 Importance[a] Value
Quercus borealis Michx. f. var. *maxima* (Marsh.) Ashe Red oak	2.5	0.9	0.6	0.2	1.7
Nyssa sylvatica Sour gum	2.5	0.9	0.6	0.2	1.7
Totals[b]	290.0	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.10 Frequencies, densities, dominance, and importance values of understory tree species at the mid-slope hardwood sample location, Fall, 1980.

Scientific Name / Common Name	Frequency	Percent Relative Frequency	Percent Relative Density	Percent Relative Dominance	Percent Importance Value[a]
Acer saccharum L. — Sugar maple	100.0	47.6	63.4	62.2	173.2
Carya ovata (Mill.) K. Koch. — Shagbark hickory	17.5	8.3	5.7	5.9	19.9
Fagus grandifolia Ehrh. — Beech	12.5	6.0	4.2	7.0	17.2
Cercis canadensis L. — Redbud	12.5	6.0	5.7	2.7	14.4
Ulmus rubra Muhl. — Slippery elm	10.0	4.8	2.9	3.5	11.2
Fraxinus americana L. — White ash	10.0	4.8	2.9	1.8	9.5
Sassafras albidum (Nutt.) Nees. — Sassafras	5.0	2.4	2.2	3.3	7.9
Carya glabra (Mill.) Sweet. — Pignut hickory	5.0	2.4	1.4	2.7	6.5
Juglans nigra L. — Black walnut	5.0	2.4	1.4	2.7	6.5
Prunus serotina Ehrh. — Black cherry	5.0	2.4	1.4	1.2	5.0
Ostrya virginiana (Mill.) K. Koch. — Hop-hornbeam	5.0	2.4	1.4	1.2	5.0
Celtis occidentalis L. — Hackberry	5.0	2.4	1.4	1.2	5.0
Quercus alba L. — White oak	2.5	1.2	1.4	1.3	3.9
Quercus shumardi Buckl. — Shumard oak	2.5	1.2	0.7	1.9	3.8
Quercus muehlenbergii Engelm. — Chinquapin oak	2.5	1.2	0.7	0.5	2.4

Table 6.10 Continued.

Scientific Name Common Name	Frequency	Percent Relative Frequency	 Relative Density	 Relative Dominance	 Importance[a] Value
Liriodendron tulipifera L. Tulip poplar	2.5	1.2	0.7	0.4	2.3
Carpinus caroliniana Walt. Ironwood	2.5	1.2	0.7	0.3	2.2
Nyssa sylvatica Marsh. Sour gum	2.5	1.2	0.7	0.3	2.2
Cornus florida L. Flowering dogwood	2.5	1.2	0.7	0.2	2.2
Totals[b]	210.0	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.11 Cover, frequencies, densities, and importance values of ground cover species at the mid-slope hardwood sample location, Spring, 1981.

Scientific Name / Common Name	Percent: Relative Cover Frequency	Relative Density	Relative Dominance	Importance[a] Value
Rhus aromatica Ait. Fragrant sumac	26.0	20.0	23.2	69.2
Brachyelytrum erectum (Schreb.) Beauv. Grass	12.0	7.5	21.4	40.9
Galium sp. Bedstraw	8.5	7.5	12.5	28.5
Parthenocissus quinquefolia (L.) Planch. Virginia creeper	4.5	10.0	8.0	22.5
Diarrhena americana Beauv. Grass	7.0	5.0	6.2	18.2
Euonymus americanus L. Strawberry-bush	1.5	7.5	2.7	11.7
Galium circaezans Michx. Wild licorice	0.6	5.0	5.4	11.0
Arisaema atrorubens (Ait.) Blume Jack-in-the-pulpit	2.5	2.5	4.4	9.4
Impatiens sp. Jewelweed	1.5	5.0	1.8	8.3
Lonicera japonica Thunb. Honeysuckle	1.0	5.0	1.8	7.8
Asarum canadense L. Wild ginger	1.5	2.5	2.7	6.7
Stellaria media (L.) Cyrillo Common chickweed	0.3	2.5	2.7	5.5
Agrimonia pubescens Wallr. Agrimony	2.0	2.5	0.9	5.4
Aster sp. Aster	2.0	2.5	0.9	5.4
Ulmus americana L. American elm seedlings	2.0	2.5	0.9	5.4
Acer saccharum Marsh. Sugar maple seedlings	1.0	2.5	0.9	4.4
Carya sp. Hickory seedlings	1.0	2.5	0.9	4.4

Table 6.11 Continued.

Scientific Name Common Name	Percent Relative Cover Frequency	Relative Density	Relative Dominance	Importance[a] Value
<u>Desmodium</u> sp. Tick-trefoil	1.0	2.5	0.9	4.4
<u>Uvularia perfoliata</u> L. Perfoliate bellwort	1.0	2.5	0.9	4.4
<u>Epifagus virginiana</u> (L.) Bart. Beech-drops	0.5	2.5	0.9	3.9
Leaf litter	22.6			22.6
Total	100.0	100.0	100.0	300.0

[a]Importance value = relative cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.12 Cover, frequencies, densities, and importance values for ground cover species at the mid-slope hardwood sample location, Summer, 1980.

Scientific Name / Common Name	Percent			
	Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Lonicera japonica Thunb. Japanese honeysuckle	8.7	5.3	19.0	33.0
Toxicodendron radicans (L.) Ktze. Poison ivy	4.8	13.2	10.5	28.4
Desmodium nudiflorum (L.) DC. Naked-leaved tick-trefoil	4.3	5.3	9.5	19.1
Galium aparine L. Cleavers	1.4	7.9	7.6	16.9
Asarum canadense L. Wild ginger	4.2	5.3	6.7	16.2
Hepatica acutiloba DC. Hepatica	2.3	2.6	8.6	13.5
Parthenocissus quinquefolia (L). Planch. Virginia creeper	1.0	5.3	3.8	10.1
Euonymus americanus L. Strawberry-bush	0.7	5.3	3.8	9.8
Ulmus americana, L. American elm	1.7	5.3	1.9	8.9
Sedum ternatum Michx. White stonecrop	0.5	2.6	5.7	8.9
Oxalis grandis Small Large wood-sorrel	1.7	2.6	3.8	8.2
Panicum sp. Panic grass	1.3	2.6	2.9	6.8
Conopholis americana (L.) Wallr. Squawroot	0.3	2.6	2.9	5.7
Cynoglossum virginianum L. Wild comfrey	1.7	2.6	1.0	5.3

Table 6.12 Continued.

Scientific Name / Common Name	Percent Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Impatiens sp.				
Jewelweed	1.7	2.6	1.0	5.3
Senecio aureus L.				
Golden ragwort	1.3	2.6	1.0	4.9
Potentilla simplex Michx.				
Oldfield cinquefoil	0.3	2.6	1.9	4.9
Agrimonia pubescens Wallr.				
Agrimony	0.9	2.6	1.0	4.5
Cantharellus sp.				
Mushroom	0.4	2.6	1.0	4.0
Unidentified grass	0.4	2.6	1.0	4.0
Quercus muehlenbergii Engelm.				
Chinquapin oak	0.4	2.6	1.0	4.0
Fagus grandifolia Ehrh.				
Beech	0.4	2.6	1.0	4.0
Muhlenbergia sp.				
Muhly	0.1	2.6	1.0	3.7
Cryptotaenia canadensis (L.) DC.				
Honewort	0.1	2.6	1.0	3.7
Stellaria media (L.) Cyrillo				
Common chickweed	0.1	2.6	1.0	3.7
Smilax rotundifolia L.				
Common greenbrier	0.1	2.6	1.0	3.7
Leaf litter	59.0			59.0
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.13 Cover, frequencies, densities, and importance values for ground cover species at the mid-slope hardwoods sample location, Fall, 1980.

Scientific Name Common Name	Percent Relative Percent Cover	 Relative Frequency	 Relative Density	 Importance[a] Value
Brachyelytrum erectum (Schreb.) Beauv. Grass	20.0	19.4	17.9	57.2
Galium circaezans Michx. Bedstraw	6.6	12.9	22.1	41.6
Toxicodendron radicans (L.) Ktze. Poison ivy	2.7	9.7	7.4	19.8
Enonymus americanus L. Strawberry-bush	3.9	3.2	10.5	17.7
Asarum canadense L. Wild ginger	2.7	6.5	7.4	16.6
Smilax sp. Greenbrier	3.1	3.2	4.2	10.6
Ulmus rubra Muhl. Slippery elm	3.1	3.2	4.2	10.6
Lonicera japonica Thumb. Japanese honeysuckle	2.0	3.2	5.3	10.4
Diarrhena americana Beauv. Grass	1.6	3.2	5.3	10.1
Polystichum acrostichoides (Michx.) Schott Christmas fern	2.4	3.2	3.2	8.7
Parthenocissus quinquefolia (L.) Planch. Virginia creeper	1.6	3.2	2.1	6.9
Fraxinus americana L. White ash	0.8	3.2	2.1	6.1
Carya glabra (Mill.) Sweet. Pignut hickory	1.2	3.2	1.1	5.5
Hepatica acutiloba DC. Hepatica	0.4	3.2	1.1	4.7

Table 6.13 Continued.

Scientific Name Common Name	Percent Relative Percent Cover	 Relative Frequency	 Relative Density	 Importance[a] Value
Laportea canadensis (L.) Wedd.				
Wood nettle	0.4	3.2	1.1	4.7
Impatiens sp.				
Jewelweed	0.4	3.2	1.1	4.7
Staphylea trifolia L.				
Bladdernut	0.4	3.2	1.1	4.7
Fagus grandifolia Ehrh.				
Beech	0.4	3.2	1.1	4.7
Quercus sp.				
Oak	0.4	3.2	1.1	4.7
Osmorhiza claytoni (Michx.) C.B. Clarke				
Sweet cicely	0.4	3.2	1.1	4.7
Leaf litter	45.6			45.6
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.14 Frequencies, densities, dominance, and importance values of overstory tree species at the up-land hardwood sample location, Fall, 1980.

Scientific Name / Common Name	Frequency	Percent: Relative Frequency	Relative Density	Relative Dominance	Importance[a] Value
Quercus velutina Lam. — Black oak	47.5	16.2	15.5	21.7	53.4
Quercus stellata Wang. — Post oak	30.0	10.3	12.6	11.5	34.4
Quercus alba L. — White oak	22.5	7.7	8.5	15.0	31.2
Carya ovata (Mill.) K. Koch. — Shagbark hickory	25.0	8.5	9.1	7.6	25.3
Juniperus virginiana L. — Red Cedar	25.0	8.5	7.8	5.4	21.7
Carya glabra (Mill.) Sweet. — Pignut hickory	25.0	8.5	7.8	5.4	21.7
Fraxinus americana L. — White ash	15.0	5.1	5.6	5.7	16.4
Nyssa sylvatica Marsh. — Sour gum	15.0	5.1	5.0	3.1	13.2
Quercus prinus L. — Chestnut oak	12.5	4.3	4.2	3.3	11.8
Quercus muehlenbergii Engelm. — Chinquapin oak	10.0	3.4	3.5	3.2	10.1
Liriodendron tulipifera L. — Tulip poplar	7.5	2.6	2.1	5.2	9.9
Diospyros virginiana L. — Persimmon	10.0	3.4	2.8	1.7	7.9
Sassafras albidum (Nutt.) Nees. — Sassafras	10.0	3.4	2.8	1.5	7.7
Platanus occidentalis L. — Sycamore	10.0	3.4	3.5	0.6	7.5

Table 6.14 Continued.

Scientific Name Common Name	Frequency	Percent Relative Frequency	Relative Density	Relative Dominance	Importance[a] Value
Quercus borealis Michx. f. var. *maxima* (Marsh.) Ashe Red oak	2.5	0.9	1.4	4.0	6.3
Carya cordiformis (Wang.) K. Koch. Bitternut hickory	5.0	1.7	1.4	2.0	5.1
Juglans nigra L. Black walnut	5.0	1.7	1.4	1.2	4.3
Quercus coccinea Muenchh. Scarlet oak	5.0	1.7	2.1	0.5	4.3
Acer saccharum L. Sugar maple	5.0	1.7	1.4	0.9	4.0
Quercus shumardi Buckl. Shumard oak	2.5	0.9	0.7	0.4	2.0
Ulmus rubra Muhl. Slippery elm	2.5	0.9	0.7	0.0	1.6
Totals[b]	292.5	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.15 Frequencies, densities, dominance, and importance values of understory tree species at the up-land hardwood sample location, Fall, 1980.

Scientific Name Common Name	Frequency	Percent Relative Frequency	 Relative Density	 Relative Dominance	 Importance[a] Value
Acer saccharum L. Sugar maple	35.0	14.0	20.0	18.4	52.4
Juniperus virginiana L. Red cedar	27.5	11.0	12.0	14.9	37.9
Quercus prinus L. Chestnut oak	30.0	12.0	12.0	11.8	35.8
Quercus velutina Lam. Black oak	22.5	9.0	10.4	8.6	28.0
Ulmus rubra Muhl. Slippery elm	17.5	7.0	5.6	6.6	19.2
Quercus stellata Wang. Post oak	10.0	4.0	3.2	6.9	14.1
Cornus florida L. Flowering dogwood	15.0	6.0	4.7	2.6	13.3
Carya glabra (Mill.) Sweet. Pignut hickory	12.5	5.0	4.0	4.1	13.1
Cercis canadensis L. Redbud	12.5	5.0	4.0	4.0	13.0
Nyssa sylvatica Marsh. Sour gum	12.5	5.0	4.0	3.1	12.1
Quercus alba L. White oak	7.5	3.0	2.4	4.1	9.5
Sassafras albidum (Nutt.) Nees. Sassafras	7.5	3.0	3.2	2.5	8.7
Ulmus alata Michx. Winged elm	10.0	4.0	3.2	1.5	8.7
Diospyros virginiana L. Persimmon	5.0	2.0	1.5	2.7	6.2
Quercus muehlenbergii L. Chinquapin oak	5.0	2.0	2.4	2.1	6.5
Carya ovata (Mill.) K. Koch Shagbark hickory	5.0	2.0	1.5	1.0	4.5
Quercus coccinea Muenchh. Scarlet oak	2.5	1.0	1.5	1.8	4.3

Table 6.15 Continued.

Scientific Name / Common Name	Frequency	Percent: Relative Frequency	Relative Density	Relative Dominance	Importance Value
Juglans nigra L. Black walnut	2.5	1.0	0.8	1.3	3.1
Platanus occidentalis L. Sycamore	2.5	1.0	0.8	1.0	2.8
Fraxinus americana L. White ash	2.5	1.0	0.8	0.3	2.1
Celtis occidentalis L. Hackberry	2.5	1.0	0.8	0.3	2.1
Carya ovalis (Wang.) Sarg. Sweet pignut hickory	2.5	1.0	0.8	0.3	2.1
Totals[b]	250.0	100.0	100.0	100.0	300.0

[a]Importance value = relative frequency, relative density, relative dominance.

[b]Columns may not add exactly due to rounding.

Table 6.16 Cover, frequencies, densities, and importance values of ground cover species at the upland hardwood sample location, Spring, 1981.

Scientific Name / Common Name	Percent: Relative Cover Frequency	Relative Density	Relative Dominance	Importance[a] Value
Potentilla simplex Michx. / Oldfield cinquefoil	8.2	13.2	15.3	36.7
Panicum sp. / Panic grass	8.0	7.9	11.5	27.4
Parthenocissus quinquefolius (L.) Planch. / Virginia creeper	9.0	5.3	10.3	24.6
Hypericum punctatum Lam. / St. Johnswort's	7.0	5.3	11.5	23.8
Cryptotaenia canadensis (L.) DC. / Honewort	3.1	7.9	6.4	17.4
Fraxinus americana L. / White ash seedlings	3.8	5.3	5.1	14.2
Carex sp. / Sedge	3.5	5.3	5.2	13.9
Eupatorium rugosum Houtt. / White snakeroot	3.0	5.3	5.1	13.4
Ulmus sp. / Elm seedlings	3.0	5.3	3.8	12.1
Cercis canadensis L. / Redbud	1.2	5.3	2.6	9.1
Desmodium ciliare (Muhl.) DC. / Tick-trefoil	1.0	5.3	2.6	8.9
Quercus alba L. / White oak	3.0	2.6	2.6	8.2
Impatiens sp. / Jewelweed	1.5	2.6	3.8	7.9
Ipomoea pandurata (L.) G.F.W. Mey / Wild potato vine	2.0	2.6	2.6	7.2
Podophyllum peltatum L. / Mayapple	3.0	2.6	1.3	6.9
Symphoricarpos orbiculatus Moench. / Coral-berry	3.0	2.6	1.3	6.9
Solidago sp. / Goldenrod	1.0	2.6	2.6	6.2
uonymus americanus L. / Strawberry-bush	1.5	2.6	1.3	5.4

Table 6.16 Continued.

Scientific Name Common Name	Relative Cover Frequency	Relative Density	Relative Dominance	Importance[a] Value
	Percent			
Unidentified grass	1.0	2.6	1.3	4.9
Unidentifed grass	0.5	2.6	1.3	4.4
Viola sp. Violet	0.5	2.6	1.3	4.4
Totals[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.17 Cover, frequencies, densities, and importance values for ground cover species at the upland hardwood sample location, Summer, 1980.

Scientific Name / Common Name	Percent: Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Toxicodendron radicans (L.) Ktze. Poison ivy	9.3	10.7	13.3	33.3
Smilax glauca Walt. Sawbrier	4.6	7.1	13.3	25.0
Desmodium ciliare (Muhl.) DC. Tick-trefoil	4.2	7.1	12.0	23.4
Muhlenbergia sobolifera (Muhl.) Trin. Muhly	1.0	7.1	14.5	22.6
Panicum boscii Poir. Panic grass	3.4	7.1	9.6	20.2
Galium circaezans Michx. Bedstraw	1.2	7.1	8.4	16.8
Potentilla simplex Michx. Oldfield cinquefoil	1.0	7.1	7.2	15.4
Parthenocissus quinquefolia (L.) Planch. Virginia creeper	2.1	7.1	6.0	15.3
Fraxinus americana L. White ash	0.8	7.1	2.4	10.4
Agrimonia pubescens Wallr. Agrimony	2.5	3.6	2.4	8.5
Desmodium nudiflorum (L.) DC. Naked-leaved tick-trefoil	0.8	3.6	2.4	6.8
Sassafras albidum (Nutt.) Nees Sassafras	0.8	3.6	1.2	5.6
Menispermum canadense L. Moonseed	0.8	3.6	1.2	5.6

Table 6.17 Continued.

Scientific Name Common Name	Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Ulmus rubra Muhl. Slippery elm	0.4	3.6	1.2	5.2
Eonymus americanus L. Strawberry-Bush	0.4	3.6	1.2	5.2
Lonicera japonica Thunb. Japanese honeysuckle	0.1	3.6	1.2	4.9
Rosa carolina L. Carolina rose	0.1	3.6	1.2	4.9
Blephilia ciliata (L.) Benth. Downy woodmint	0.1	3.6	1.2	4.9
Bareground and plant debris	66.1			66.1
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.18 Cover, frequencies, densities, and importance values for ground cover species at the upland hardwood sample location, Fall, 1980.

Scientific Name / Common Name	Percent: Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Potentilla simplex Michx. Oldfield cinquefoil	7.4	16.7	20.0	44.1
Lonicera joponica Thumb. Japanese honeysuckle	9.9	12.5	20.0	42.4
Cunila origanoides (L.) Britt. Dittany	6.2	8.3	8.3	22.8
Toxicodendron radicans (L.) Ktze. Poison ivy	2.9	4.2	10.0	17.0
Desmodium ciliare (Muhl.) DC. Tick-trefoil	2.1	4.2	8.3	14.6
Panicum boscii Poir. Panic grass	3.3	4.2	6.7	14.1
Smilax sp. 2 Greenbrier	1.6	8.3	3.3	13.3
Fraxinus americana L. White ash	1.6	8.3	3.3	13.3
Solidago sp. Goldenrod	1.2	4.2	5.0	10.4
Galium circaezans Michx. Bedstraw	0.2	4.2	5.0	9.4
Acer rubrum L. Red maple	2.5	4.2	1.7	8.3
Liriodendron tulipifera L. Tulip tree	1.6	4.2	1.7	7.5
Cercis canadensis L. Redbud	0.8	4.2	1.7	6.7
Aster sp. Aster	0.8	4.2	1.7	6.7
Smilax sp. 1 Greenbrier	0.8	4.2	1.7	6.7

Table 6.18 Continued.

Scientific Name Common Name	Percent Relative Percent Cover	 Relative Frequency	 Relative Density	 Importance[a] Value
Blephilia ciliata Downy woodmint	0.4	4.2	1.7	6.2
Leaf litter	56.5			56.5
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding.

Table 6.19 Cover, frequencies, densities, and importance values for ground cover species at the old field sample location Summer, 1980.

Scientific Name / Common Name	Relative Percent Cover (Percent)	Relative Frequency (Percent)	Relative Density (Percent)	Importance[a] Value (Percent)
Lespedeza stipulacea Maxim. Korean lespedeza	20.0	19.0	32.2	71.2
Andropogon virginicus L. Broom-sedge	21.3	13.7	34.4	69.3
Festuca elatior L. Meadow fescue	11.6	13.1	18.7	43.4
Eupatorium coelestinum L. Mistflower	4.2	5.9	1.2	11.3
Aristida longispica Poir. Three-awned grass	3.1	2.0	5.0	10.1
Panicum anceps Michx. Panic grass	0.9	7.2	1.4	9.4
Solidago altissima L. Tall goldenrod	2.0	4.6	0.6	7.2
Elephantopus carolinianus Willd. Elephant's-foot	2.4	3.9	0.8	7.1
Panicum sp. Panic grass	0.6	5.2	0.9	6.7
Paspalum sp. Paspalum grass	1.3	2.0	2.1	5.3
Rudbeckia hirta L. Black-eyed susan	0.9	2.0	0.1	3.0
Rubus sp. Blackberry	0.8	2.0	0.3	3.0
Plantago lanceolata L. English plantain	0.3	2.0	0.1	2.4
Aster sp. Aster	0.7	1.3	0.2	2.2
Fraxinus americana L. White ash	1.3	0.7	0.0	2.0
Cassia fasciculata Michx. Partridge-pea	0.9	0.7	0.3	1.8

Table 6.19 Continued.

Scientific Name / Common Name	Percent: Relative Percent Cover	Relative Frequency	Relative Density	Importance[a] Value
Solidago sp. Goldenrod	0.3	1.3	0.1	1.7
Ambrosia trifida L. Great ragweed	0.3	1.3	0.1	1.7
Lonicera japonica Thunb. Japanese honeysuckle	0.3	1.3	0.1	1.7
Artemisia absinthium L. Wormwood	0.2	1.3	0.1	1.6
Sassafras albidum (Nutt.) Nees Sassafrass	0.1	1.3	0.1	1.5
Desmodium perplexum Schub. Tick-trefoil	0.0	1.3	0.1	1.4
Ascyrum hypericoides L. St. Andrew's cross	0.2	0.7	0.4	1.2
Prunella vulgaris L. Selfheal	0.3	0.7	0.2	1.2
Solanum carolinense L. Horse-nettle	0.2	0.7	0.0	0.9
Diodia teres (Walt.) Buttonweed	0.1	0.7	0.1	0.9
Plantago major L. Common plantain	0.1	0.7	0.0	0.8
Eupatorium rugosum Houtt. White snakeroot	0.1	0.7	0.0	0.8
Vernonia altissima Nutt. Ironweed	0.1	0.7	0.0	0.8
Juniperus virginiana L. Red cedar	0.1	0.7	0.0	0.8
Setaria viridis (L.) Beauv. Green foxtail	0.1	0.7	0.0	0.8

Table 6.19 Continued.

Scientific Name Common Name	Percent Relative Percent Cover	 Relative Frequency	 Relative Density	 Importance[a] Value
Prunus serotina Ehrh.				
Black cherry	0.0	0.7	0.0	0.7
Carex grisea Wahl.				
Sedge	0.0	0.7	0.0	0.7
Litter and plant debris	25.2			25.2
Total[b]	100.0	100.0	100.0	300.0

[a]Importance value = relative percent cover, relative frequency, relative density.

[b]Columns may not add exactly due to rounding

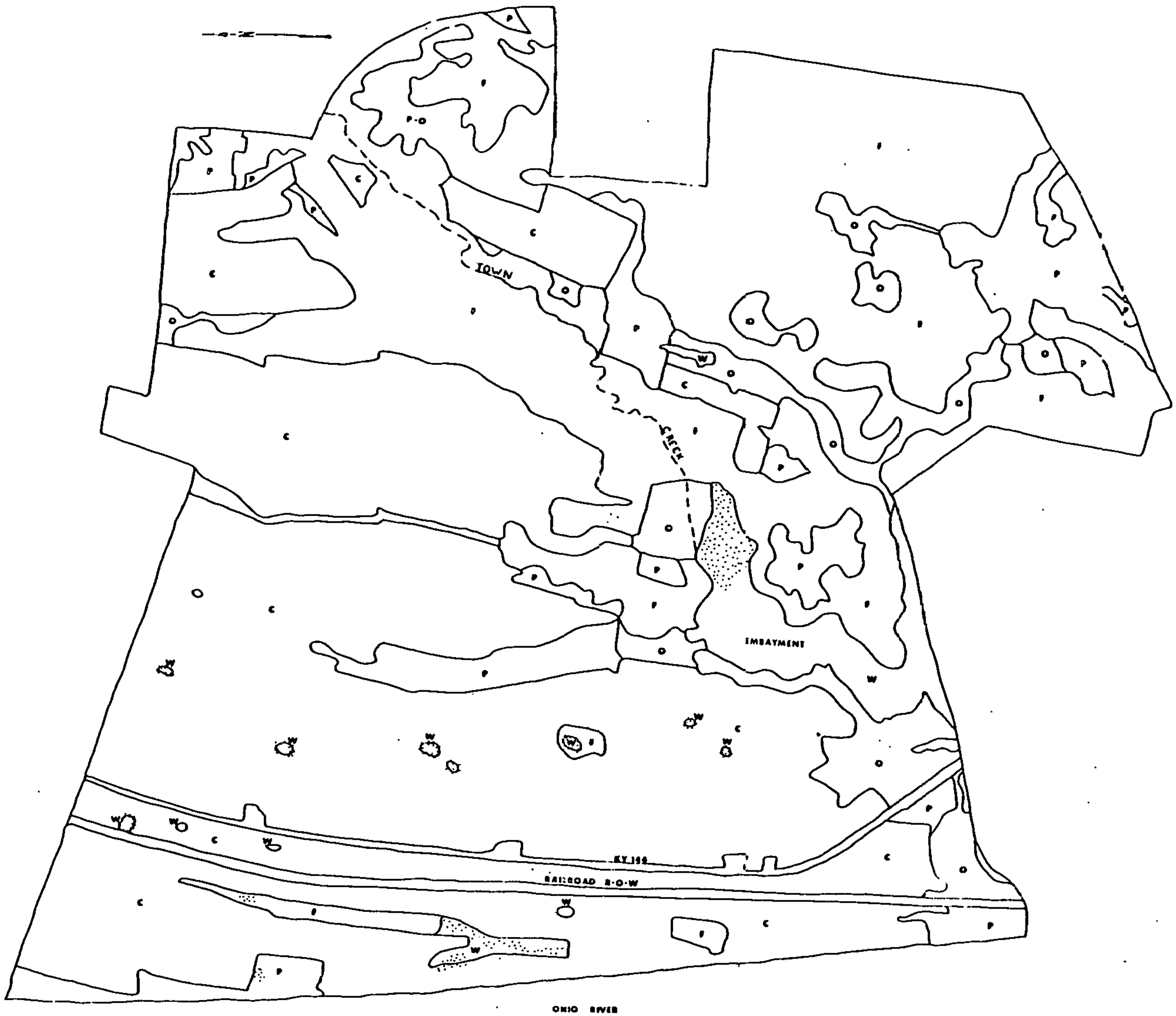
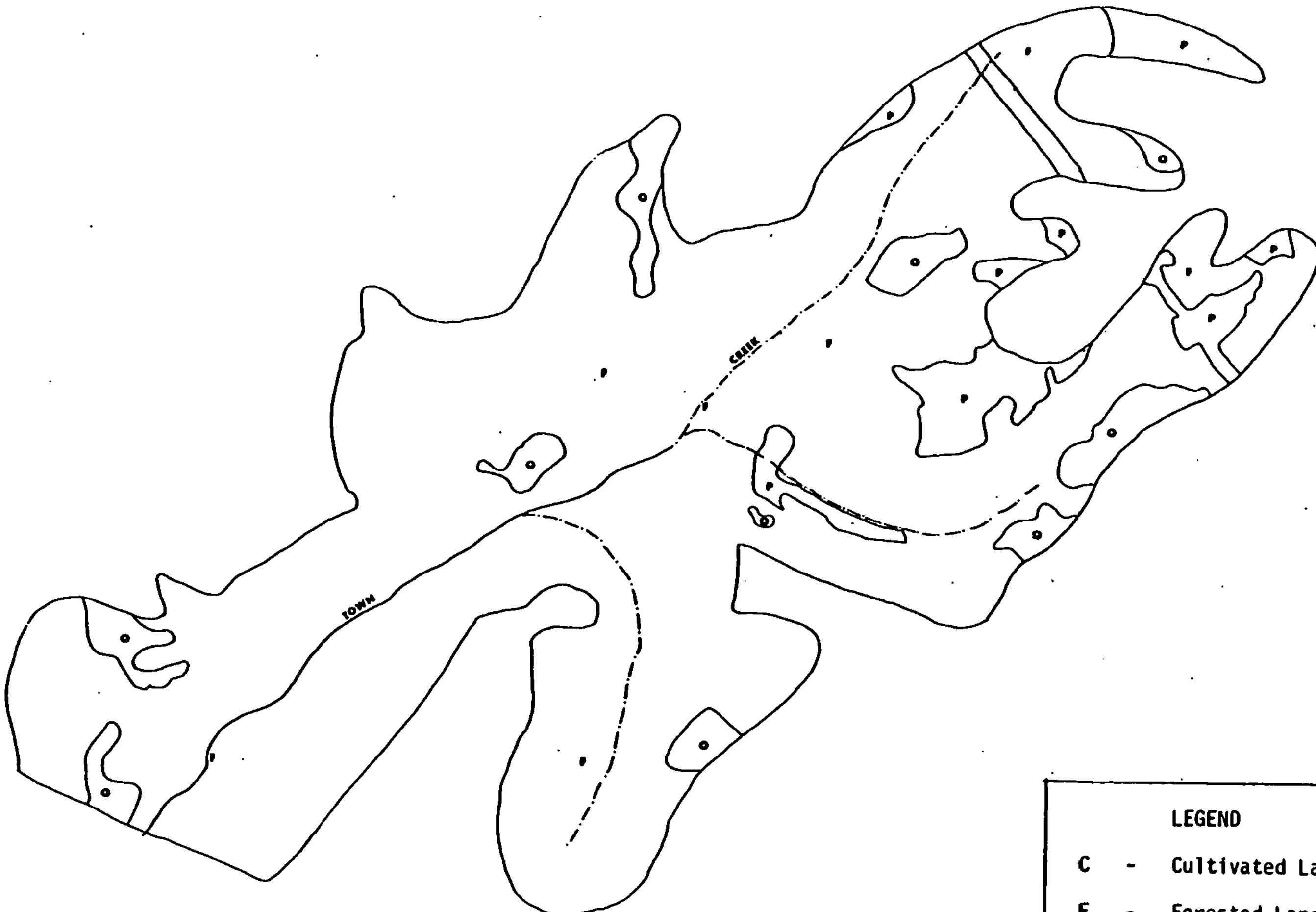


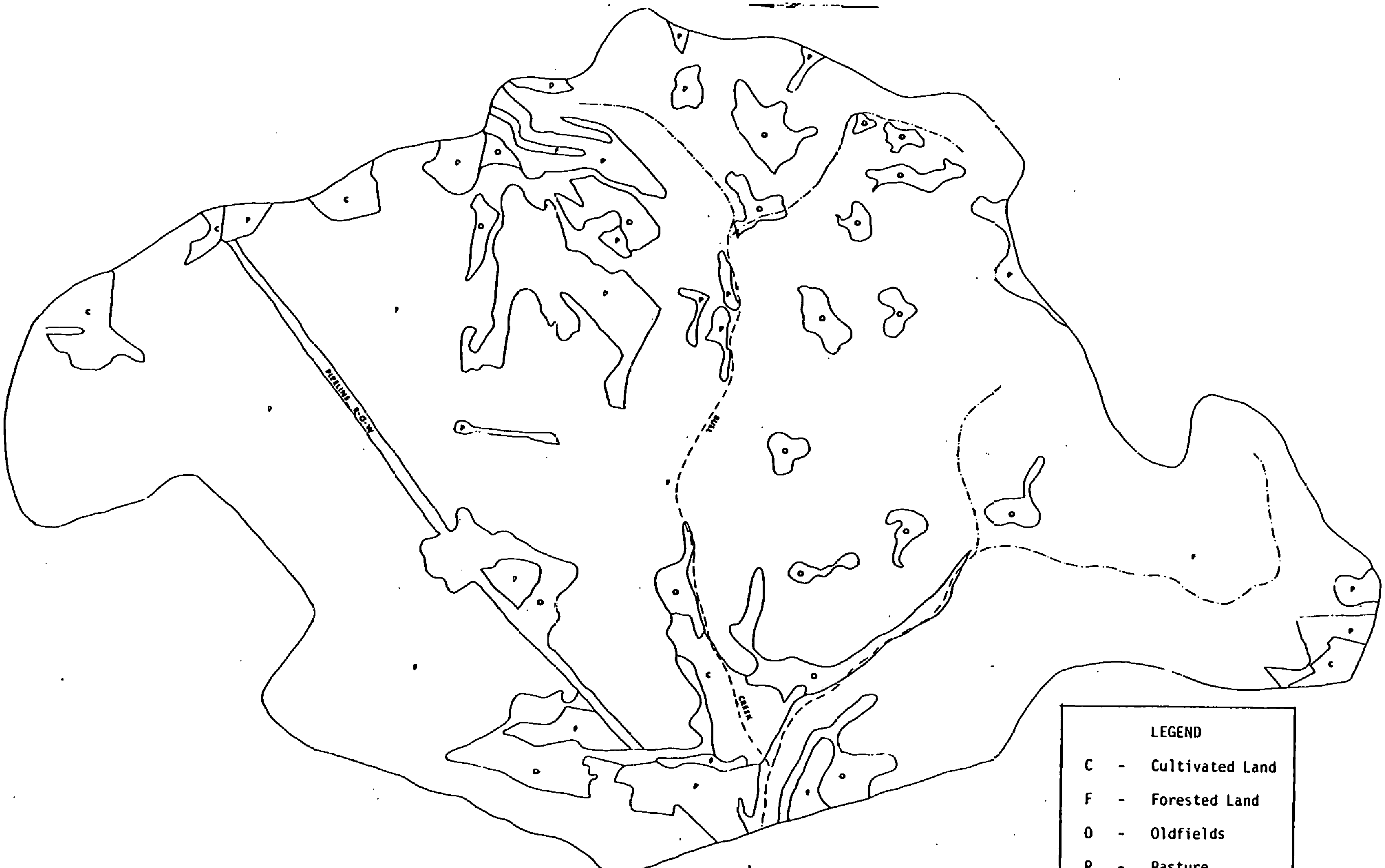
Figure 6.2a Vegetation Cover Type Map of Plant Site.



LEGEND

C - Cultivated Land
F - Forested Land
O - Oldfields
P - Pasture
W - Water
- Wetlands

Figure 6.2b Vegetation Cover Type Map of Northern Waste Disposal Area.



LEGEND

C - Cultivated Land
F - Forested Land
O - Oldfields
P - Pasture
W - Water
∴ - Wetlands

Figure 6.2c Vegetation Cover Type Map for Southern Waste Disposal Area.

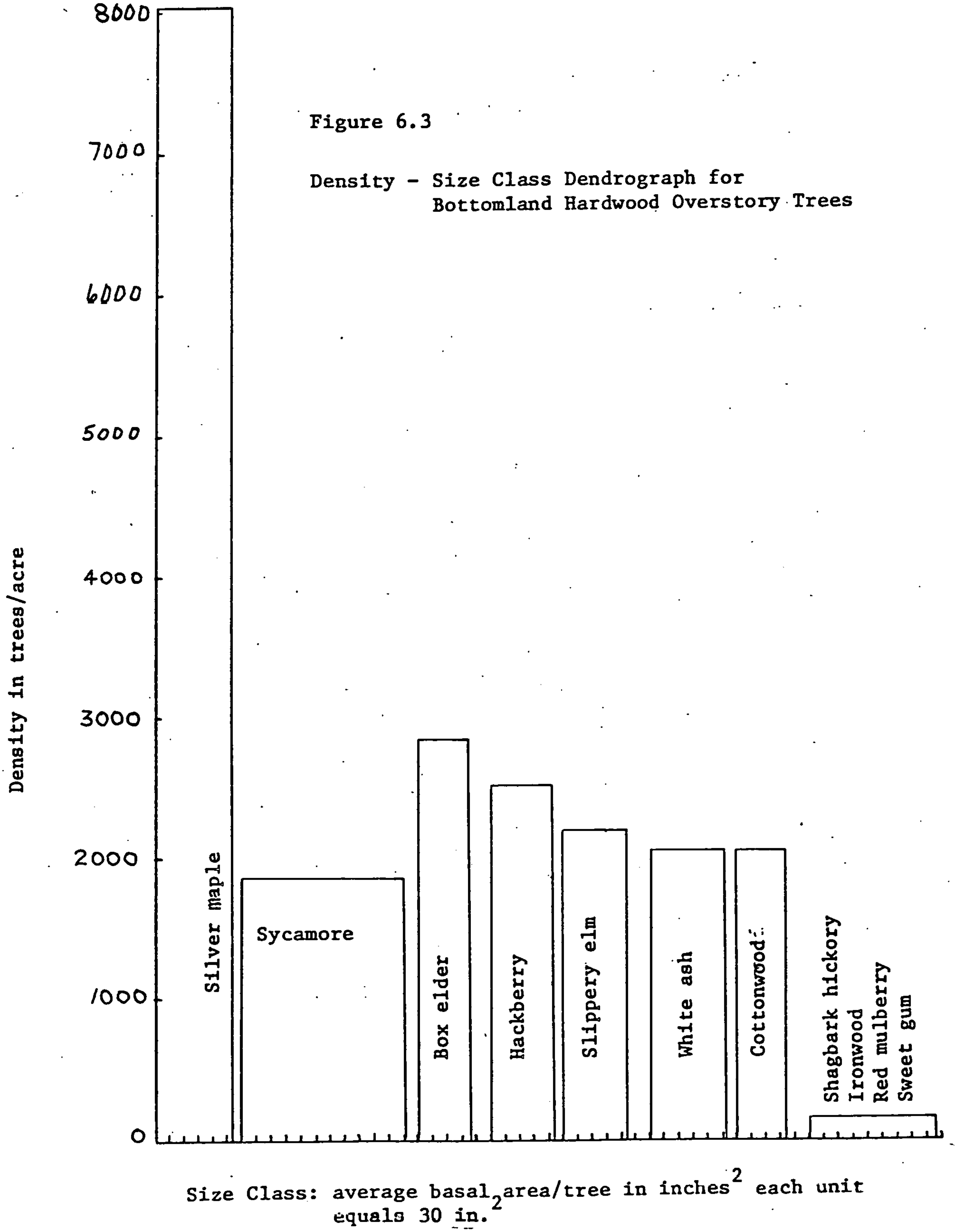
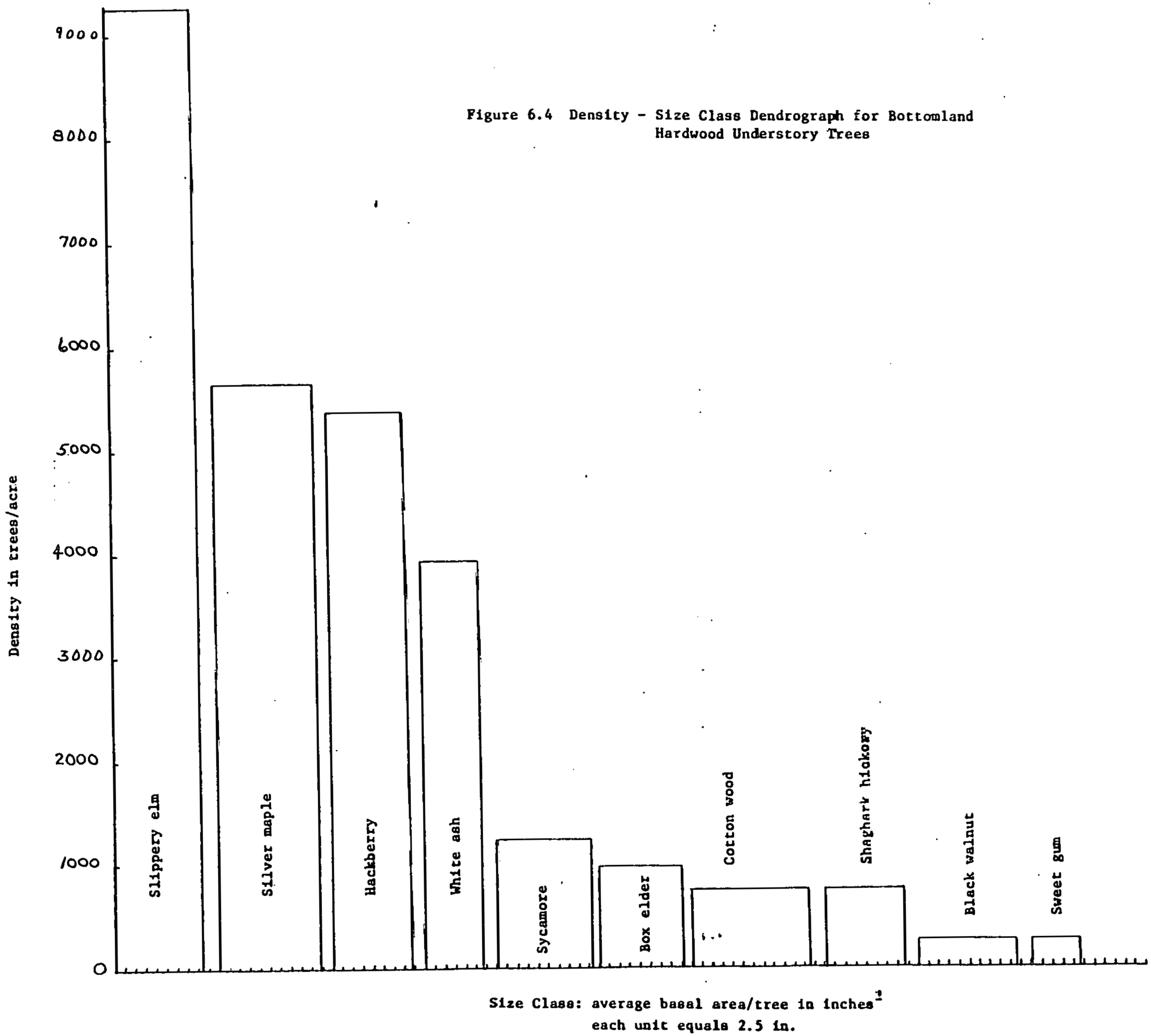


Figure 6.3

Density - Size Class Dendrograph for Bottomland Hardwood Overstory Trees

Figure 6.4 Density - Size Class Dendrograph for Bottomland Hardwood Understory Trees



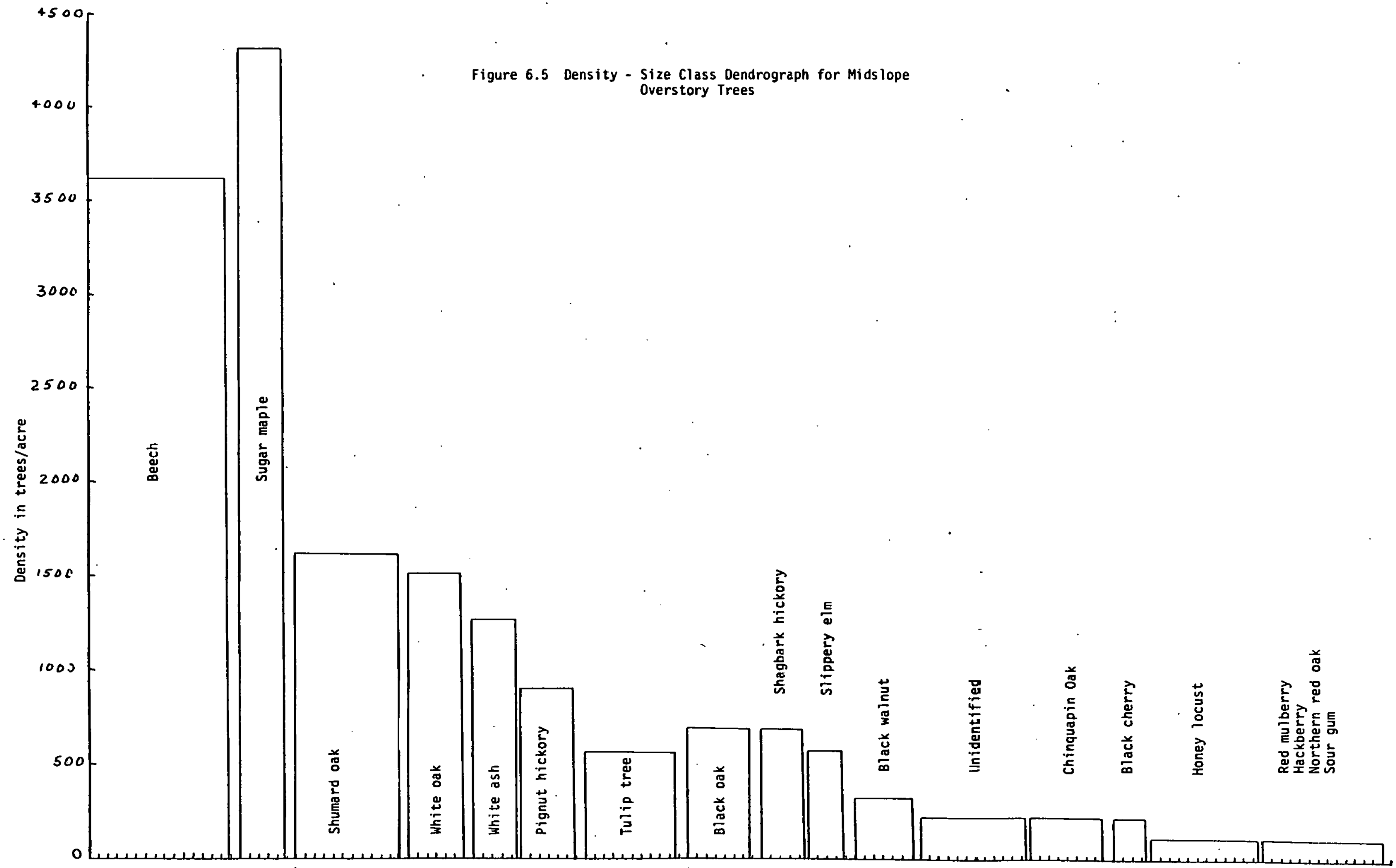


Figure 6.5 Density - Size Class Dendrograph for Midslope Overstory Trees

Size Class: average basal area/tree in inches^2. Each unit equals 30 in.^{2}.

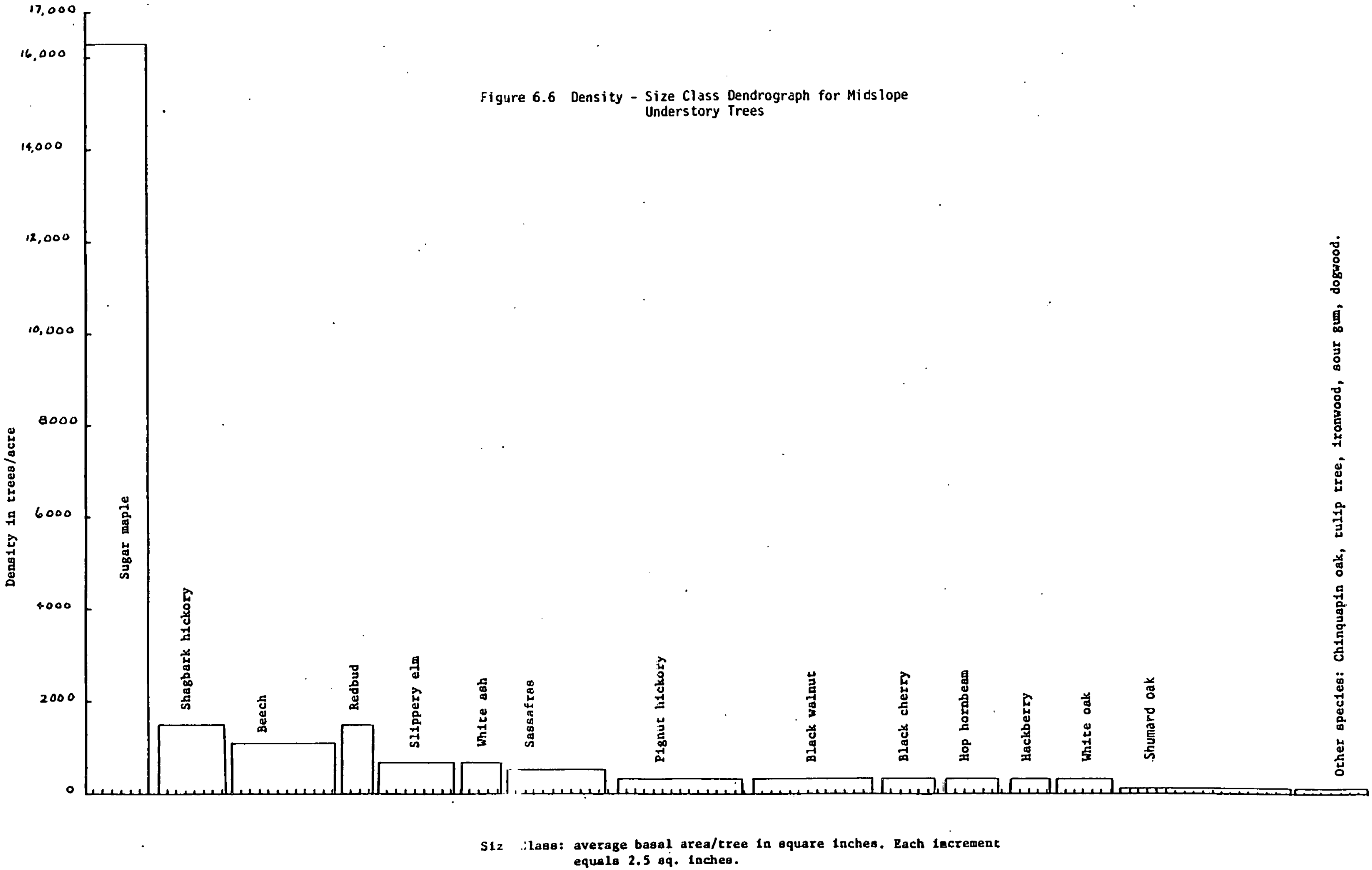
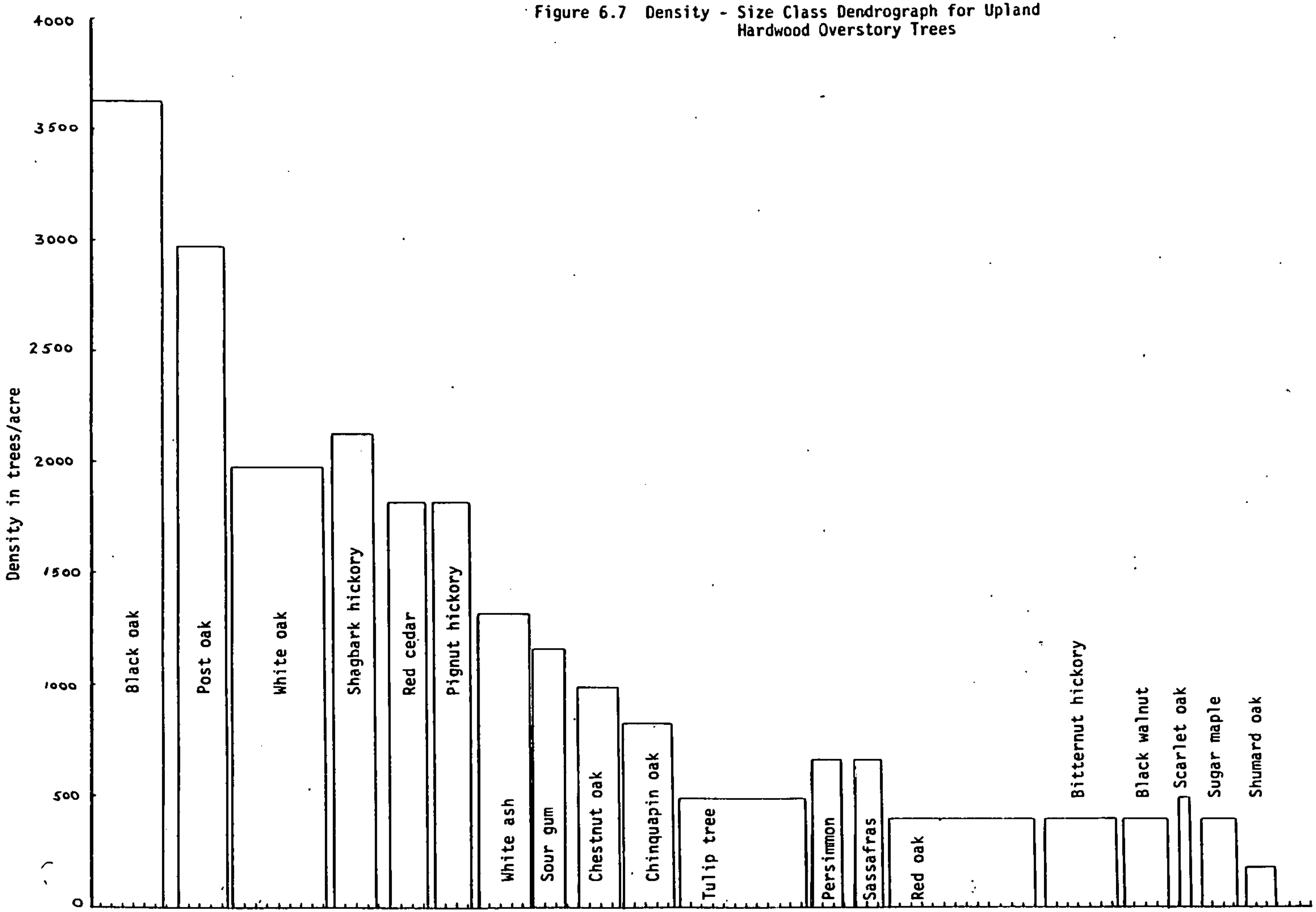
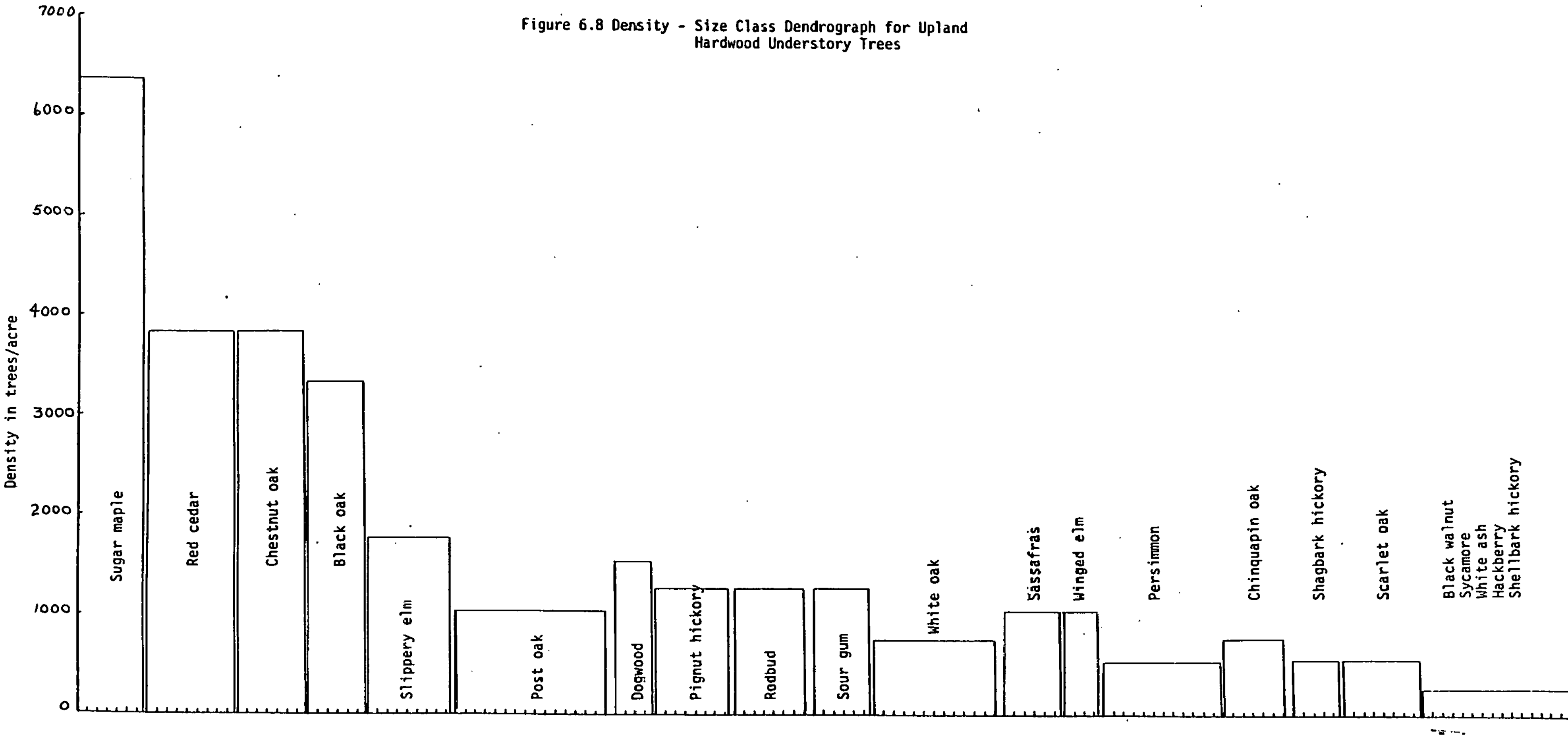


Figure 6.6 Density - Size Class Dendrograph for Midslope Understory Trees

Figure 6.7 Density - Size Class Dendrograph for Upland Hardwood Overstory Trees



Size Class: average basal area/tree in inches^2. Each unit equals 30 in.^{2}.



Size Class: average basal area/tree in inches^2. Each unit equals 2.5 in.^{2}.

Wildlife

7.0 WILDLIFE

7.1 INTRODUCTION

The wildlife of an area refers to all animal life (protozoans, invertebrates, and vertebrates) within specified temporal and spatial limits. The current study, while recognizing the importance of the invertebrate communities to area ecosystems, concentrated on investigations of the vertebrates; amphibians, reptiles, birds, and mammals. These investigations consisted of quantitative sampling techniques for birds and mammals, and qualitative observations for all groups.

This chapter is divided into the following sections; background and objectives, threatened and endangered species, sampling frequency and methodology, sampling location and rationale, results and discussion, quality assurance, and references. The wildlife is discussed by taxonomic groups.

7.2 BACKGROUND AND OBJECTIVES

The project area, because of its approximately central location in the eastern United States, contains faunal components characteristic of northern, southern, and western areas as well as the assemblages typical of an eastern fauna. This situation is due, in part, to the distinctive seasonal climate, and diversity of topographic and vegetational features. The site vicinity is rich in habitat types and this provides an abundance of available niches, which the fauna can occupy.

The reptile and amphibian fauna, although a rather covert, generally unnoticed component, is highly important to the stability of area trophic structure. Of the 122 species and subspecies of herptiles that occur in Kentucky (Barbour, 1971), the ranges of 79 species overlap the project area, or come close enough to it to allow a reasonable expectation of their occurrence here. This represents approximately 65 percent of the taxa in the state.

The avifauna of the state is quite diverse; Mengel (1965) lists 296 species within Kentucky's boundaries, while Barbour, et al. (1973) notes 275 species as regular breeders or visitors. Due to the great diversity of habitats, approximately 190 species potentially occur in the local area. This represents approximately 65 percent to 69 percent (depending upon which number of total taxa is used) of the bird species occurring in Kentucky.

The site lies on the border between the Western Upland Avifaunal Region and the Alluvial Forest Avifaunal Region (Mengel, 1965). Species such as the great blue heron (Ardea herodias), great egret (Casmerodius albus), wood duck (Aix sponsa), hooded merganser (Lophodytes cucullatus), and prothonotary warbler (Proteonotaria citrea) are characteristic of the Alluvial Forest Avifaunal Region. The Western Upland Avifaunal Region is distinguished by the relative abundance of the American woodcock (Philohela minor), whip-poor-will (Caprimulgus vociferus), yellow-throated vireo (Vireo flavivfrons), black-and-white warbler (Mniotilla varia), worm-eating warbler (Helmitheros vermivorus), northern parula (Parula americana), prairie warbler (Dendrocica discolor), pine warbler (Dendroica pinus), hooded warbler (Wilsonia citrina), ovenbird (Seiurus aurocapillus), American redstart (Setophaga ruticilla), and scarlet tanger (Piranga olivacea) (Mengel, 1965). Because of the site's location between these two avifaunal regions, characteristic species of both regions are found at the site.

The mammalian fauna of the area is generally characteristic of that of the eastern United States. However, several species with northern, southern, and western affinities also occur in the region, due to its central location in the east. For example, the eastern harvest mouse and swamp rabbit are primarily southern in distribution and approach the northern limits of their range in Kentucky, while the woodchuck and meadow jumping mouse, northern species, approach their southern range limits in or just south of the state (Barbour and Davis, 1974). Because of its location, the mammal fauna of Kentucky is quite diverse with the occurrence of approximately 76 species and subspecies probable in the state. The ranges of approximately 46 mammals overlap or closely approach the project vicinity; this represents about 61 percent of the taxa occurring in the state.

The major wildlife habitats in the project area are woodlands, woodland edges, and oldfields. These areas offer the safest shelter and most consistent food supplies.

From the preceding background information, it is evident that the project vicinity has a rather diverse fauna. It is the objective of this study to assess the existing species composition and general condition of the amphibian, reptile, bird, and mammal populations in the area, so as to be able to predict, as accurately as possible, the potential effects of site development on the fauna.

7.3 THREATENED AND ENDANGERED SPECIES

Summer, fall and winter sampling have not revealed the presence of any federally threatened or endangered animals on site. The KNPC Natural Areas Plan (Harker et al., 1980), noted in the vegetation section, contains sixteen animals of concern in the state. These are briefly noted below.

Scientific and Common Name	Location	State Status
Cryptobranchus alleganiensis, Hellbender	Breckinridge County	Threatened
Hyla avivoca, Bird-voice Treefrog	Henderson County	Special Concern
Clonophis kirtlandi, Kirtland's Water Snake	Ohio County	Endangered
Ophisaurus attennatus, Slender Glass Lizard	Hardin County	Undetermined
Ammodrammus savannarum, Grasshopper Sparrow	Hardin County	Threatened
Bartramia longicauda, Upland Sandpiper	Hardin County	Threatened
Circus cyaneus, Marsh Hawk	On Site	Undetermined
Pandion haliaetus, Osprey	On Site	Special Concern
Thryomanes bewickii, Bewick's Wren	Meade County	Threatened
Microsorex thompsoni, Thompson's Pygmy Shrew	Breckinridge County	Endangered
Myotis keenii, Keen's Bat	Breckinridge County	Undetermined
Myotis griscens, Gray Bat	Meade County	Endangered (Federal List)

Scientific and Common Name	Location	State Status
Myotis leibii, Small-Footed Myotis	Breckinridge County	Undetermined
Myotis sodalis, Indiana Bat	Breckinridge County	Endangered (Federal List)
Sorex longirostris, Southeastern Shrew	Meade County	Threatened
Sylvilagus aquaticus Swamp Rabbit	Hancock County	Threatened

Monroe (1978) reported on declining species of breeding birds in Kentucky. His analysis of eleven years of bird counts included eight species observed during the present study. Those species are the eastern meadowlark, field sparrow, mockingbird, yellow-breasted chat, tufted titmouse, chipping sparrow, eastern bluebird, and carolina wren.

Annually, the editors of American Birds and the American Ornithologists Union publish a Blue List of birds. This list is designed as an early warning of species currently giving indications of non-cyclical population declines or range contractions, either locally or widespread (Tate, 1981). The 1981 Blue List contains 19 species observed in the present study; osprey, northern harrier, sharp-shinned hawk, American kestrel, bobwhite, yellow-billed cuckoo, screech owl, common nighthawk, ruby-throated hummingbird, red-headed woodpecker, hairy woodpecker, cliff swallow, purple martin, Carolina wren, eastern bluebird, golden-crowned kinglet, loggerhead shrike, yellow warbler, yellow-breasted chat, and eastern meadowhark.

The pygmy shrew is extremely rare in the state. Barbour and Davis (1974) discussed its recent occurrence in the state, but no longer considered it a member of the fauna here. They noted its remains found in Welch Cave in Woodford County and a dried specimen with no locality data in the museum of the University of Kentucky. However, a specimen was recently collected near Garfield in the interior of Breckinridge County. Consequently this species may occur in the project area.

Both the gray bat and Indiana bat (endangered on the federal list) have been recorded in Breckinridge County (Barbour and Davis, 1974). The gray bat is almost completely a cave dwelling species and its presence in the project area is unlikely. The Indiana bat uses wooded streambank areas for nursery colonies (Humphrey, Richter, and Cope, 1977). Excellent habitat of this type is found in the project area. Additionally there are summer records of Indiana bats along the Green River in Daviess County (Harvey and Kennedy, 1980) which is approximately 40 miles west-southwest of the project area. In June, 1979 a small maternity colony of Indiana bats was discovered along Knob Creek in Bullitt County, Kentucky. This site is approximately 40 miles east-northeast of the project area (Kessler, Turner, and Morgan, 1981). Based on these records and the presence of suitable habitat, it is likely that Indiana bats occur in the project area.

7.4 SAMPLING FREQUENCY AND METHODOLOGY

7.4.1 Amphibians and Reptiles

The herpetofauna of the project area is being investigated by a variety of qualitative methods. The major plant communities were searched by turning logs, rocks, and debris. These were replaced in their original positions so as not to degrade the condition of the habitat. The stream habitats were investigated using the previously mentioned techniques and a portable backpack electroshocker (Section 5.4). Area roads were driven at night to assess primarily frog, toad and salamander populations. Additionally, all road kills were checked and identified. This is a particularly good method of inventorying snake populations. Small ponds in the area were searched at night. During the fishery study all turtles caught in hoop nets were identified. The majority of amphibian and reptile surveys took place during the spring sample period.

7.4.2 Birds

Surveys of the resident and migratory avifauna were conducted with the oldfield, bottomland, and midslope hardwood forests, and along roadsides from August 11 through 17, December 15 through 18, 1980, and May 12 through 16, 1981. A modification of Emlens (1971) strip census technique was used to determine species composition, diversity and population densities. Censuses were conducted beginning at sunrise for three consecutive days during each survey. The order in which the areas were visited was changed each day to offset the normal decrease in bird activity as the morning wanes. The oldfield, bottomland hardwoods and midslope hardwoods were investigated along various transect lengths and widths. The average number of individual birds per species was converted to the mean number of birds per 2.47 hectares (1 acre) within each habitat.

Bird diversity is theoretically a function of the quantity and quality of the habitat available in a given area. Kricher (1973) and Graber and Graber (1976) indicated that species diversity reflects the successional stage of the habitat. MacArthur and MacArthur (1961) and MacArthur (1965) have found that there is a direct correlation between bird species diversity and habitat heterogeneity. High diversity reflects the volume of diverse habitat provided by herbaceous, shrub, and tree layers of vegetation. A high volume of diverse habitat theoretically provides a greater number of micro-habitats, and hence supports a diverse array of bird species.

Bird diversity for each of the five major habitat types was calculated using the Shannon-Weaver function, $\bar{d}$. The machine formula below is that of Lloyd, Zar, and Karr, 1968.

$$\bar{d} = \frac{C}{N} (N \log_{10} N - \quad n_i \log_{10} ni)$$

where C = 3.321928 (converts base 10 to base 2 [bits]); N = total number of individuals and ni = total number of individuals in the ith species.

where P_i = the proportion of all individuals belonging to the ith species: i = 1, 2........, n)

In general, a species diversity value of 3.00 or higher indicates that the given area is of high quality and supports a rich assemblage of species.

A diversity value of 1.00 or lower indicates that the area is of lower quality and cannot support a large number of species. Evenness (or equitability) was also calculated from components of Shannon's formula (where $E = \bar{d}/\bar{d}$ maximum, d maximum being based on the distribution obtained from MacArthur's, 1957, broken stick model) to show the relative distribution of individuals among the various species in each habitat during each seasonal survey. For a more detailed discussion of this method, see Weber, 1973. This information provides insight into the effect that a numerically dominant bird species or group of species has on the calculated bird diversity in a particular habitat.

A roadside survey was utilized to determine bird abundances in agricultural, developed, and edge habitats. The survey was conducted beginning at sunrise over roads in the site vicinity. During the survey, 3-minute stops were made at regular intervals along the selected route, and all birds seen or heard were counted. The relative abundance of birds along the route was determined from the total number of observations made.

7.4.3 Mammals

Species composition and relative abundance of small mammals were determined from snap-trapping during October, 1980 and April, 1981 in bottomland, midslope, and upland hardwoods, and oldfield communities on the plant site and in the proposed waste disposal areas. Traps were set for three consecutive nights in lines with approximately 12 stations per line and two traps at each station. Selective pitfall trapping was done in midslope and bottomland woodlands to determine presence of shrews in the area. Trap locations were selectively chosen in habitats which appeared suitable for shrews. Sixteen ounce open-top cans (tall-boy beer cans) were placed upright in the ground with the top flush with the soil surface. Traps were checked once a day.

Signs (tracks, scat, nests, dens, etc.) of medium to large-sized mammals were sought by reconnaissance of all major habitat types. Much of these data were gathered while doing the vegetation field work. In addition, evening survey routes were established in the area. These roadside surveys were conducted for three evenings during the early winter survey. Investigators drove area roads at slow speeds (16 to 32 kph or 10-20 mph) with a 200,000 candlepower sealed-beam spotlight. Mammals observed were recorded by habitat type, and the number of observations was expressed as observations per 1.6 km (1 mi.) and 32.2 km (20 mi.).

7.5 SAMPLING LOCATION AND RATIONALE

Amphibians and reptiles were not quantitatively sampled. Rather, searchs were made in suitable habitats on site and in the waste disposal areas. Some of these searches were made in conjunction with other portions of the terrestrial ecology while others were herptile specific, such as shocking and night road surveys. Shocking surveys were made in Town and Bull Creeks at the same locations as were the aquatic samplings (see Section 5.4 for locations). The night survey route included all roads on site and in the general vicinity such as Route 144 from Bull Creek to New Bethel Road, then New Bethel Road south and southwest back to Route 144. This route completely circumnavigated the site and both waste disposal areas. Since road collecting for amphibians is especially successful on rainy spring nights, this route was driven under such conditions.

Bird transect locations coincided with the bottomland and midslope hardwoods and the oldfield vegetation sampling areas. Upland hardwoods were not quantitatively sampled for birds, because of the similarity of this woodland type with that of the midslope. The roadside survey was done on the site boundary and interior roads (Figure 6.1). Qualitative assessments for avifauna were made in conjunction with vegetation assessments on railroad R.O.W. and fencerows.

Mammal sampling locations coincided with the midslope and bottomland hardwood and oldfield vegetation transects. Night spotlighting routes included site boundary and interior roads and the project area circumnavigation route used for amphibian road collecting.

For all wildlife studies, survey routes, transect locations, and qualitative assessment areas were selected so as to provide the most information on species composition, abundance, habitat preference, etc. as was practicable.

7.6 RESULTS AND DISCUSSION

7.6.1 Amphibians and Reptiles

During all field surveys, 29 species of amphibians and reptiles were recorded onsite, in the waste disposal areas, or on roads in the vicinity. A list of species in the project area and vicinity is found in Table 7.1. This list contains the site records, Breckinridge County records of Westerman and Westerman (1979) and those of probable occurrence from Barbour (1971). Westerman and Westerman collected in the northeast portion of the county approximately 10 to 15 miles from the project vicinity and species they collected are likely inhabitants of the project area.

No threatened, endangered, unique or unusual species were found during the surveys or by the Westermans. However, the eastern narrow-mouthed toad locality in the county is on the northern extremity of its range.

7.6.2 Birds

During the course of the baseline study, 105 bird species were observed in the project area. This is approximately 55 percent of the 190 species likely to occur here (see Table 7.2).

Table 7.3 shows the estimated bird density per acre in the major habitat types. The bottomland and midslope hardwoods contained the greatest number of species and birds per acre. During spring migration the bottomland hardwoods supported 41 species and 18.7 birds per acre. This reflects the importance of this habitat to migrating birds. During the summer the midslope hardwoods supported the greater number of birds per acre but contained five less species than the bottomland hardwoods. Of particular interest was the use of the midslope forest as a nest site by a pair of red-tailed hawks, who raised two young here. The oldfield community contained almost the same number of species in summer and spring, but bird usage almost doubled in spring due to migrants. Habitat usage in winter was decidedly greater in the bottomland hardwoods and was the same for the other two surveyed habitats. Again this illustrates the importance of this habitat to the bird fauna of the area.

Bird diversity and equitability for each habitat was calculated and is shown in Table 7.5. These data are graphically represented in Figure 7.2. For a discussion of the statistical methodology, see section 7.4.2. Species diversity was very high for all sampled habitats. In general, a diversity index over 3.00 indicates a high quality habitat. Weber (1973) indicates that equitability, calculated in this manner (see section 7.4.2 for methodology), ranges from 0 to 1 except in the situation where the equitability in the sample is greater than that of the MacArthur model. Values greater than one can occur in a sample where only a few specimens from several taxa are represented. In the present situation, E values greater than one occur because a large number of individuals are represented by a proportionally larger number of taxa. Equitability is highest when all species in the sample are as nearly equal in population as is possible (Kricher, 1973). This again points to the extremely high quality of the habitats.

Migratory waterfowl usage of the site is fair to moderate with 2,500 to 3,500 ducks using the Town and Bull Creek embayments as winter stop-over areas. (Personal communication. June 21, 1981 telephone conversation with Bob Kesseler, Kentucky Department of Fish and Wildlife Resources) Primary waterfowl usage is by breeding wood ducks (Personal communication. June 21, 1981 telephone conversation with Vernon Anderson, Kentucky Department of Fish and Wildlife Resources).

Anderson also related an apparently valid report of wild turkeys in the Town Creek area. Turkeys were stocked in an area near the Breckinridge - Hancock County line two years ago by Fish and Wildlife personnel, but are unlikely the source of the individuals in the project area. Anderson postulated that turkeys in the Hoosier National Forest across the Ohio River in Indiana glided across the river. Regardless of how they got to the area, their presence represents a potentially valuable wildlife resource.

7.6.3 Mammals

Forty-seven species of mammals potentially occur in the project area. These species, along with a brief distributional status and preferred habitat, are presented in Table 7.6. Eighteen species, or 38 percent of the species listed in the table, were recorded in the project area.

The most outstanding mammal resource in the area is an extremely high and apparently very healthy population of white-tailed deer. At least one deer, and usually three to five, were seen on every day of field work. Anderson (personal communication, June, 1981) indicated that there was a rather large population in the hilly areas adjacent to the Ohio River, at least from the Yellowbank Creek area southward to the Breckinridge - Hancock County line. The bottomlands and adjacent areas along Town Creek seem to be the central area of use. Deer trails are abundant and heavily used here. Also, the vegetation is not over browsed, indicating that the habitat has not exceeded carrying capacity. Local residents say the deer are so numerous as to be pests in gardens and soybean and corn fields.

During the winter of 1980-1981, a small colony of beavers moved into the Town Creek bottomland and built a dam on the creek. It appears that beaver are increasing in the area. (Personal communication. June 21, 1981 telephone converstaion with Vernon Anderson, Kentucky Department of Fish and Wildlife Resources).

Results of the small mammal trapping are in Table 7.7. Only five species were taken, with the meadow jumping mouse the most unusual. The species seems uncommon, but this may be a reflection of the difficulty of trapping them rather than actual scarcity. Barbour and Davis (1974) note that they are seldom attracted to bait.

In conclusion, the area supports a fairly diverse assemblage of mammals with the deer population representing an outstanding wildlife resource.

7.7 QUALITY ASSURANCE

The study of the fauna, from planning of the sampling stragegy and locations to the technical editing, has been subjected to a quality assurance program. In the planning phase, sampling detail, methodology, and locations were developed by two wildlife biologists and two plant ecologists. The plant ecologists were included to insure that the wildlife and vegetation programs were compatible.

The accuracy of the field data was checked by two individuals. In addition, the interpretation of such data, was concurred upon by both wildlife biologists.

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Table 7.1 Amphibians and Reptiles of the Project Area and Vicinity[a].

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Ambystoma jeffersonianum Jefferson's salamander	Breckinridge County record Breeding colonies in Meade and several other counties	Low woodlands and swampy areas
Ambystoma texanum Small-mouthed salamander	Breckinridge County record Site record Probably statewide distribution	Wooded areas near streams
Ambystoma opacum Marbled salamander	Breckinridge County record State distribution	A variety of woodlands
Ambystoma maculatum Spotted salamander	Breckinridge County record Statewide distribution	Moist woodlands, usually near ponds
Ambystoma tigrinum Tiger salamander	Breckinridge County record Approximately western half of state	Variety of habitats; woodlands to open grassland
Notophthalmus v. viridescens Red-spotted newt	Breckinridge County record Statewide distribution	Moist woodlands, pools, ponds
Desmognathus f. fuscus Northern dusky salamander	Breckinridge County record Site record Statewide distribution	Woodland streams

[a]Source: Barbour 1971, Westerman and Westerman, 1979. Conant, 1975.

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Plethodon dorsalis Zig-zag salamander	Breckinridge County record Site record Occurs in western two thirds of state	Rocky woodlands
Plethodon glutinosus Slimey salamander	Breckinridge County record Site record Statewide distribution	Variety of woodlands
Pseudotriton montanus Eastern mud salamander	Breckinridge County record East and central state distribution	Muddy areas along streams and in springs
Pseudotriton ruber Northern red salamander	Breckinridge County record Occurs in eastern three quarters of state	Clear, rocky streams and springs
Eurycea b. bislineata Northern two-lined salamander	Breckinridge County record Site record Statewide distribution for species	Rocky streams
Eurycea i. longicauda Long-tailed salamander	Breckinridge County record Statewide distribution	Woodland streams and wet shale outcrops
Eurycea lucifuga Cave salamander	Breckinridge County record Statewide distribution except Jackson Purchase	Wet caves, springs, along Wooded streams

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Necturus maculosus Mudpuppy	Breckinridge County record Statewide distribution	Lakes, sluggish stream, sloughs, swamps, etc.
Scaphiopus h. holbrooki Eastern spadefoot toad	Breckinridge County record Breeding colony record Occurs in western half of state	Woodlands to cultivate Burrows extensively
Rana catesbeiana Bullfrog	Breckinridge County record Site record Statewide distribution	Variety of aquatic areas
Rana clamitans melanota Green frog	Breckinridge County record Site record Statewide distribution for species	Variety of aquatic areas
Rana utricularia Southern leopard frog	Breckinridge County record Site record Occurs in western two thirds of state	Variety of aquatic habitats
Rana palustris Pickerel frog	Breckinridge County record Statewide distribution	Variety of aquatic habitats

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Gastrophryne c. carolinensis Eastern narrow-mouthed toad	Breckinridge County record Breeding colony record Occurs in the western central portion of state	Variety of habitats with shade and moisture
Bufo a. americanus American toad	Breckinridge County record Site record Statewide distribution	Variety of habits from lawns and gardens to deep woodlands
Bufo woodhousei fowleri Fowler's toad	Breckinridge County record Site record Statewide distribution	Same as above
Acris crepitans blanchardi Blanchard's cricket frog	Breckinridge County record Site record Statewide distribution	Farm ponds, lakes, large creek and rivers
Hyla crucifer Spring peeper	Breckinridge County record Site record Statewide distribution	Woodlands and thickets near water
Hyla chrysoscelis Southern gray treefrog	Breckinridge County record Site record Statewide distribution	Woodlands

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Pseudacris triseriata feriarum Upland chorus frog	Breckinridge County record Site record Occurs in the western two thirds of state	Grassy open area near water
Chelydra serpentina Common snapping turtle	Breckinridge County record Site record Statewide distribution	Almost any body of water
Sternotherus odoratus Stinkpot	Statewide distribution	Shallow mud-bottomed ponds and lakes
Terrepene carolina Box turtle	Breckinridge County record Site record Statewide distribution	Variety of woodlands; occasionally found in suburban area
Graptemys geographica Map turtle	Breckinridge County record Site record Occurs statewide except Jackson Purchase	Large rivers and lakes
Chrysemys picta marginata Midland painted turlte	Breckinridge County record Site record	Quiet, shallow water of ponds, lakes, doughs
Chrysemys scripta elegans Red-eared turtle	Breckinridge County record Site record Statewide distribution	Quiet large bodies of water

Table 7.1 Continued.

Scientific Name / Common Name	Kentucky Distributional Status	Preferred Habitat
Sceloporus undulatus hyacinthinus Northern fence lizard	Breckinridge County record Site record Statewide distribution	Dry, open woodlands, old houses, and barns
Scinecella lateralis Ground skink	Breckinridge County record Site record Statewide except Bluegrass	Woodlands
Eumeces fasciatus Five-lined skink	Breckinridge County record Site record Statewide	Cut-over woods, old houses and barns, sawdust and rock piles
Carphophis amoenus helenae Midwest worm snake	Breckinridge County record Statewide for the species	Woodlands and woods edges
Diadophis punctatus edwardsi Northern ringneck snake	Breckinridge County record Statewide distribution for the species	Woodlands
Heterodon platyrhinos Eastern hognose snake	Breckinridge County record Site record Statewide	Varied from pastures to deep woodlands
Opheodrys aestivus Rough green snake	Breckinridge County record Statewide	Woodlands, woods edges and swampy areas

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Coluber constrictor priapus Southern black racer	Breckinridge County record Site record Statewide	Varied from woodlands to cultivated fields
Elaphe obsoleta Black rat snake	Breckinridge County record Occurs in western half of state	Old fields, grasslands, open woods
Lampropeltis getulus niger Black kingsnake	Breckinridge County record Statewide	Open woodland and old fields
Lampropeltis t. triangulum Eastern milksnake	Breckinridge County record Site record Statewide	Varied from woodlands to suburban areas
Thamnophis sirtalis Garter snake	Breckinridge County record Site record Statewide	Varied but prefers moist areas
Virginia v. valeriae Eastern smooth earth snake	Breckinridge County record Statewide	Woodlands
Storeria dekayi wrightorum Midland brown snake	Breckinridge County record Statewide	Woodlands, old fields pastures, suburbs

Table 7.1 Continued.

Scientific Name Common Name	Kentucky Distributional Status	Preferred Habitat
Storeria o. occipitomaculata Northern redbelly snake	Breckinridge County record Statewide except Bluegrass	Woodlands
Regina septemvittata Queen water snake	Breckinridge County record Site record Central half of state	Small rocky streams
Nerodia sipedon pleuralis Midland watersnake	Breckinridge County record Site records Statewide	Variety of aquatic habitats
Agkistrodon contortrix mokeson Northern copperhead	Breckinridge County record Site record Statewide	Rock woodlands
Crotalus horridus Timber rattlesnake	Breckinridge County record Statewide	Rocky woodlands

Table 7.2 Birds of The Area[a]

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Red-necked grebe[b]	Podiceps grisegena	-	-	-	T
Pied-billed grebe[b]	Podilymbus podiceps	-	-	-	Su,M,RB
Double-crested cormorant[b]	Plalacrocorax auritus	-	-	-	T,Su
Great blue heron	Ardea herodias	-	-	-	Su,Wr,RB
Green heron	Butorides virescens	X	-	X	Su,RB
Little blue heron	Florida caerulea	-	-	-	Su,M
Great egret	Casmerodius albus	-	-	-	Su,RB
Yellow-crowned night heron[b]	Nyctanassa violacea	-	-	-	Su,RB
Least bittern[b]	Ixobrychus exilis	-	-	-	Su,RB
American bittern[b]	Botaurus lentiginosus	-	-	-	T
Canada goose	Branta canadensis	-	X	-	Wr
Snow goose	Chen caerulescens	-	-	-	T
Mallard	Anas platyrhynchos	-	X	-	T,Wr
Black duck	Anas rubripes	-	-	-	T,Wr
Gadwall	Anas strepera	-	-	-	T
Pintail	Anas acuta	-	-	-	T,Wr
Green-winged teal	Anas carolinensis	-	-	-	T
Blue-winged teal	Anas discors	-	-	-	T
American widgeon	Anas americana	-	-	-	T
Northern shoveler	Anas clypeata	-	-	-	T
Wood luck	Aix sponsa	X	-	X	Su,RB
Ring-necked duck	Aythya collaris	-	-	-	T,Wr
Lesser scaup	Aythya affinis	-	-	-	T,Wr
Common goldeneye	Bucephela clangula	-	-	-	Wr
Bufflehead	Bucephala albeola	-	-	-	Wr
Hooded merganser	Lophodytes cucullatus	-	-	-	T,Wr
Common merganser	Mergus merganser	-	-	-	T

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Red-breasted merganser	*Mergus serator*	-	-	-	T
Turkey vulture	*Cathartes aura*	X	X	X	Pr
Black vulture	*Coragyps atratus*	-	-	-	Pr,RB
Sharp-shinned hawk	*Accipiter striatus*	-	-	-	Pr,RB
Cooper's hawk	*Accipiter cooperii*	-	X	-	Pr,RB
Red-tailed hawk	*Buteo jamaicensis*	X	X	X	Pr,RB
Red-shouldered hawk	*Buteo lineatus*	-	-	-	Pr,RB
Broad-winged hawk	*Buteo platypterus*	-	-	-	Su,T
Bald eagle	*Haliaeetus leucocephalus*	-	-	-	T,Wr
Marsh hawk	*Circus cyaneus*	-	X	-	T,Wr
Osprey	*Pandion haliaetus*	X	-	-	T,Su
American kestrel	*Falco sparverius*	X	X	X	Pr,RB
Bobwhite	*Colinus virginianus*	X	X	X	Pr,RB
Wild turkey	*Meleagris gallopavo*				Pr
Sora[b]	*Porzana carolina*	-	-	-	T
American coot	*Fulica americana*	-	-	-	T
Semipalmated plover[b]	*Charadrius semipalmatus*	-	-	-	T
Killdeer	*Charadrius vociferus*	X	-	X	Pr,RB
American golden plover	*Pluvialis dominica*	-	-	-	T
American woodcock	*Philohela minor*	X	-	-	Su,RB
Common snipe[b]	*Capella gallinago*	-	-	-	T,Wr
Upland sandpiper	*Bartramia longicauda*	-	-	-	T
Spotted sandpiper	*Actitis macularia*	-	-	-	T
Solitary sandpiper	*Tringa solitaria*	-	-	-	T
Lesser yellowlegs[b]	*Calidris minutilla*	-	-	-	T
White-rumped sandpiper	*Calidris fuscicollis*	-	-	-	T
Least sandpiper[b]	*Calidris minutilla*	-	-	-	T
Herring gull	*Larus argentatus*	-	X	-	Wr

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Rock dove	Columba livia	-	-	X	Pr,RB
Mourning dove	Zenaida macroura	X	X	X	Pr,RB
Yellow-billed cuckoo	Coccyzus americanus	X	-	X	Su,RB
Black-billed cuckoo	Coccyzus erythropthalmus	-	-	-	T
Barn owl	Tyto alba	-	-	-	Pr,RB
Screech owl	Otus asio	X	-	-	Pr,RB
Great horned owl	Bubo virginianus	-	-	-	Pr,RB
Barred owl	Strix varia	X	X	-	Pr,RB
Short-eared owl	Asio flammeus	-	-	-	Wr
Whip-poor-will	Caprimulgus vociferus	-	-	X	Su,RB
Chuck-will's-widow	Caprimulgus carolinensis	-	-	-	Su,RB
Common nighthawk	Chordeiles minor	X	-	-	Su,RB
Chimney swift	Chaetura pelagica	-	-	X	Su,RB
Ruby-throated hummingbird	Archilochus colubris	X	-	-	Su,RB
Belted kingfisher	Megaceryle alcyon	X	-	X	Pr,RB
Common flicker	Colaptes auratus	X	X	X	Pr,RB
Pileated woodpecker	Dryocopus pileatus	X	X	X	Pr,RB
Red-bellied woodpecker	Centurus carolinus	X	X	X	Pr,RB
Red-headed woodpecker	Melanerpes erythrocephalus	X	X	X	Pr,RB
Yellow-bellied sapsucker	Sphyrapicus varius	-	X	-	T,Wr
Hairy woodpecker	Dendrocopos villosus	X	-	X	Pr,RB
Downy woodpecker	Dendrocopos pubescens	X	X	X	Pr,RB
Eastern kingbird	Tyrannus tyrannus	X	-	X	Su,RB
Great crested flycatcher	Myiarchus crinitus	X	-	X	Su,RB
Eastern phoebe	Sayornis phoebe	-	-	X	SR,RB
Acadian flycatcher	Iridoprocne bicolor	X	-	-	Su,RB
Eastern wood pewee	Contopus virens	X	-	X	Su,RB

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Horned lark	Eremophila alpestris	-	-	X	Pr,RB
Tree swallow	Tridoprocne bicolor	-	-	-	T
Bank swallow	Riparia riparia	-	-	-	T,Su,RB
Rough-winged swallow	Stelgidopteryx ruficollis	-	-	-	Su,RB
Barn swallow	Hirundo rustica	X	-	X	Su,RB
Cliff swallow	Petrochelidon	-	-	X	Su,T
Purple martin	Progne subis	-	-	-	Su,RB
Blue jay	Cyanocitta cristata	X	X	X	Pr,RB
Common crow	Corvus brachyrhynchos	X	X	X	Pr,RB
Carolina chickadee	Parus carolinensis	X	X	X	Pr,RB
Tufted titmouse	Parus bicolor	X	X	-	Pr,RB
White-breasted nuthatch	Sitta carolinensis	X	X	X	Pr,RB
Red-breasted nuthatch	Sitta canadensis	-	X	-	T,Wr
Brown creeper	Certhia familiaris	-	X	-	T,Wr
House wren	Troglodytes aedon	-	-	-	T
Winter wren	Troglodytes troglodytes	-	-	-	T,Wr
Bewick's wren	Thryomanes bewickii	-	-	-	Su,RB
Carolina wren	Thryomanes ludovicianus	X	-	X	Pr,RB
Mockinbird	Mimus polyglottos	X	-	X	Pr,RB
Gray catbird	Dumetella carolinensis	-	-	X	Su,RB
Brown thrasher	Toxostoma rufum	X	-	X	Su,RB
American robin	Turdus migratorius	X	X	X	Pr,RB
Wood thrush	Hylocichla mustelina	X	-	X	Su,RB
Hermit thrush	Catharus guttatus	-	-	-	T,Wr
Swainson's thrush	Catharus ustulatus	-	-	X	T
Gray-cheeked thrush	Catharus minimus	-	-	-	T
Veery	Catharus fuscescens	-	-	-	T

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Eastern bluebird	*Sialia sialis*	X	-	-	Pr,RB
Blue-gray gnatcatcher	*Polioptila caerulea*	X	-	X	Su,RB
Golden-crowned kinglet	*Regulus satrapa*	-	X	-	T,Wr
Ruby-crowned kinglet	*Regulus calendula*	-	-	-	T
Cedar waxwing	*Bombycilla cedrorum*	-	X	X	Pr,RB
Loggerhead shrike	*Lanius ludovicianus*	X	X	-	Pr,RB
Starling	*Sturnus vulgaris*	X	X	X	Pr,RB
White-eyed vireo	*Vireo griseus*	X	-	X	Su,RB
Yellow-throated vireo	*Vireo flavifrons*	X	-	X	Su,RB
Solitary vireo	*Vireo solitarius*	-	-	-	T
Red-eyed vireo	*Vireo olivaceus*	X	-	X	Su,RB
Philadelphia vireo	*Vireo philadelphicus*	-	-	-	T
Warbling vireo	*Vireo gilvus*	-	-	-	Su,RB
Black-and-white warbler	*Mniotilta varia*	X	-	X	T
Prothonotary warbler	*Protonotaria citrea*	X	-	X	Su,RB
Swainson's warbler	*Limnothlypis swainsonii*	-	-	-	Su,RB
Worm-eating warbler	*Helmitheros vermivorus*	X	-	-	Su,RB
Golden-winged warbler	*Vermivora chrysoptera*	-	-	-	T
Blue-winged warbler	*Vermivora pinus*	-	-	X	T,Su
Tennessee warbler	*Vermivora peregrina*	X	-	X	T
Nashville warbler	*Vermivora ruficapilla*	-	-	X	T
Northern parula	*Parula americana*	-	-	-	Su,RB
Yellow warbler	*Dendroica petechia*	X	-	X	Su,RB
Magnolia warbler	*Dendroica magnolia*	-	-	X	T
Cape may warbler	*Dendroica tigrina*	-	-	-	T
Black-throated blue warbler	*Dendroica caerulescens*	-	-	-	T
Yellow-rumped warbler	*Dendroica coronata*	-	-	X	T,Wr

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Black-throated green warbler	*Dendroica virens*	-	-	-	T
Cerulean warbler	*Dendroica cerulea*	-	-	-	Su,RB
Blackburnian warbler	*Dendroica fusca*	-	-	X	T
Yellow-throated warbler	*Dendroica dominica*	X	-	X	Su,RB
Chestnut-sided warbler	*Dendroica pensylvanica*	-	-	X	T
Blackpoll warbler	*Dendroica striata*	-	-	X	T
Pine warbler	*Dendroica pinus*	-	-	X	T,Su
Prairie warbler	*Dendroica discolor*	X	-	X	Su,RB
Palm warbler	*Dendroica palmarum*	-	-	-	T
Bay-breasted warbler	*Dendroica castanea*	-	-	X	T
Ovenbird	*Seiurus aurocapillus*	-	-	X	T,Su,RB
Northern waterthrush	*Seiurus noveboracensis*	-	-	-	T
Louisiana waterthrush	*Seiurus motacilla*	-	-	-	Su,RB
Kentucky warbler	*Oporornis formosus*	X	-	-	Su,RB
Connecticut warbler	*Oporornis agilis*	-	-	-	T
Mourning warbler	*Oporornis philadelphia*	-	-	-	T
Common yellowthroat	*Geothlypis trichas*	X	-	X	Su,RB
Yellow-breasted chat	*Icteria virens*	X	-	X	Su,RB
Hooded warbler	*Wilsonia citrina*	X	-	-	Su,RB
Wilson's warbler	*Wilsonia pusilla*	-	-	-	T
Canada warbler	*Wilsonia canadensis*	X	-	-	T
American redstart	*Setophaga ruticilla*	X	-	X	Su,RB
House sparrow	*Passer domesticus*	X	X	X	Pr,RB
Bobolink	*Dolichonyx oryzivorus*	-	-	-	T
Eastern meadowlark	*Sturnella magna*	X	X	X	Pr,RB
Red-winged blackbird	*Agelaius phoeniceus*	X	X	X	Pr,RB
Orchard oriole	*Icterus spurius*	-	-	-	Su,RB

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
Northern oriole	*Icterus galbula*	-	-	X	Su,RB
Rusty blackbird	*Euphagus carolinus*	-	-	-	T
Brewers blackbird	*Euphagus cyanocephalus*	-	-	-	T
Common grackle	*Quiscalus quiscula*	X	X	X	Pr,RB
Brown-headed cowbird	*Molothrus ater*	-	X	X	Pr,RB
Scarlet tanager	*Piranga olivacea*	-	-	X	T,Su
Summer tanager	*Piranga rubra*	-	-	X	Su,RB
Cardinal	*Cardinalis cardinalis*	X	X	X	Pr,RB
Rose-breasted grosbeak	*Pheucticus ludovicianus*	-	-	-	T
Indigo bunting	*Passerina cyanea*	X	-	X	T
Dickcissel	*Spiza americana*	-	-	-	Su,RB
Evening grosbeak	*Hesperiphona verpertina*	-	-	-	V
Purple finch	*Carpodacus purpureus*	-	-	-	T,Wr
House finch	*Carpodacus mexicanus*	-	-	X	Pr
Pine siskin	*Spinus pinus*	-	-	-	Wr
American goldfinch	*Spinus tristis*	-	X	X	Pr,RB
Rufous-sided towhee	*Pipilo erythrophthalmus*	-	X	X	Pr,RB
Savannah sparrow	*Paserculus sandwichensis*	-	-	X	T
Grasshopper sparrow	*Ammodramus savannarum*	-	-	-	Su,RB
Vesper sparrow	*Pooecetes gramineus*	-	-	-	T
Lark sparrow	*Chondestes grammacus*	-	-	-	Su,RB
Bachman's sparrow	*Aimophila aestivalis*	-	-	-	Su,RB
Dark-eyed junco	*Junco hyemalis*	-	X	-	T,Wr
Tree sparrow	*Spizella arborea*	-	-	-	Wr
Chipping sparrow	*Spizella passerina*	-	-	X	Su,RB
Field sparrow	*Spizella pusilla*	X	X	X	Pr,RB
White-crowned sparrow	*Zonotrichia leucophrys*	-	X	X	Wr

Table 7.2 Continued.

Common Name	Scientific Name	Late Summer	Winter	Spring	Status[c]
White-throated sparrow	Zonotrichia albicollis	-	X	X	Wr
Fox sparrow	Passerella iliaca	-	-	-	T
Lincoln's sparrow	Melospiza lincolnii	-	-	-	T
Swamp sparrow	Melospiza melodia	-	-	-	T,Wr
Song sparrow	Melospiza georgiana	X	X	X	Pr,RB
Lapland longspur	Calcarius lapponicus	-	-	-	Wr

[a]Includes those species recorded during Dames & Moore field surveys and those that may be found on the site based upon known species range, documented records and accounts of area residents.

[b]Habitat for these species in the site area is restricted.

[c]Status: Pr - Permanent resident
Su - Summer resident
Wr - Winter resident
M - Migrant
T - Transient
V - Visitant
RB - Regular breeder

Data Sources: Dames & Moore field observations.

R. W. Barbour, et al., Kentucky Birds: A Finding Guide, University Press of Kentucky, Lexington, 1973.

R. M. Mengel, The Birds of Kentucky, American Ornithologists' Union, Ornithological Monograph No. 3, 1965.

B. I. Monroe, Jr., "Summary of Occurrence of Birds of Kentucky," Kentucky Warbler 45: 47-56 (1969).

C. S. Robbins, B. Brun, and H. S. Zim, Birds of North America, Golden Press, New York, 1966.

Table 7.3 Estimated Bird Density Per Acre in The Major Habitat Types, 1980, 1981[a,b]

Common	Bottomland[c] Hardwoods			Midslope Hardwoods			Oldfield		
	Su	W	Sp	Su	W	Sp	Su	W	Sp
Red-tailed hawk	1		2	1		2			1
Green heron	1		1						
Woodcock	5								
Mourning dove	5			6					
Yellow-billed cuckoo	8		9	6		2	1		
Screech owl	2			1			1		
Barred owl	1			3					
Ruby-throated hummingbird							2		
Pileated woodpecker	5	1	2	4	2	2			
Red-bellied woodpecker	1	5	13	6	6	10	1		
Downy woodpecker	9	8		9	6		2		
Great crested flycatcher	4			1					
Eastern wood pewee	4		7	20		9	14		
Eastern phoebe	1								
Blue jay	10	5	12	8	6	9	4	3	2
Common crow	3					1	1	3	1
Carolina chickadee	17	18	14	16	15	6	8	6	9
Tufted titmouse	14	9	11	15	6	2	4	7	2
White-breasted nuthatch	5	5	7	25	2	5	2	1	
Blue-gray gnatcatcher	1			6		1	1		4
Red-eyed vireo	3		10	6		12			
Worm-eating warbler	2								
Blue-winged warbler	1			1					3
Cerulean warbler	1								

Table 7.3 Continued.

Common	Bottomland[c] Hardwoods			Midslope Hardwoods			Oldfiled		
	Su	W	Sp	Su	W	Sp	Su	W	Sp
Common yellowthroat	9		9						4
Kentucky warbler	2		3						
Warbler sp.	2		2						
Scarlet tanager	2		2	2		3			
Yellow warbler	1								
Prothonotary warbler	1		3						
Summer tanager	1			5		1			2
Cardinal	9	6	15	16	1	1		5	5
Indigo bunting	7		37			5	2		19
Hooded warbler	1			2					
Rufous-sided towhee			5	4			2		5
White-eyed vireo			4	2		8			
Wood thrush			3	17		13			
Tennessee warbler			3	2					
Empidonax sp.			6	8		10			
Turkey vulture			1		1		1		1
Field sparrow			1				9	1	12
Yellow-throated warbler							1		
Eastern kingbird							2		
Eastern bluebird							5		
Chimney swift							1		
Red-breasted nuthatch							1		
Carolina wren			2			5	1		
Northern harrier					1				

Table 7.3 Continued.

Common	Bottomland[c] Hardwoods			Midslope Hardwoods			Oldfield		
	Su	W	Sp	Su	W	Sp	Su	W	Sp
Common flicker		3	2		3			1	
Yellow-bellied sapsucker					1				
Yellow-rumped warbler					1	1			
White-crowned sparrow								5	
White-throated sparrow		3						6	
Dark-eyed junco		9						3	
Golden-crowned kinglet								4	
Song sparrow		1	1					4	
Red-headed woodpecker		4	1			2			
Brown creeper		3							
Robin		1							
Cedar waxwing		10	3						
Common grackle		50	34			2			
Goldfinch		8							
Black-and-white warbler			2						
Red-winged blackbird			62			2			1
Northern oriole			4			1			
Blue grosbeak			1						
Hairy woodpecker			9			4			1
Wood duck			2						
Catbird			1						
American redstart			2						
Blackpoll warbler			7						
Magnolia warbler			1						

Table 7.3 Continued.

Common	Bottomland[c] Hardwoods			Midslope Hardwoods			Oldfield		
	Su	W	Sp	Su	W	Sp	Su	W	Sp
Bay-breasted warbler			1						
Belted kingfisher			1						
Yellow-breasted chat									8
Prairie warbler									11
Bobwhite									1
Blackburnian warbler						1			
Pine warbler									1
Mockinbird									1
Brown-headed cowbird									3
Swainson's thrush						2			
Ovenbird						1			
Blackburnian warbler						1			
Other unidentified birds		6	23		3	16			4
Total Number of Species	33	19	41	28	13	30	22	13	23
Total Number of Individuals	139	155	336	197	54	139	66	49	128
Birds Per Acre	7.7	8.6	18.7	17.9	2.2	5.6	3.0	2.2	5.8

[a]Estimates based upon total observations of birds made while walking a given transect on three consecutive days.

[b]Bird transect locations are shown in Figure 7.1.

[c]The areas sampled within each habitat type (from left to right) were 18 acres, 25 acres, and 22 acres.

Table 7.4 Realtive Abundance of Birds Observed Along the Roadside Survey at the Proposed Plant Site, 1980-1981[a]

Common Name	Relative Abundance[b] Summer	Winter	Spring
Cardinal	C	C	C
Mourning dove	C	U	C
Indigo bunting	C		C
Starling	C	A	U
Common crow	C	C	C
Mockingbird	I		I
Robin	C	I	C
Red-winged blackbird	A		C
Catbird	I		I
Eastern kingbird	I		I
Yellow-breasted chat	I		I
Barn swallow	C		C
Eastern meadowlark	I	I	I
House sparrow	C	C	C
Bobwhite	U		C
Song sparrow	U	C	U
Prothonotary warbler	I		I
Brown thrasher	I		I
Ruby-throated hummingbird	I		
Kestrel	U	U	U
Killdeer	I	C	U
Yellow-billed cuckoo	I		
Downy woodpecker	I		
Common flicker	I	I	U
Red-billed woodpecker	U	U	
Pileated woodpecker	I	I	I
Great blue heron	I		
Field sparrow	I		
White-breasted nuthatch	I		
Wood thrush	I		
Purple martin	I		
Warbler sp.	I		
Eastern wood pewee	U		I
Blue-gray gnatcatcher			
Yellow warbler	I		
Carolina chickadee	U	U	I

Table 7.4 Continued.

Common Name	Relative Abundance[b] Summer	Winter	Spring
Brown-headed cowbird	I		I
Tufted titmouse	U		
Screech owl	I		
Rufous-sided towhee	I		I
Blue jay	U	U	U
Turkey vulture	I	I	I
Cliff swallow			I
Common yellowthroat			U
Northern oriole			I
Red-headed woodpecker			I
Prairie warbler			I
Red-eyed vireo			I
Wood duck			I
Chimney swift			U
Common grackle			C
Goldfinch			U
White-crowned sparrow			U
Eastern phoebe			I
House finch			I
Yellow-rumped warbler			I
Red-tailed hawk			I
White-throwted sparrow			I
Eastern bluebird			I

[a]The roadside survey route is depicted in Figure 7.1

[b]Relative abundance classifications are based on the following criteria:

Abundant - Species likely to be seen in large numbers (more than 50 birds) in its preferred habitat per field visit during its expected occurrence.

Common - Species likely to be seen in smaller numbers (10-50) in at least half of the field visits in its preferred habitat at the proper season.

Table 7.4 Continued.

Uncommon	-	Species seen in small numbers (4-9) in the appropriate habitat and season in at least half of the field visits.
Infrequent	-	Species seen as fewer than four birds per field trip only 1-3 times during the entire survey. The criteria does not apply for herons or hawks.

Table 7.5 Bird Diversity[a] and Equitability Within Each Major Habitat Type in the Area, 1980-1981.

Habitat Type	Diversity d̄			Equitability E		
	Su	W	Sp	Su	W	Sp
Bottomland Hardwoods	4.48	3.51	4.42	1.0	0.89	0.78
Midslope Hardwoods	3.59	3.27	4.37	0.63	1.07	1.02
Oldfields	2.35	3.49	4.77	0.32	1.2	1.78

Table 7.6 Mammals of the Project Area and Vicinity[a]

Scientific Name Common Name	Distributional Status	Preferred Habitat
Dipelphis virginiana Oppossum	Site Records	Varied from woodlands to urban areas.
Sorex cinereus Masked shrew	Henderson Co. record; Harlan Co. is only other state record.	Moist woodlands.
Sorex longirostris Southeastern shrew	Bullitt, Hardin, Meade Co. records known from western half of state.	Low swampy weedfields, moist woods and honeysuckle patches.
Blarina brevicauda Short-tailed shrew	Site records. Statewide.	Moist woods but uses wide variety of habitats.
Cryptotis parva Least shrew	Statewide.	Grasslands.
Microsorex thompsoni Pigmy shrew	Breckinridge Co. record. Distribution unknown; extremely rare.	Woodlands.
Scalopus aquaticus Eastern mole	Site record. Statewide.	Variety of habitats with loose loamy soil.

[a]Barbour, 1974.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
Myotis lucifugus Little brown bat	Statewide.	Wood ecges, old fields, suburban areas generally near water.
Myotis griscens Gray bat	Breckinridge Co. record. Occurs in karst areas of state.	Caves near water.
Myotis keenii Keen's bat	Breckinridge Co. record. Statewide except Purchase.	Caves near streams.
Myotis sodalis Indiana bat	Breckinridge Co. record. Statewide except Purchase.	Caves in winter. Maternity colonies use wood stream areas.
Myotis leibii Small-footed bat	Breckinridge Co. record Cave regions of south east Kentucky and Mammouth Cave National Park.	In Kentucky, around caves in summer months.
Lasionycteris noctivagans Silver-haired bat	Statewide, rare.	Woodland ponds and streams.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
Pipistrellus subflavus Eastern pipistrelle	Statewide.	Woodland edges usually near water.
Eptesicus fuscus Big brown bat	Statewide.	Urban and suburban areas.
Lasiurus borealis Red bat	Statewide.	Woodlands but sometimes uses suburban areas.
Lasiurus cinereus Hoary bat	Statewide.	Woodlands.
Nyticeius humeralis Evening bat	Statewide.	Suburban areas with abundant trees.
Sylvilagus floridanus Eastern cottontail	Site records. Statewide.	Wide variety of habitats.
Sylvilagus aquaticus Swamp rabbit	Two Hancock Co. localities near project area.	Lowland swamps and wooded floodplains.
Tamias striatus Chipmunk	Site records.	Woodlands.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
Marmota monax Groundhog	Site records. Statewide.	Wood edges, fencerows, roadsides, postures.
Sciurus carolinensis Gray squirrel	Site records. Statewide.	Woodlands, especially oak and hickory.
Sciurus niger Fox squirrel	Site records Statewide.	Fencerows, open areas with scattered trees.
Glaucomys volans Southern flying squirrel	Statewide.	Woodlands.
Castor canadensis Beaver	Site record. Statewide.	Creeks, rivers, lakes.
Reithrodontomys humulis Eastern harvest mouse	Statewide.	Dense weedfields.
Peromyscus maniculatus bairdii Prairie deer mouse	Statewide except eastern mountains.	Old fields, grasslands, agricultural land.
Peromyscus leucopus White-footed mouse	Site records. Statewide distribution	Prefer woodlands with good ground cover, but occur in a variety of habitats.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
<u>Rattus norvegious</u> Norway rat	Statewide.	Open garbage dumps, grain storage areas.
<u>Mus muculus</u> House mouse	Site records. Statewide.	Barns, granaries, houses, garbage dumps.
<u>Zapus hudsonius</u> Meadow jumping mouse	Site record. Western and central Kentucky.	Tall grasslands in low areas.
<u>Vulpes vulpes</u> Red fox	Statewide.	Farmlands and open areas.
<u>Urocyon cinereoargenteus</u> Gray fox	Statewide.	Woodlands.
<u>Procyon lotor</u> Raccoon	Statewide. Site records.	Woodlands.
<u>Mustela frenata</u> Long-tailed weasel	Statewide.	Forest edge, fencerows, stream banks.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
Ochrotomys nuttalli Golden mouse	Statewide except inner bluegrass.	Woodlands with dense understory of greenbrier, honeysuckle and/or wild grape.
Neotoma floridana magister Eastern woodrat	Site records from sign statewide except inner Bluegrass.	Rock outcrops and larger boulder piles.
Microtus pennsylvanicus Meadow vole	Breckinridge Co. record inner bluegrass and knobs.	Moist grasslands and open swamps.
Microtus ochrogaster Prairie vole	Site records. Statewide except extreme southeastern mountains.	Any habitat with grassy cover
Microtus pinetorum Pine vole	Statewide.	Variety of habitats from woodlands of grassland.
Ondatra zibethicus Muskrat	Statewide. Site records.	Sluggish lowland streams and farm ponds.
Synaptomys cooperi Southern bog lemming	Breckinridge Co. record. Eastern mountains, bluegrass and along Ohio River.	Grassy areas with some brush.

Table 7.6 Continued.

Scientific Name Common Name	Distributional Status	Preferred Habitat
Mustela vison Mink	Statewide.	Any riparian wooded area
Mephitis mephitis Striped skunk	Site records Statewide.	Variety of habitats.
Lynx rufus Bobcat	Statewide.	Remote woodlands.
Odocoileus virginianus White-tailed deer	Site records. Statewide.	Woodlands, edges, brushland.

Table 7.7 Results of Small Mammal Snaptrapping in Major Habitat Types for Spring and Fall

Habitat	Species	Total Captures		Trap Nights		Trap Success(%)	
		Spring	Fall	Spring	Fall	Spring	Fall
Bottomland Hardwoods	Meadow jumping mouse	--	4	150	150	--	2.6
	White-footed mouse	--	6	150	150	--	4.0
	House mouse	--	2	150	150	--	1.3
Midslope Hardwoods	White-footed mouse	4	8	150	150	2.7	5.3
	Short-tailed shrew	4	-	150	150	2.7	--
Oldfields	Prairie vole	18	10	150	150	12.0	6.7
	Short-tailed shrew	6	--	150	150	4.0	--

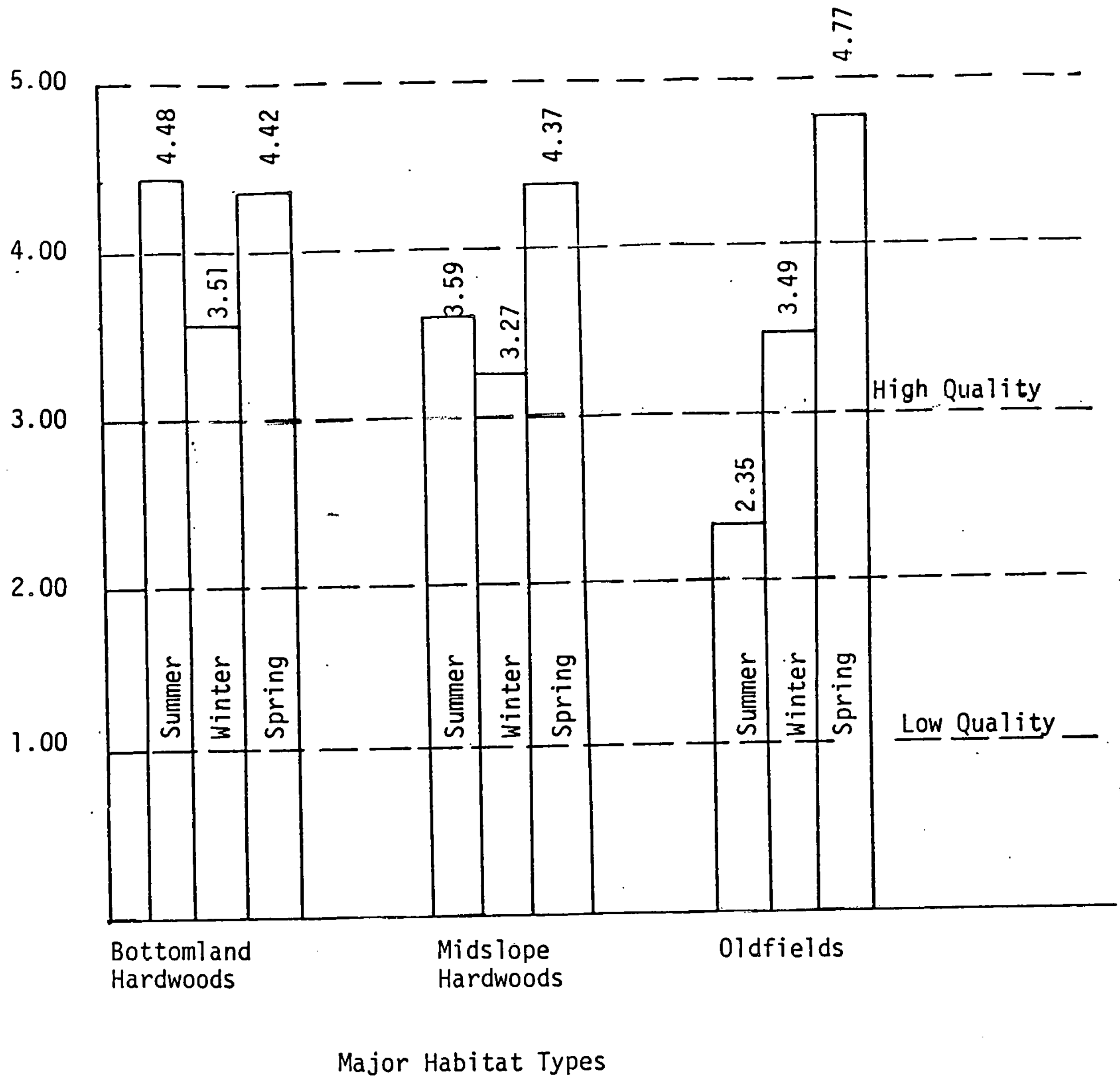


Figure 7.1 Comparative bird diversity indexes for major habitat types.

Source: Dames & Moore field data 1980-1981.

Geology

8.0 GEOLOGY

8.1 INTRODUCTION

The geology of the proposed plant site and waste disposal areas, while not complex, does involve several lithologies with varying histories. In order to most completely represent site geology, several aspects have been considered. Background investigations, objectives, methods of study, and sources are listed. Regional physiography and stratigraphy are discussed in a broad-brush manner. Site specific stratigraphic relationships are described in greater detail as necessary, with the plant site and waste disposal areas considered separately.

Important structural features affecting areas closest to the site are presented along with a discussion of regional seismicity. Finally, potential and actual mineral resources are evaluated.

8.2 BACKGROUND AND OBJECTIVES

Baseline information provided by this chapter will serve as a source document for design of structural elements of the proposed plant and development of possible mitigating measures to provide for environmentally sound conditions, for the storage of coal, products or waste materials. The chapter will be used as a source of information concerning regional geology and site specific geology as it relates to ground water quality and hydrology (Chapter 11.0).

8.3 METHODOLOGY AND SOURCES

Regional aspects of interest such as physiography, regional stratigraphy, and structure were gathered from various sources of published and unpublished data. These sources include U.S., Illinois, and Kentucky Geological Survey publications, maps and data as well as regional reports previously prepared by Dames & Moore.

Site specific conditions are described on the basis of previous environmental reports available to Dames & Moore, where applicable; in addition, information provided by a field reconnaissance program supervised by Dames & Moore personnel and a geotechnical and geohydraulic investigation conducted in 1981 by Dames & Moore is included.

8.4 PHYSIOGRAPHY

The proposed site lies within the Mammoth Cave Plateau area of the arcuate Mississippian Plateau region (See Figure 8.1). The Mammoth Cave Plateau, lying immediately to the east of the Western Coal Field region, is separated from the lower Pennyroyal Plateau by the south-facing, U-shaped Dripping Springs Escarpment (Brown and Lambert, 1963; Hopkins, 1966).

Surface drainage in the region is by short, small streams with steep gradients (Brown and Lambert, 1963). The area lies within the Ohio River drainage basin, with flows generally down dip to the west. Man-made ponds have altered the surface drainage somewhat.

Within the plant site area surface drainage is primarily directly into the Ohio River, or into the upper branch of Town Creek. Drainage in the waste disposal area is into Bull Creek. Both creeks empty into the Ohio River.

The proposed plant site area is generally flat with a slight westward slope. Elevations above mean sea level range from 113 m. (370 ft.) close to the river to over 131 m. (430 ft.) on the eastern half of the site. The borrow area is moderately flat in part, ranging in elevation from 122 m. (400 ft.) to approximately 131 m. (430 ft.), but contains ridges and hills in the western portion with elevations as high as 210 m. (690 ft.).

The waste disposal areas exhibit greater overall relief than the plant site area. The southern waste disposal area encompasses roughly the upper portion of the Bull Creek watershed (refer to Chapter 10). Elevations range from 122 m (400 ft) in the lower portions of Bull Creek to 229 m (750 ft) along the ridges. The northern waste disposal area is composed of valleys and ridges whose surface drainage is into the easternmost portion of Town Creek. Elevations there range from 126 m (415 ft) to 198 m (650 ft).

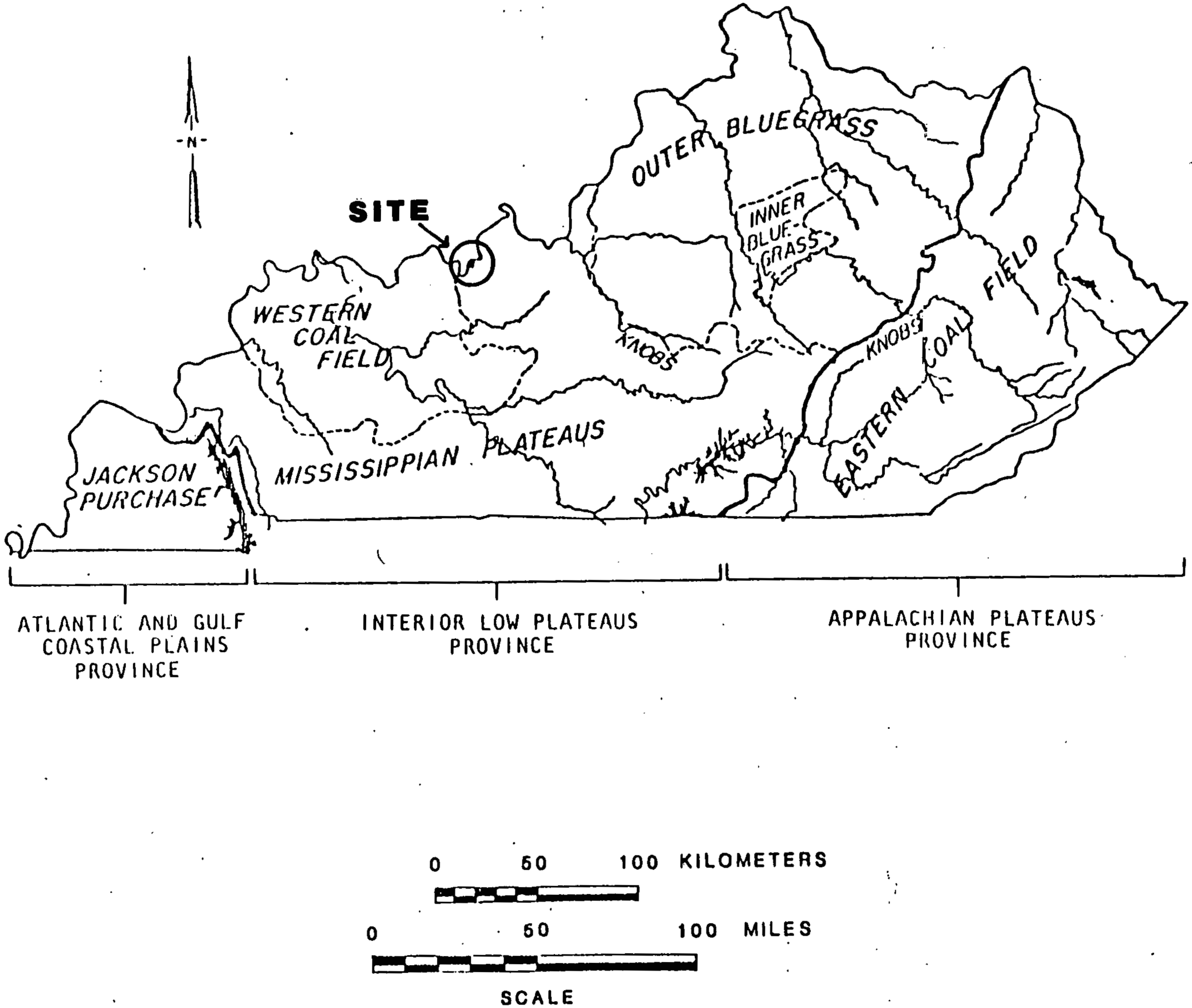


Fig. 8.1 PHYSIOGRAPHIC PROVINCES OF KENTUCKY. Source: H.T. Hopkins, Fresh-Saline Water interface Map of Kentucky, Series 10, Kentucky Geological Survey, 1966.

8.5 STRATIGRAPHY

8.5.1 Regional Setting

The early geologic history of the region is fragmentary due to the absence of deep drill holes in the area. However, it is possible that the oldest, most deeply buried rocks are a thick sequence of layered volcanic and sedimentary rocks similar to that found in southern Oklahoma (Swann, 1968).

The oldest known rocks in the Mammoth Cave Plateau are Middle to Late Mississipian in age. These rocks formed from sediments deposited within what was then a large structural depression encompassing parts of southern Illinois, southern Indiana, and western Kentucky, known as the Illinois Basin. An ancient river system, the Michigan River, brought silt and fine sand over the broad Canadian Shield from the rising Franklin Mountains of the Arctic. The river formed a deltaic complex on the northern and eastern portions of the Illinois Basin (Swann, 1968).

The Mississippian consists of thin alternating formations of limestone and shale or sandstone and shale. Each clastic unit represents an advance of the Michigan River delta over hundreds of miles. The limestone units record the return of the sea due to a decrease in the ancient river's sediment load and gradual sinking of the basin. These changes in the characteristics of the river were linked to climatic cycles spanning thousands of years.

These older Mississippian formations are generally less than 15 m.(50 ft.) thick, with the exception of the Big Clifty Sandstone Member of the Golconda Formation, which may be close to 100 feet in thickness. Major members of this group are, from oldest to youngest, the Beaver Bend and

Paoli Limestones, the Golconda Formation, the Hardinsburg Sandstone, the Glen Dean Limestone, and the Tar Springs Formation. Individual thicknesses and characteristics are catalogued in Figure 8.2, the geologic column for the area.

Overlying these thinner sedimentary deposits is the 61+ m. (200+ ft.) thick Buffalo Wallow Formation. Youngest of the Late Mississippian rocks, it is a thick grayish shale unit. Occasional much smaller sandstone or limestone beds are included within this unit and serve as marker beds.

Following the Mississippian, the Illinois Basin was uplifted and tilted to the north. The next 300 million years were a period of erosion. The Michigan River, meandering back and forth, cut away a wide, deep valley extending well into the deep bedrock of the region. During the last million years, four major Pleistocene ice sheets covered the northern portion of the basin. Although the glacial advances did not extend into Breckinridge County, periods of major flooding as the ice melted allowed repeated deposition of coarse sand, pebbles and cobbles of glacially derived material. Fine-grained sediments were deposited by tributary streams in temporal lakes accompanying the ice movement. These lacustrine deposits formed the thick clay units discussed in Section 8.5.2. This deposit, up to 46 m. (150 ft.) thick, of Pleistocene alluvium and terrace material, accounts for the exceptional ground water storage characteristics of the alluvium.

Overlying the Pleistocene is a thinner (up to 9 m. or 30 ft.) deposit of silt, sand, and clay. This deposit is thickest along the Ohio River flood plain, and represents sediment laid down within the last 10,000 years. It is also present to a lesser degree in intermittertly flooded sloughs and along tributaries of the Ohio River such as Town Creek.

Era	Period		Series	Formation and Member		Thickness m. (ft.)	Description
Cenozoic	Quaternary		Recent	Younger alluvium		0-9.1 (0-30)	Silt, sand, clay, and gravel; gravel of locally derived rocks along tributaries
			Pleistocene	Older alluvium and lacustrine and older terrace deposits		0-45.7? (0-150?)	Clay and silt, forming terraces along Town Creek to about 430 ft. Sand, silt, and gravel; silty in upper 25-30 ft.
Mesozoic				Missing			
Paleozoic	Carboniferous	Mississippian	Upper Mississippian	Buffalo Wallow Formation		64+(210+)	Shale, olive-gray, fissile to platy; with minor thin limestone or sandstone beds.
				Tar Springs Formation		0-13.7 (0-45)	Sandstone and shale members, indistinguishable from Upper Member of Glen Dean Limestone.
				Glen Dean Limestone	Upper Member	18.3-27.5 (60-90)	Shale and limestone.
					Lower Member	7.6-12.2 (25-40)	Limestone, pale-gray, abundant fossil fragments.
				Hardinsburg Sandstone		7.6-15.2 (25-50)	Sandstone, gray to light brown: shale, olive gray, grayish-red or dark grey. Shale usually at base and top.
				Golconda Formation	Haney Limestone Member	6.1-13.7 (20-45)	Limestone, light-yellowish-gray to light olive gray. Chert occurs as thin lenses.
					Big Clifty Sandstone Member	18.3-30.5 (60-100)	Sandstone and shale: sandstone, light-brown to buff. Shale, light-gray to olive gray at base.
					Beech Creek Limestone Member	1.5-3.1 (5-10); 9.1-15.2 (30-50)	Limestone, medium-to light-gray, weathers light brown. Fossils present in abundance.
				Equivalent of Elwren Sandstone of Malott (1919)		6.1-12.2 (20-40)	Sandstone and siltstone; sandstone, light-brown, fine to very fine grained. Ripple marks common.

Figure 8.2. Generalized Stratigraphic Column of the Area.

8.5.2 Site Condition - Plant Area

8.5.2.1 Surficial deposits

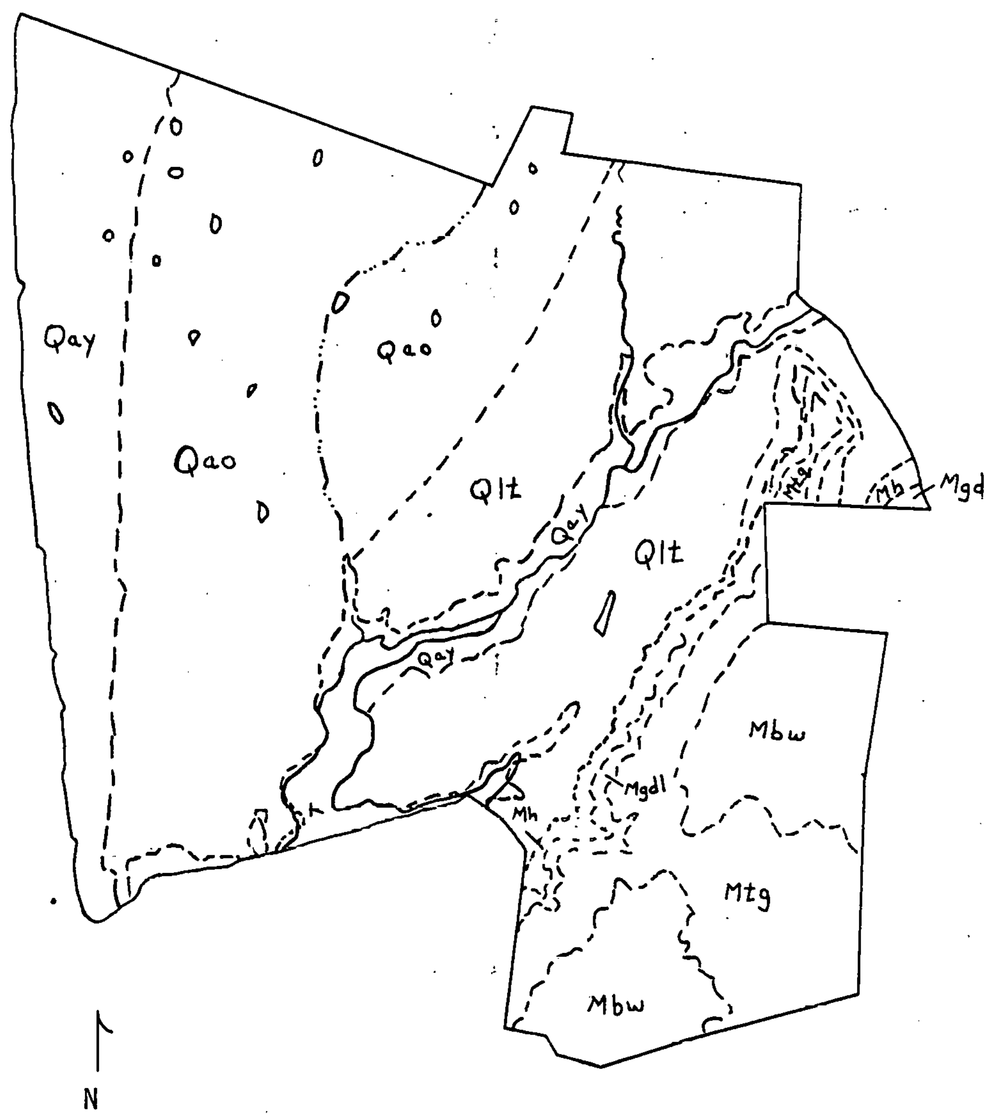
Two major types of surficial deposits are found on the site: Recent alluvial deposits of the Ohio River and Town Creek, and older alluvium of Pleistocene age from glacial meltwater. In addition, bedrock present beneath the surficial deposits outcrops at elevations above 134 m (440 ft.) as shown in Figure 8.3.

Recent alluvium - Clayey silt with seams and pockets of fine sand has been deposited by the Ohio River during flood stage. This deposit varies in depth from 0-7.6 m (0-25 ft.), and extends 305 to 610 m (1000 to 2000 ft.), forming a crescent marked by the river to the west and the Louisville and Nashville Railroad right-of-way to the east. Thinner deposits are formed along Town Creek during flood stage as well.

Deposits of this age and type are found in Borings 101, 102 and 103 in the plant site area (Figure 8.4).

Pleistocene older alluvium and terrace deposits - Surficial deposits generally west of the railroad are composed of older alluvium deposited within the last million years. A small linear ridge above the 131 m ((430-ft.) contour may represent a Pleistocene dune deposit (Crittenden and Hose, 1965). A minor topographical rise (west of Boring 8 in Figure 8.4) has been interpreted as a locally conspicuous terrace deposit representing an older, slightly higher river valley (Crittenden and Hose, 1965).

Clayey to sandy silt, 4 to 8 m (14-25 ft.) thick, overlies a fine to medium coarse silty sand. The clayey silt, becoming sandy clay to the south, is generally medium stiff, and may contain occasional silty sand seams.



Scale 1:24000

0 1 mile

0 2,000 Feet

Figure 8.3 Geology of the Plant Area.

Legend on following page.

Recent		Qay: Younger Alluvium
Pleistocene		Qao: Older Alluvium Qlt: Lacustrine and Terrace Deposits
Upper Mississippian		Mbw: Buffalo Wallow Formation Mts: Tar Springs Formation Mgdu: Upper Glen Dean Limestone Mddl: Lower Glen Dean Limestone Mh: Hardinsburg Sandstone
	Golconda Formation	Mgh: Haney Limestone Member Mgb: Big Clifty Sandstone Member Mbc: Beech Creek Sandstone Member

Figure 8.3 continued. Geologic Map Legend

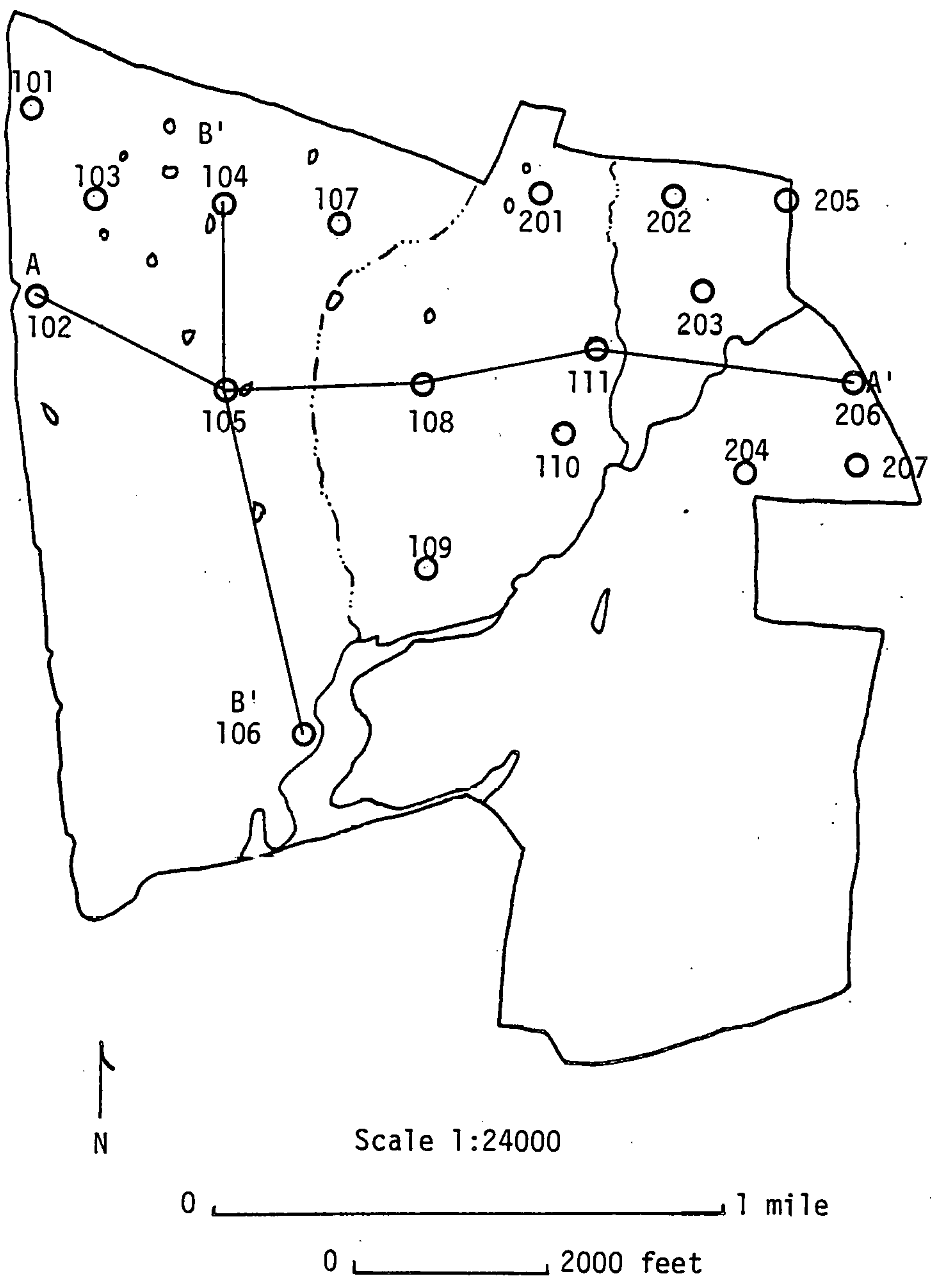


Figure 8.4. Location of borings and cross-sections in plant area

Beneath these upper soils lies a thick sequence of silty sands ranging in thickness from 12 m (40 ft.) beneath the river bed to more than 40 m (130 ft.) a few hundred meters west (Figures 8.5 and 8.6). Generally, the sand becomes less silty and more dense with depth. Approximately 6 m (20 ft.) of dense sand and gravel marks the lowermost limit of the stratum. To the west, the silty sand is absent, giving way to a large lacustrine deposit (up to 20 m, or 65 ft.) of gray clay and silty clay (Figure 8.5).

8.5.2.2 Bedrock

The bedrock under the surficial deposits reflects the erosional history of the area. The youngest, uppermost deposits were eroded almost entirely, and are left in small patches on the tops of hills and ridges. Progressively older units appear downslope, as the ancient Michigan River eroded deeper into the section toward its valley bottom.

Rock units exposed by erosion extend from the Buffalo Wallow Formation down to the Big Clifty Sandstone Member of the Golconda Formation. Later, when glacial meltwater increased flooding in the area, the Mississippian rocks exposed in the lower regions were covered by Pleistocene alluvium. Figure 8.3 illustrates the relationships of the various bedrock units based on outcrop studies. Figures 8.7 and 8.8 represent the probable position of bedrock units in the vicinity based on known regional dip and on-site borings.

Bedrock depth varies from 0.2 m. (0-7 ft.) beneath the surface on the hills in the southeast portion of the plant site to 44 m. (145 ft.) in the central portion of the site beneath a thick blanket of unconsolidated deposits.

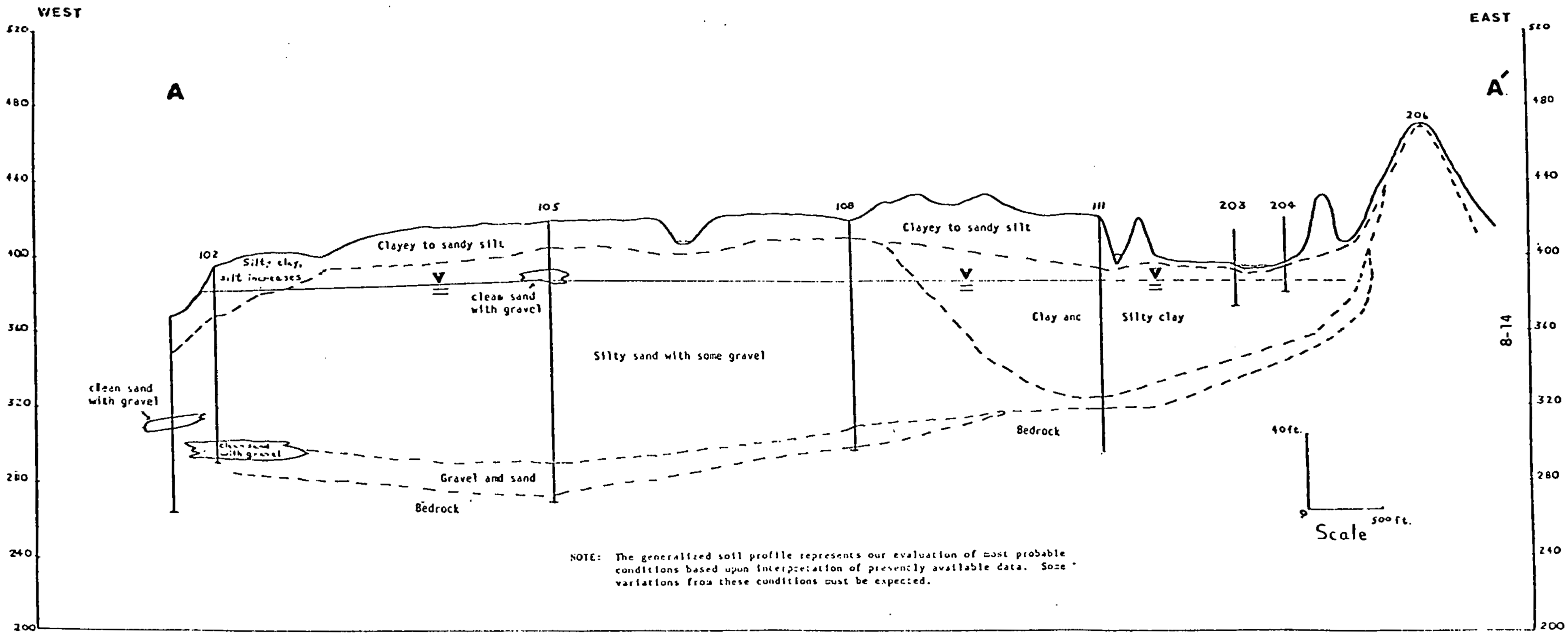


Figure 8.5 GENERALIZED CROSS SECTION A-A'

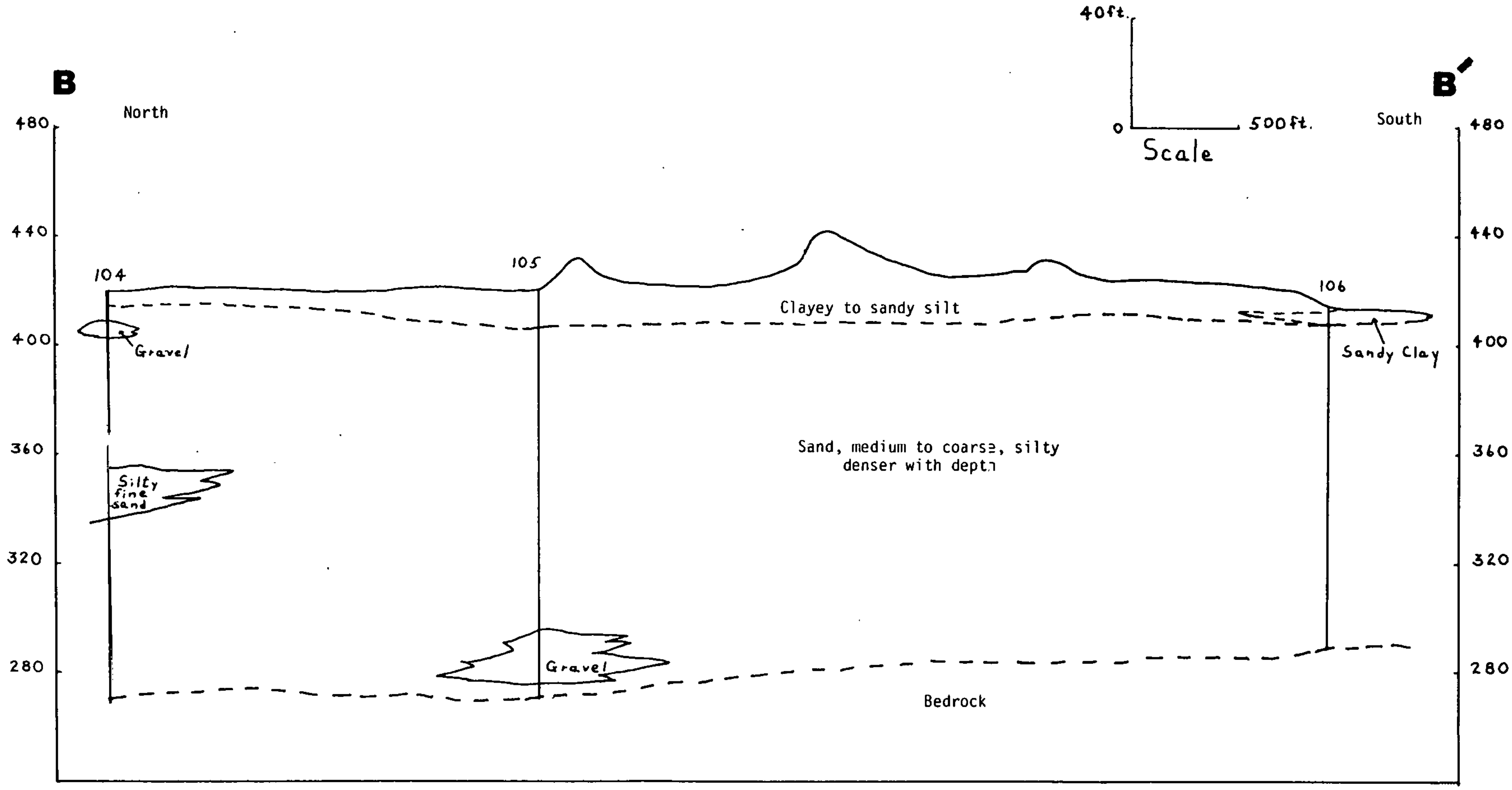


Figure 8.6 Generalized Cross-section B-B'

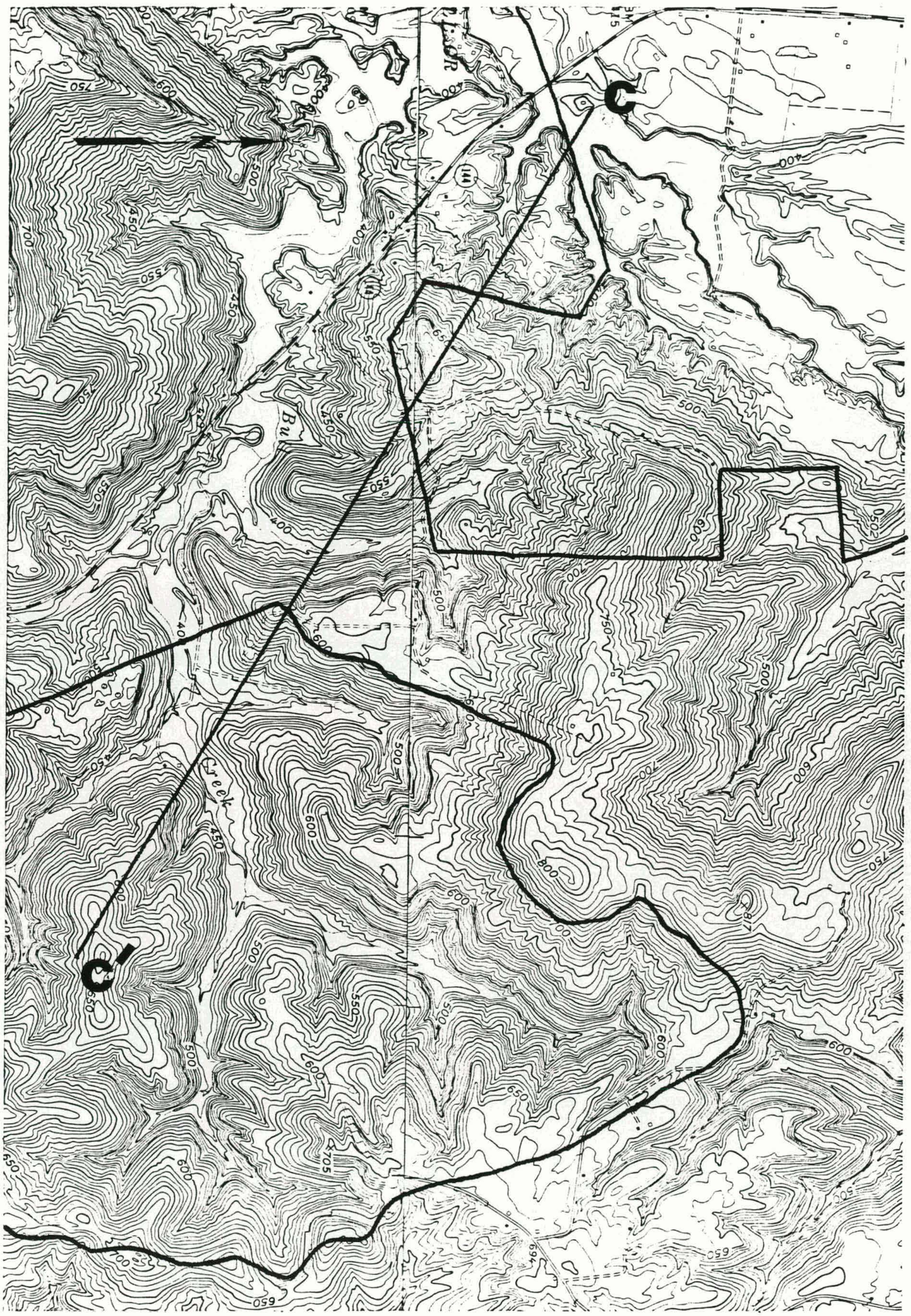


Figure 8.7 Location of Cross-Section C-C'

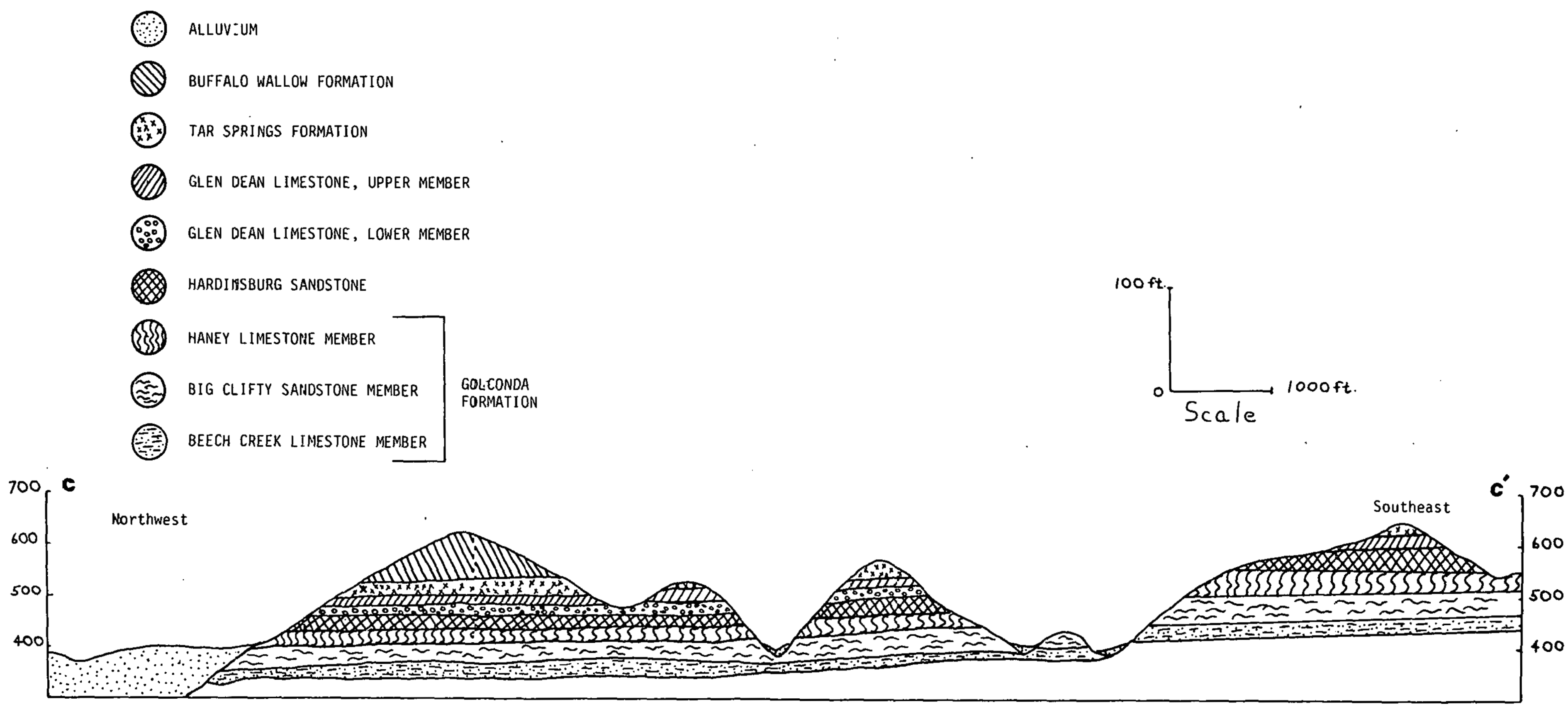


Figure 8.8 Generalized Geologic Cross-Section CC'

SOURCE: Clark and Crittenden, 1965; and Crittenden and Hose, 1965

8.5.3 Site Conditions - Southern Waste Disposal Area

8.5.3.1 Surficial deposits

Surficial deposits are not of major significance in the waste disposal area; however, both Recent and Pleistocene deposits occur along Bull Creek. Bedrock is at surface or near-surface elevations on hillsides, and 7 - 9 m (24 - 30 ft) below surface elevation in creek bottoms (Figure 8.9).

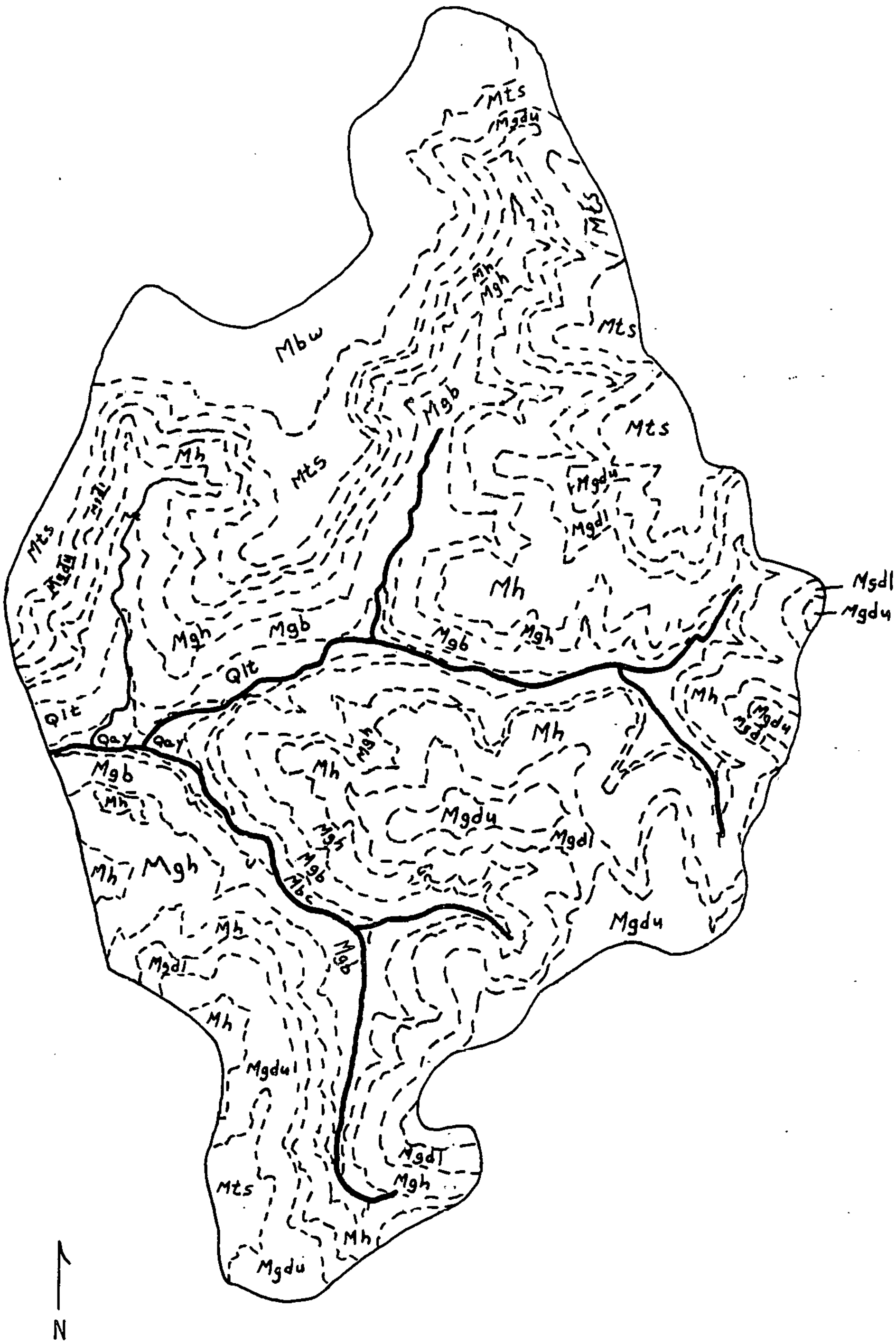
Recent alluvium - A thin blanket of silty clay, approximately one to 1.5 m (4-5 ft.) represents the youngest flood deposits of Bull Creek. This is found in two of the three borings drilled in the waste disposal area (Figures 8.10 and 8.11).

Pleistocene older alluvium and terrace deposits - A layer of silty, poorly graded sand, 4 to 6 m. (15-20 ft.) thick, underlies the Recent alluvium in the westernmost boring. Toward the east this stratum quickly gives way to an equally thick clay unit, locally interrupted by thin sand or coarse sand with gravel seams. The clay is brown and silty, grading downwards to gray and sandy.

8.5.3.2 Bedrock

Bedrock in the waste disposal area lies near surface under 0-2 m. layer of soil (refer to Chapter 9.0 for discussion). Rocks exposed include the Buffalo Wallow Formation to the north at elevations higher than 190 m. (630 ft.) through the Tar Springs Formation, Glen Dean Limestone, Hardinsburg Sandstone and Golconda Formation at progressively lower elevations.

The Beech Creek Limestone Member of the Golconda Formation represents a unit not found in outcrop in the plant area, but which is found in the waste disposal area along the upper portions of Bull Creek. However, it is found in subsurface at both localities, underlying the alluvial deposits.



Scale 1:24000

0 ______________________ 1 mile

0 __________ 2000 feet

Figure 8.9 Geology of the Southern Waste Disposal Area

Legend on following page

Recent		Qay: Younger Alluvium
Pleistocene		Qao: Older Alluvium Qlt: Lacustrine and Terrace Deposits
Upper Mississippian		Mbw: Buffalo Wallow Formation Mts: Tar Springs Formation Mgdu: Upper Glen Dean Limestone Mddl: Lower Glen Dean Limestone Mh: Hardinsburg Sandstone
	Golconda Formation	Mgh: Haney Limestone Member Mgb: Big Clifty Sandstone Member Mbc: Beech Creek Sandstone Member

Figure 8.9 continued. Geologic Map Legend

<table>
<tr><td colspan="2">Recent</td><td>Qay: Younger Alluvium</td></tr>
<tr><td colspan="2">Pleistocene</td><td>Qao: Older Alluvium
Qlt: Lacustrine and Terrace Deposits</td></tr>
<tr><td rowspan="2">Upper Mississippian</td><td></td><td>Mbw: Buffalo Wallow Formation
Mts: Tar Springs Formation
Mgdu: Upper Glen Dean Limestone
Mddl: Lower Glen Dean Limestone
Mh: Hardinsburg Sandstone</td></tr>
<tr><td>Golconda Formation</td><td>Mgh: Haney Limestone Member
Mgb: Big Clifty Sandstone Member
Mbc: Beech Creek Sandstone Member</td></tr>
</table>

Figure 8.9 continued. Geologic Map Legend

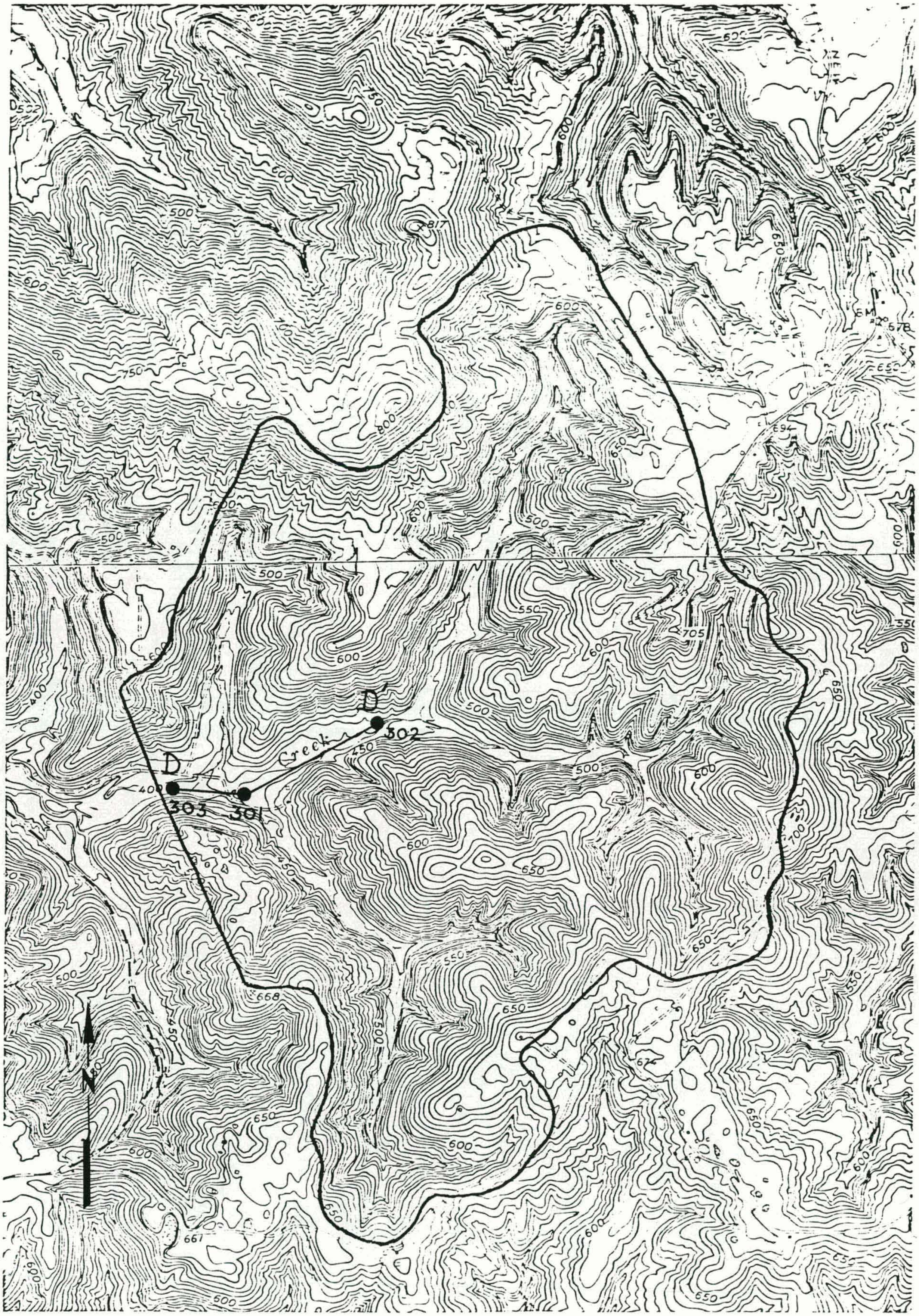
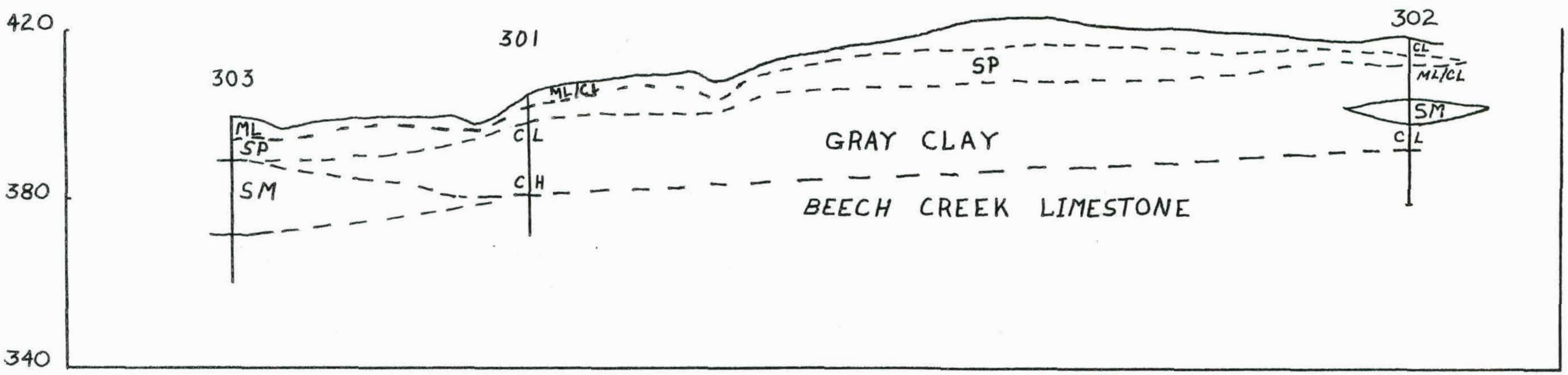


Figure 8.10: Location of borings and cross-section in Southern waste disposal area



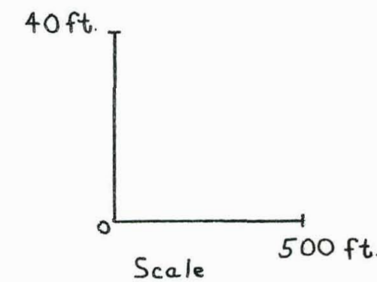


Figure 8.11 Generalized Cross-Section D-D'
(Symbol explanation on following page)

NOTE: The generalized soil profile represents our evaluation of most probable conditions based upon interpretation of presently available data. Some variations from these conditions must be expected.

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

Figure 8.11 (cont.)

UNIFIED SOIL CLASSIFICATION SYSTEM

8.5.4 Site Conditions - Northern Waste Disposal Area

8.5.4.1 Surficial deposits

Surficial deposits in the northern waste disposal area are minor. As with the southern waste disposal area, however, some Recent and Pleistocene deposits occur along the creek bed (a branch of Town Creek). Younger (Recent) alluvium is found at elevations below about 128 m (420 ft), while older (Pleistocene) alluvial deposits are found at elevations between 128 m and 131 to 137 m (430 to 450 ft).

8.5.4.2 Bedrock

Bedrock in the northern waste disposal area outcrops at elevations beginning at 131 to 137 m (430 to 450 ft), topographically above the highest surficial deposits. Outcropping units include the Haney Limestone Member of the Golconda Formation, the Hardinsburg Sandstone, the Glen Dean Limestone, and the Tar Springs Formation.

8.6 STRUCTURE

8.6.1. Regional Setting

The region around Breckinridge County is divided into three main structural provinces; the Illinois Basin, Cincinnati Arch and Mississippi Embayment (Figure 8.12). Breckinridge County is along the eastern limit of the Illinois Basin bordering on the Cincinnati Arch province. Many smaller features are in each province (or crosscuts more than one province).

Fault zones (Figure 8.13) near the proposed plant site of interest are:

1) Rough Creek Fault Zone
2) Wabash River Fault Zone
3) Faulted Mineralized Area
4) New Madrid Seismic/Fault Zone (Mississippi Embayment area).

Rough Creek Fault System

This System is the closest structural feature to the proposed coal conversion plant. It is approximately 280 km.(174 mi) long, trending east-west through Southern Illinois and Western Kentucky. The System's nearest expression is 50 km. to the south in Ohio and Grayson Counties (Figure 8.13)

The System is basicly a compressional fold between the Moorman Syncline and the Illinois Basin. The faulting is mostly high angle, reverse with the downthrown block(s) to the north. Complexity of the System ranges from a single high-angle reverse fault to a network of block faults usually normal. The last recognized time of movement along the System was post-Pennsylvanian, about 280 million years ago.

Two north-northeast trending normal fault zones are within 33 km. of the proposed plant site, one through southeast Breckinridge County and one extending from Perry County, Indiana, to Hancock County, Kentucky (Figure.8.14). Both are predominately downthrown to the northwest and

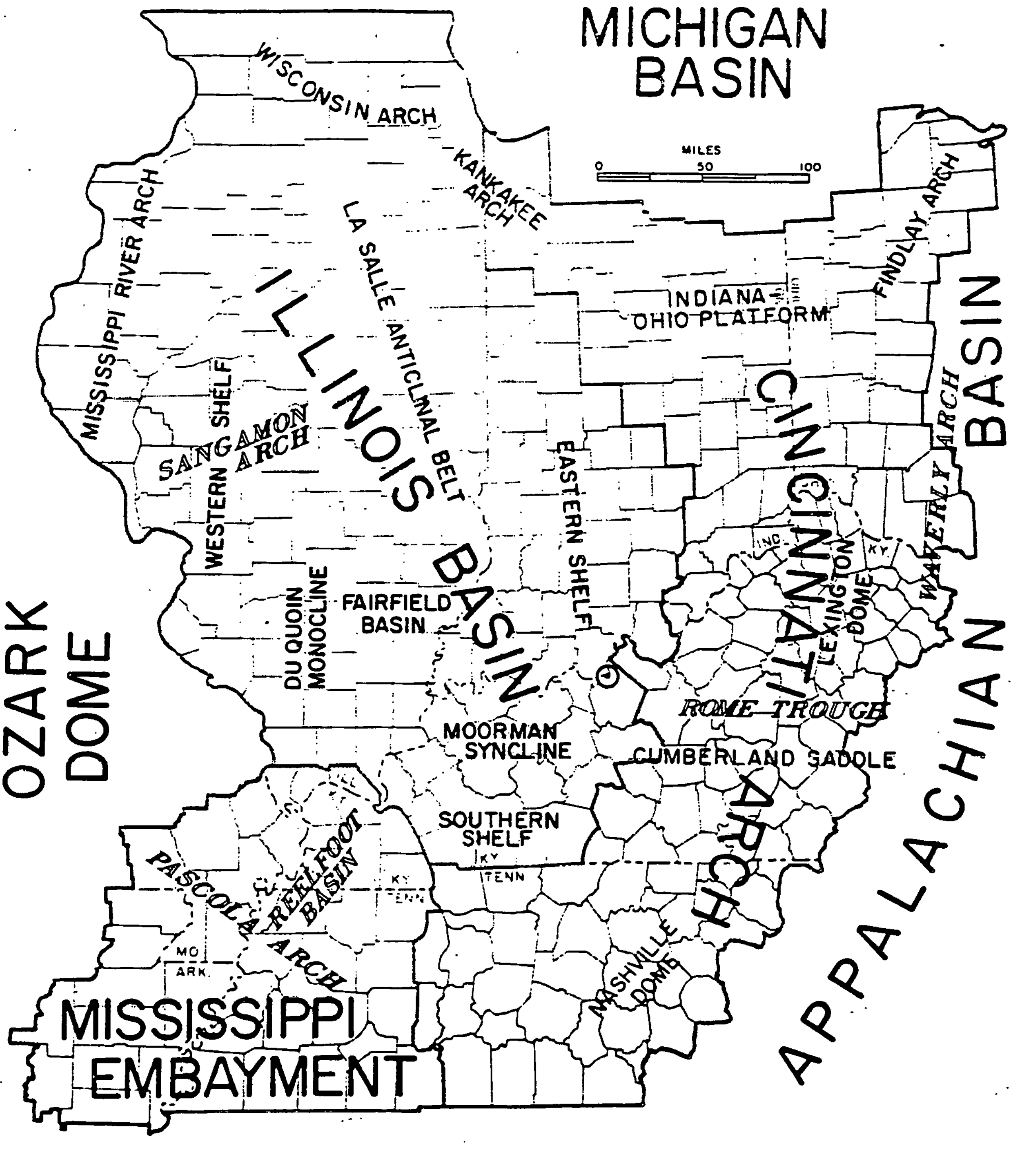


Figure 8.12 Major Structural Provinces
SOURCE: Bristol and Buschbach, 1971
⊙ Proposed coal conversion plant

Figure 8.13 Fault zones and major faults
SOURCE: Bristol and Buschbach, 1971
⊙ Proposed coal conversion plant

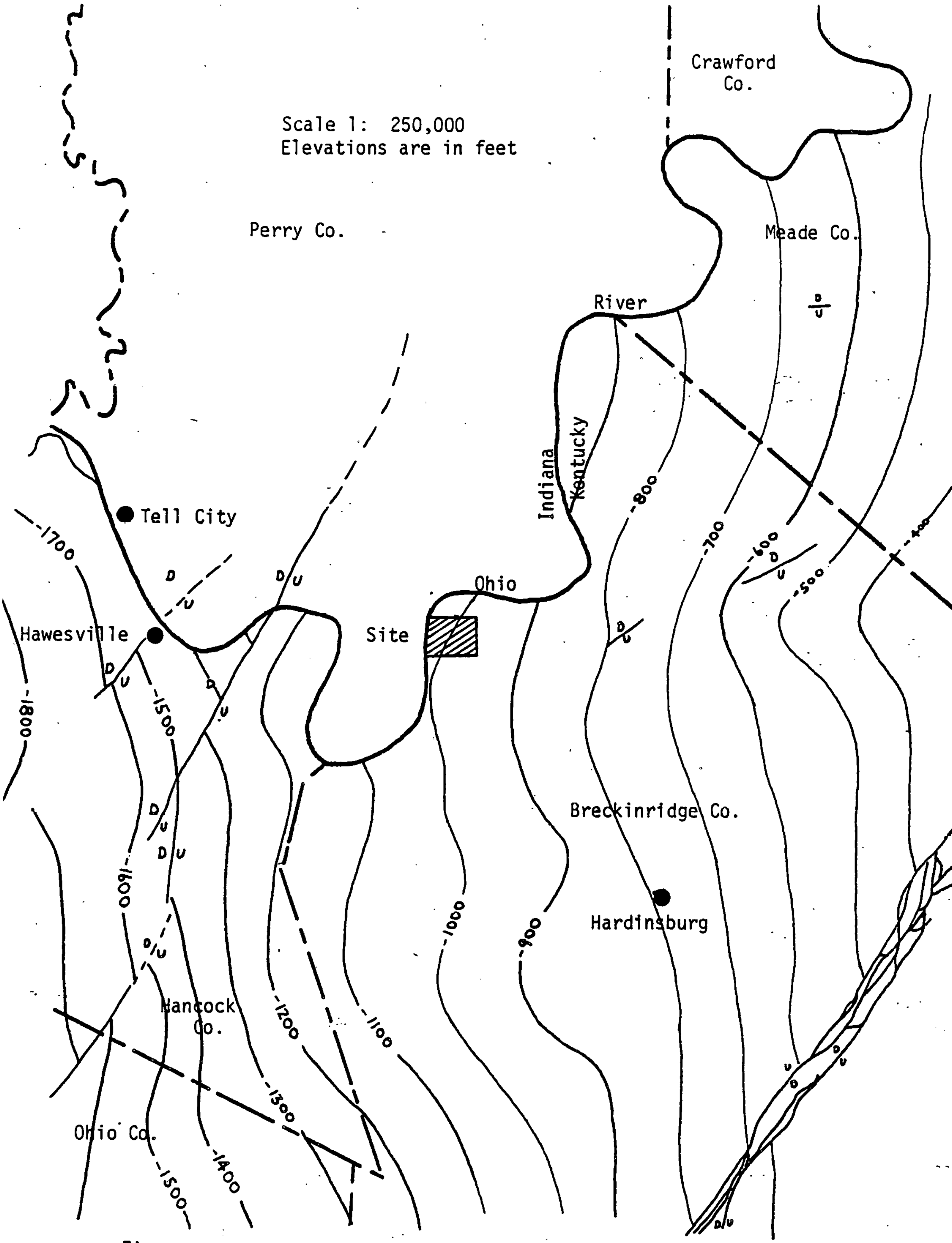


Figure 8.14 Faults and structure contours on the Devonian-Mississippian shales on and near Breckinridge County, Kentucky.
SOURCE: Schwalb and Potter, 1978
Gray, Wayne, and Wier, 1970.

considered inactive. Displacement on the northwestern fault is approximately 20 m.

Wabash River Fault Zone

This fault zone trends north-northeast from Gallatin County to Wabash County, Illinois. Width is roughly 30 km. and length 130 km. Southern extent is into the very complex Faulted Mineralized Area. This zone is still seismically active with future earthquakes not expected to exceed m_b = 6.5 (Nuttli, 1979). The Wabash Valley Seismic Zone is much larger than the known fault zone, 100 km. by 200 km.

The strongest earthquake in the zone occurred on November 9, 1968 (m_b = 5.5) but because of its great depth (20 km.) only moderate damage resulted at the epicenter (Nuttli, 1979).

Over 30 major faults are known to be in this fault zone (Heyl, Jr. and Brock, 1961). The longest fault is approximately 65 km. long and located under the Wabash River.

Faulted Mineralized Area

Hundreds of faults have been mapped in this area. The interrelationship of these faults is complicated. The Rough Creek Fault in the area (high angle reverse with over 900 m. displacement) is considered the northern boundary (Heyl, Jr. and Brock, 1961). This area is within the northern part of a collapsed north-northwest trending domal anticline which is also the juncture of the three sub-linear fault zones discussed in this section.

New Madrid Seismic/Fault Zone

This Zone coincides with the Mississippi Embayment province on Figure 8.12. Sediments of Upper Cretaceous and younger age cover the Zone and this masks the faults present in the Paleozoic rocks. Seismic and other geophysical data identified two large faults and several small faults

(Figure 8.15b). The map of epicenters of microearthquakes (Figure 8.15a) shows a large seismically active area. Focal depths range from 5km. to 20 km.

Large earthquakes (body-wave magnitude of over m_b = 6.0) have occurred five times (Nuttli, 1979); three (7.2, 7.1, 7.4) during the winter of 1811-1812, one each on January 4, 1843 (6.0) and October 31, 1895 (6.2). Because these have occurred om recent time this area is considered very active.

8.6.2 Site conditions

No structural features are known to be present under the proposed plant site. Alluvial deposits of older Ohio River terraces mask any features which may be present. Depth to bedrock exceeds 30 m throughout the area. A linear series of hills trends through the proposed plant site. Actual origin of these hills is unknown but they have morphologic similarities to dunes.

Bedrock east and west (across the Ohio River) of the site is flatlying with slight dip toward the northwest. Structural contours of bedrock at depth (Figure 8.15b) indicate dip to the west or northwest. Nearest mapped fault zones are 8 km to the west (mentioned in 8.8.1) and 10 km to the east. The two near faults to the east trend east-northeast with downthrown displacement of the northwest block approching 9 m. These faults may be two surface expressions of the same lineament. Their direction and character are consistent with the nearby larger fault zones.

Faults near the plant site are tensional in origin as opposed to the compressional Rough Creek Fault System. (Compressional and tensional are descriptive terms characterizing the tectonics involved in the formation

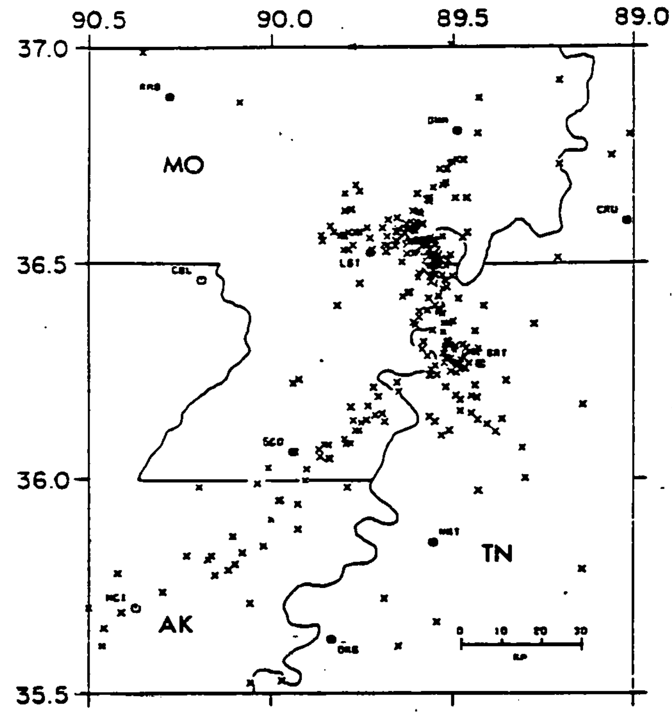


Figure 8.15a Microearthquakes in the New Madrid seismic zone from June 29, 1974 through March 31, 1976.

SOURCE: Nuttli, 1979

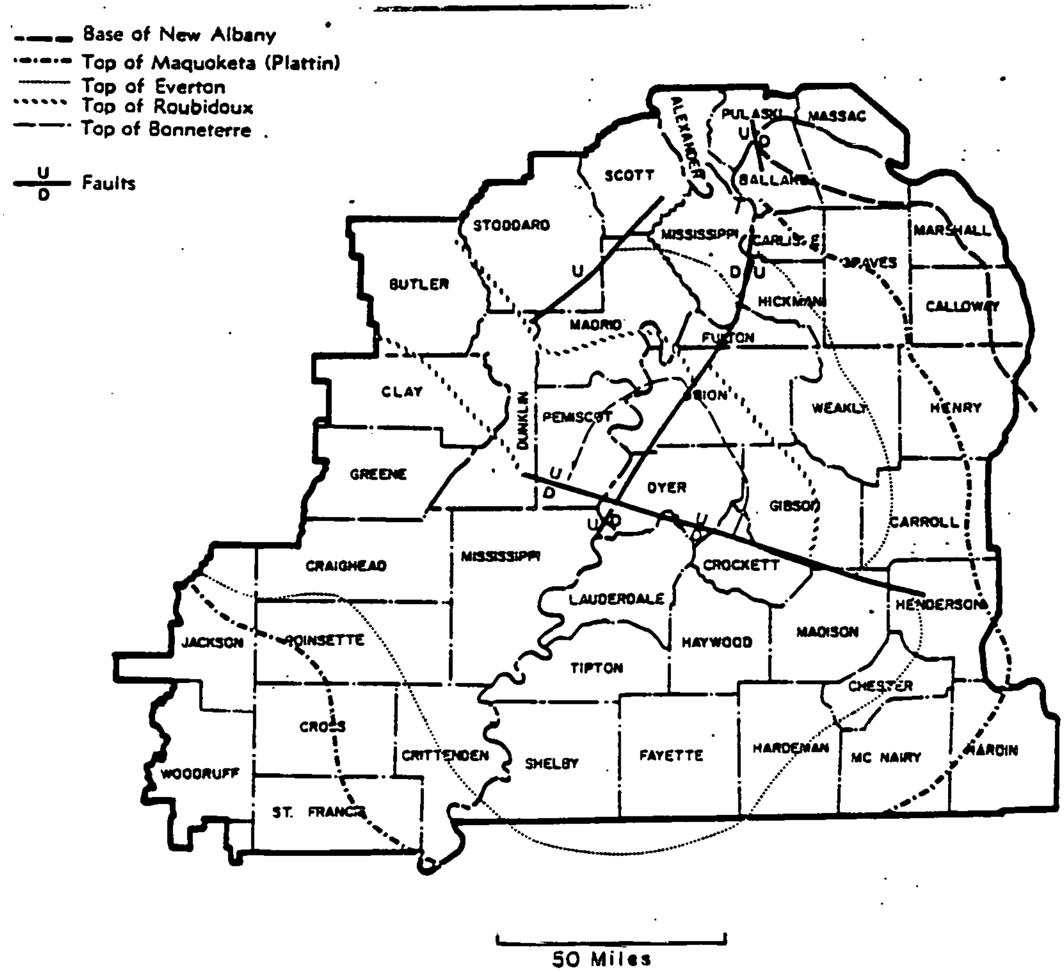


Figure 8.15b Subsurface faults and Paleozoic subcrop map of Mississippi Embayment.
SOURCE: Schwalb, 1971

of various structural features. Compressional features result when tectonic forces are directed towards an area, i.e. a squeezing action. Tensional features result when tectonic forces are directed away from an area, i.e. a pulling-apart action. Two possible origins for the near faults could be:

1) From rotational movement of the bedrock during the compressional event creating the Rough Creek Fault system or,

2) Tensional release of confined forces after the compressional phase.

8.7 SEISMICITY

Figures 8.16 and 8.17 show the proposed site to be within two different seismic acceleration areas as determined by the Applied Technology Council (1978). Figure 8.18 shows the site to be within seismic zone 2 of Algermissen (1969). Breckinridge County, Kentucky is in Area 1 with respect to the Effective Peak Acceleration (coefficient A_a) and Area 2 with respect to the Effective Peak Velocity-Related Acceleration (coefficient A_v). Even though the site is located in two different acceleration areas the two coefficient values are equal; $A_a = A_v = 0.05$. Zone 2 of Algermissen (1969) can expect moderate damage due to earthquakes. Moderate damage extends up to Intensity VII on the Modified Mercalli Intensity (MMI) scale (Figure 8.19).

Six seismic zones are present in the Central United States (Nuttli, 1979). The Wabash, New Madrid, Ozark and Anna (Figure 8.20) seismic areas, all within 400 km (250 miles) of the proposed site, will be discussed.

The Wabash Valley Seismic Zone is approximately 100 km by 200 km (60 miles by 120 miles). The largest historic earthquakes were about m_b = 5.5 and future earthquakes should not exceed m_b = 6.5 or one unit larger. Focal mechanisms for four earthquakes were developed for this zone, three indicate reverse faulting with north-south fault planes and one indicates right-lateral strike-slip faulting with a north-northwest fault plane (Nuttli, 1979).

Five earthquakes had m_b valves of 5 or greater. These were events on 29 April, 1899 (m_b = 5.0), 27 September, 1909 (m_b = 5.3), 26 November, 1922 (m_b = 5.0), 26 April, 1925 (m_b = 5.0), and 9 November, 1968

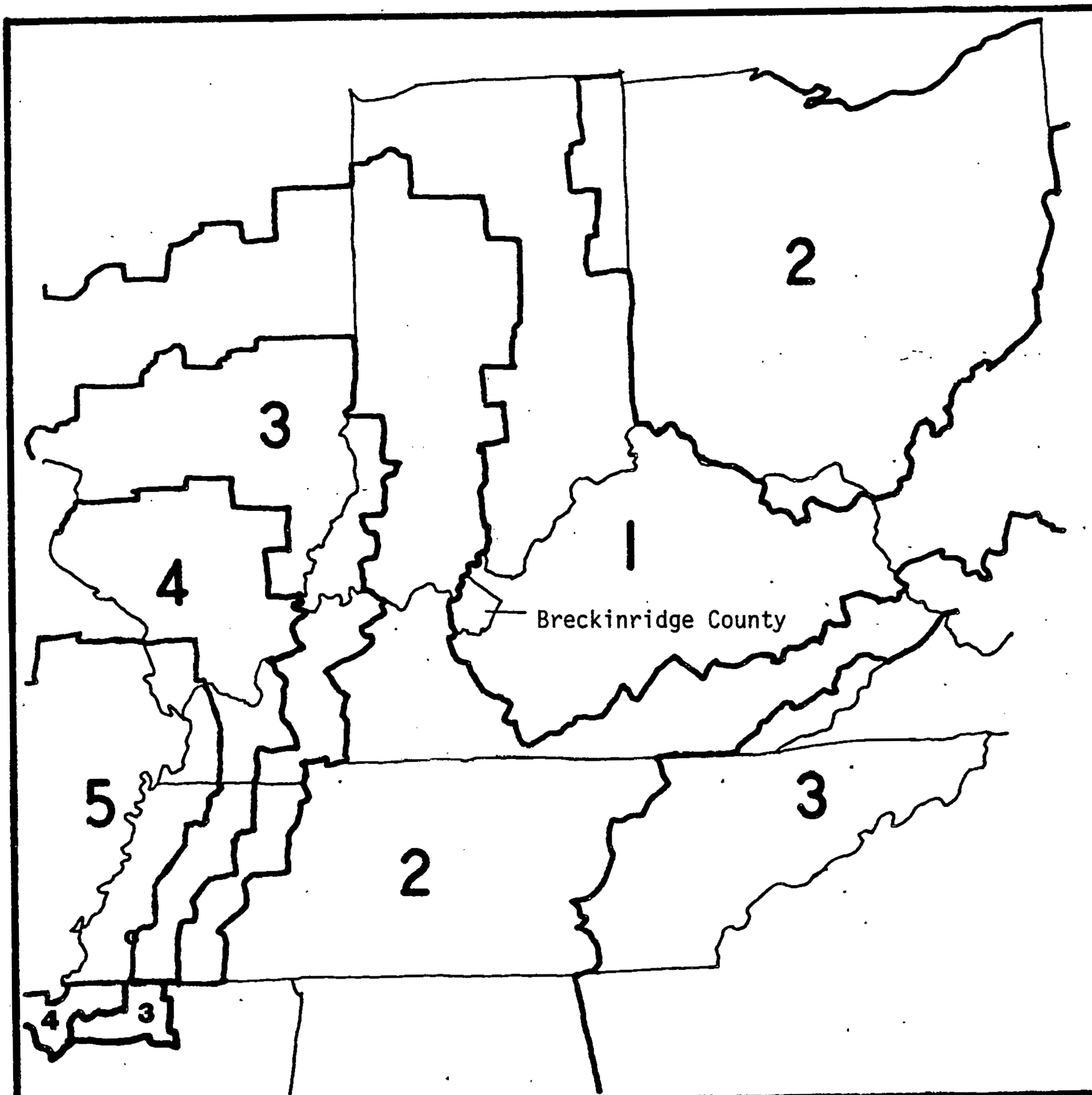
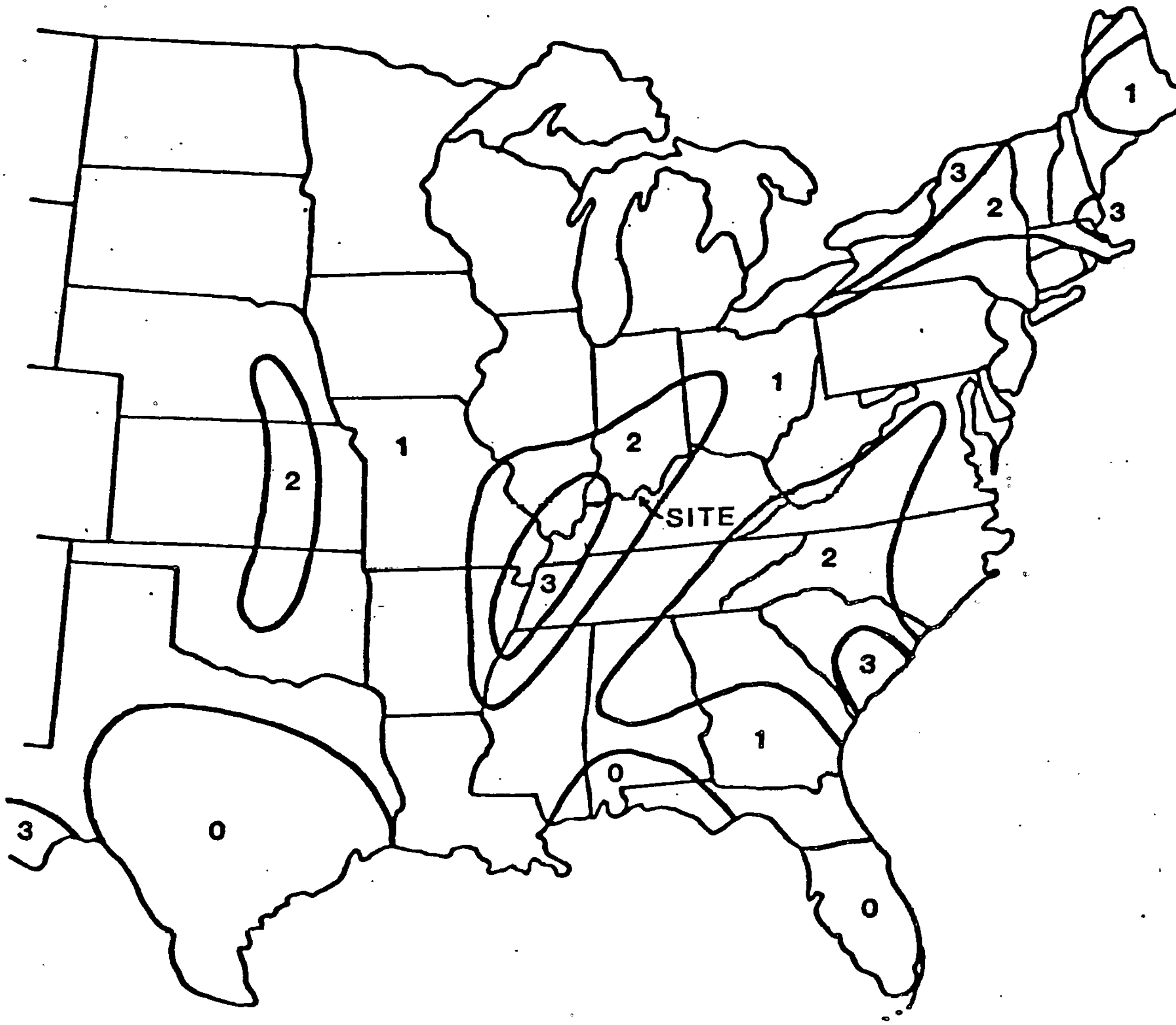


Figure 8.16 Map for Coefficient A_a

SOURCE: Applied Technology Council, 1978.

Figure 8.17 Map for Coefficient A_v

SOURCE: Applied Technology Council, 1978.



EXPLANATION

0 NO REASONABLE EXPECTANCY OF EARTHQUAKE DAMAGE

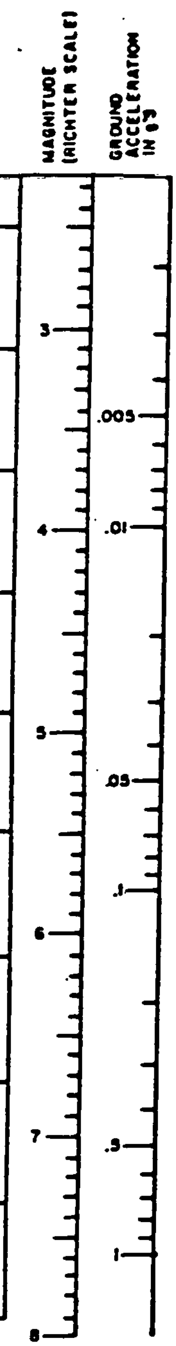
1 EXPECTED MINOR DAMAGE

2 EXPECTED MODERATE DAMAGE

3 MAJOR DESTRUCTIVE EARTHQUAKES MAY OCCUR

Figure 8.18 SEISMIC RISK ZONES IN THE EASTERN UNITED STATES.
Source: S. T. Algermissen, Seismic Risk Studies in the United States, National Oceanic and Atmospheric Administration, 1969.

I.	Not felt except by a very few under especially favorable circumstances.
II.	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V.	Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
VI.	Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures, considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.



Intensities XI and XII not included.

Figure 8.19 MODIFIED MERCALLI EPICENTRAL INTENSITY SCALE FOR EARTHQUAKES. Sources: H. O. Wood and F. Newmann, "Modified Mercalli Intensity Scale of 1931," Bulletin of the Seismological Society of America 21:278-283 (1931); U.S. Atomic Energy Commission, Nuclear Reactors and Earthquakes, Report No. TID-7024, Washington, D.C., 1975.

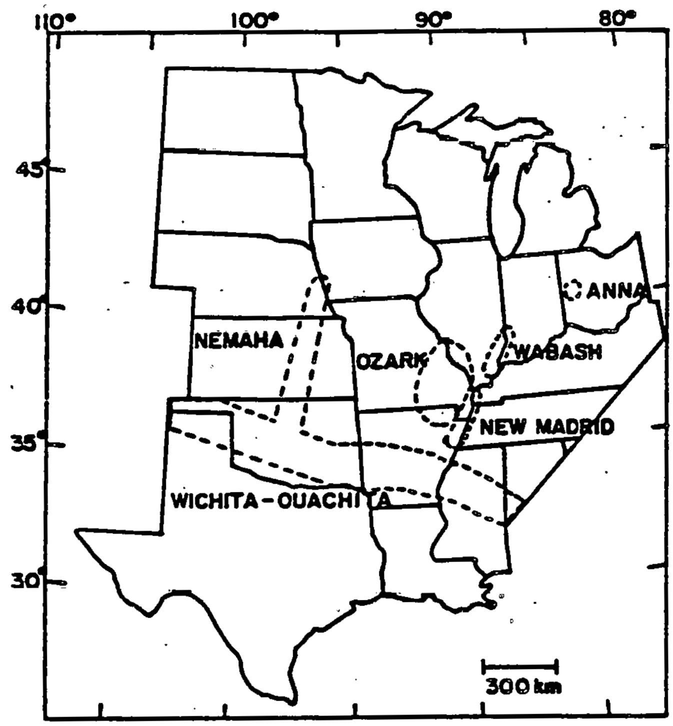


Figure 8.20 Seismic Zones of the Central United States.

SOURCE: Nuttli, 1979.

(m_b = 5.5). The focal depth of the largest event (9 November, 1968) was 20 km and caused minor damage in Evansville, Indiana; St. Louis, Missouri and Chicago, Illinois. The felt area extended to Mobile, Alabama; Boston, Massachusetts and Southern Ontario.

The New Madrid Seismic Zone has roughly the same size and trend as the Wabash Valley Seismic Zone but data is insufficient to determine if they are parts of one continous zone. The New Madrid Zone is the most active area in the central United States, accounting for over one-third of the felt earthquakes. The most seismically active three-month period in the recorded history of the United States occurred there during the winter of 1811 and 1812. Three shocks were over m_b = 7.0 during this period; 16 December, 1811 (m_b = 7.2); 23 January, 1812 (m_b = 7.1) and 7 February, 1812 (m_b = 7.4). The two largest shocks after this period occurred 4 January, 1843 (m_b = 6.0) and 31 October, 1895 (m_b = 6.2) near, respectively, the southern and northern terminus of the seismic zone. Nuttli, (1979) calculated there will be annual averages of 300 earthquakes of m_b = 1 $\pm$ 0.5 or greater and 1.5 earthquakes of m_b = 4 $\pm$ 0.5.

The Ozark area is named the St. Francois Mountain Seismic Zone. Three focal mechanisms indicate normal (or tensional) faulting (Nuttli, 1979) which is expected in an area of uplift, i.e. the Ozark Dome Uplift. Seismographs have been in use in this area since 1909 and because of this there have been large numbers of earthquake epicenters recorded. On 9 April, 1917 a large earthquake (m_b = 5.0, Intensity VI) occurred near the town at Ste. Genevieve, Missouri but the Ste. Genevieve Fault (a western extension of the Rough Creek Fault System) does not appear to be the cause.

The Anna, Ohio Seismic Region is a small area which had moderate-damage producing earthquakes. Five m_b = 5.3 earthquakes have occurred from 1875 to 1937, one in 1875 and the other four between 1930 and 1937. Possible mechanisms are unknown owing to insufficient reliable data.

A list of all earthquakes up to 1974 with Intensity V or greater is included in Figure 8.21 (Nuttli, 1974).

Figure 8.21

SEISMIC HISTORY
EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 175 MILES OF SITE

Year	Date	Intensity	Approximate Location	Lat. °N	Long. °W	Distance From Site (in miles)
1820	Nov. 09	V	Cape Girardeau, Missouri	37.3	89.5	170
1827	Aug. 07	VI	New Albany, Indiana	38.3	85.8	51
1838	Jun. 09	VII-VIII	Southern Illinois	38.5	89.0	145
1841	Dec. 27	V	Western Kentucky	36.6	89.2	172
1842	Nov. 04	V	Western Kentucky	36.6	89.2	172
1853	Dec. 18	IV-V	Western Kentucky	36.6	89.2	172
1857	Oct. 08	VII	Southern Illinois	38.7	89.2	148
1858	Sep. 21	VI	Western Kentucky	36.5	89.2	175
1876	Sep. 25	VI	Southern Illinois-Indiana Border	38.5	87.7	72
1878	Mar. 12	V	Missouri-Kentucky Border	36.8	89.1	155
1882	Jul. 20	V	Missouri-Illinois-Kentucky Border Region	36.9	89.2	168
1882	Sep. 27	VI	Near Springfield, Illinois	39.0	89.5	175
1882	Oct. 14	V	Near Springfield, Illinois	39.0	89.5	175
1882	Oct. 15	V	Near Springfield, Illinois	39.0	89.5	175
1883	Jan. 11	V-VI	Cairo, Illinois	37.0	89.2	155
1883	Apr. 12	VI-VII	Cairo, Illinois	37.0	89.2	155
1883	Jul. 14	IV-V	Cairo, Illinois	37.0	89.2	155
1887	Feb. 06	V-VI	Vincennes, Indiana	38.7	87.5	73
1887	Aug. 02	V	Cairo, Illinois	37.0	89.2	155
1891	Jul. 26	V-VI	Southern Illinois-Indiana Border	37.9	87.5	49
1895	Oct. 31	IX	Charleston,	37.0	89.4	170
1899	Apr. 29	VI-VII	Southern Illinois-Indiana Border	38.5	87.0	46
1903	Feb. 08	VI	Southern Missouri-Illinois Border	37.8	89.3	142
1903	Nov. 04	VII	Missouri-Illinois-Kentucky Border Region	36.9	89.3	170
1903	Nov. 04	VI	Missouri-Illinois-Kentucky Border Region	36.9	89.3	170

Figure 8.21 (Continued)

SEISMIC HISTORY
EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 175 MILES OF SITE

Year	Date	Intensity	Approximate Location	Lat. °N	Long. °W	Distance From Site (in miles)
1906	May 11	V	Southwestern Indiana	38.5	87.2	52
1906	May 21	V	Southern Illinois	38.7	88.4	120
1907	Jan. 29	V	Southern Indiana	39.5	86.6	115
1907	Jan. 30	V	Near Springfield, Illinois	38.9	89.5	170
1908	Oct. 27	IV-V	Cairo, Illinois	37.0	89.2	155
1909	Sep. 22	V	Ohio Valley	38.7	86.5	55
1909	Sep. 27	VII	Southern Illinois-Indiana Border	39.5	87.4	93
1909	Oct. 23	V-VI	Southeastern Missouri	37.0	89.5	96
1909	Oct. 23	V	Near Robinson, Illinois	39.0	87.8	174
1915	Oct. 26	V	Mayfield, Kentucky	36.7	88.6	137
1915	Dec. 07	V-VI	Near mouth of Ohio River	36.7	89.1	160
1916	Dec. 18	V-VI	Hickman, Kentucky	36.6	89.2	170
1919	Feb. 10	III-IV	Illinois-Indiana-Kentucky Border Region	37.8	87.5	65
1919	May 25	V	Southern Indiana	38.4	87.5	64
1920	May 01	IV-V	Missouri	38.5	89.5	165
1920	Dec. 24	V	Rockwood, Tennessee	36.0	85.0	150
1921	Mar. 31	IV	Illinois-Indiana-Kentucky Border Region	37.9	87.8	63
1922	Jan. 10	IV-V	Illinois-Indiana-Kentucky Border Region	37.9	87.8	63
1922	Mar. 22	V	Southern Illinois	37.3	88.9	117
1922	Nov. 26	VI-VII	Southern Illinois	37.8	88.5	103
1924	Mar. 02	V	Kentucky	37.0	89.1	150
1925	Apr. 26	VI-VII	Indiana	38.3	87.6	61
1925	May 13	V	Kentucky	36.7	88.6	125
1925	Sep. 02	VI	Kentucky	37.8	87.5	55

Figure 8.21 (Continued)

SEISMIC HISTORY
EARTHQUAKES OF INTENSITY V OR GREATER WITHIN 175 MILES OF SITE

Year	Date	Intensity	Approximate Location	Lat. °N	Long. °W	Distance From Site (in miles)
1927	May 07	VII	Mississippi Valley	36.5	89.0	167
1931	Jan. 05	V	Elliston, Indiana	39.0	87.0	80
1934	Aug. 19	VI	Rodney, Kentucky	36.9	89.2	170
1937	Nov. 17	V	Centralia, Illinois	38.6	89.1	142
1940	May 31	V	Paducah, Kentucky	37.1	88.6	125
1948	Jan. 05	IV-V	Southern Illinois	38.6	89.1	142
1957	Mar. 26	V	Paducah, Kentucky	37.0	88.4	120
1958	Jan. 27	V	Illinois-Kentucky-Missouri Border	37.1	89.2	155
1958	Nov. 07	VI	Illinois-Indiana Border	38.4	87.9	78
1962	Jun. 27	V	Southern Illinois	37.7	88.5	104
1963	Aug. 02	V	Illinois-Kentucky Border	37.0	88.8	135
1965	Aug. 14	VII	Southwestern Illinois	37.1	89.2	155
1965	Aug. 15	V	Southwestern Illinois	37.4	89.5	163
1965	Aug. 15	V	Southwestern Illinois	37.4	89.5	163
1968	Nov. 09	VII	South-central Illinois	38.0	88.5	104
1968	Dec. 11	V	Louisville, Kentucky	38.2	85.9	40
1974	Apr. 03	VI	Southern Illinois	38.6	88.1	94
1974	Aug. 22	V	Southern Illinois	38.2	89.7	170

8.8 MINERAL RESOURCES

Mineral resources in Breckinridge County include, in order of importance, stone, sand and gravel, petroleum and coal. Total value of mineral production for 1971 (the last available year Breckinridge County released such figures for publication) was $508,000.

8.8.1 Petroleum

In 1962, oil was discovered less than ten miles south of the site, near Mattingly, Kentucky. The producing zone, in the Big Clifty Member of the Golconda Formation, is less than 550 feet deep in most wells, and, in some wells, is little more than 200 feet deep.

Breckinridge County production of crude oil has declined considerably from a high of 18 thousand barrels in 1971 and 1972 to 4 thousand barrels per year since 1976 (Table 8.1). No oil is produced in the site vicinity.

8.8.2 Coal

The site lies on the eastern edge of the Western Kentucky coal field. Coal in the Western coal field is estimated at 34.8 billion metric tons (38.4 billion, short tons). Twenty-five percent of the total tonnage is contained in the Mulford (No. 9) coal seam with an additional 68% from six smaller seams (Nos. 11, 12, 6, 4, 13 and 14).

Breckinridge County contains an estimated 243,076 metric tons (268,000 short tons) of coal, none of which have been, or are currently being, commercially mined as of January 1976. Only one bed, the Breckinridge Cannel seam, is present within the county. The seam is uncorrelated. Of the total estimate, 9,070 metric tons (10,000 short tons) have been measured and the remainder are inferred (Smith and Brant, 1978).

Table 8.1 Mineral Production in Breckinridge County

Production Years	Oil and Gas Well Drilling Completions No. Wells	Footage	Crude Oil Production (thousands of 42-Gallon barrels)	Crushed Stone (thousands of short tons)	Total Value of Mineral Production (thousands of dollars)
1969	-	-	12	-	499
1970	8	2,396	13	48	-
1971	4	1,423	18	55	508
1972	22	41,039	18	-	-
1973	2	725	13	-	-
1974	4	7,227	9	-	-
1975	6	1,777	7	-	-
1976	-	-	4	-	-
1977	-	-	4	-	-
1978	-	-	-	-	-
1979	-	-	4	-	-
1980	-	-	4	-	-

Dashes indicate data unavailable, generally withheld at request of companies involved.

No coal has been reported in or near the site; however, some has been recorded on the extreme western boundary of Breckinridge County.

8.8.3 Sand and Gravel

A small amount of gravel is present in the terrace deposits and stream beds near the cemetary at Stephensport, approximately 6.4 km (four mi) from the site. This is a minor occurrence, and is limited to local use.

A sand and gravel operation has been functioning at Cloverport, 11.3 km (7 mi) from the site, for approximately twenty years. Sand production is estimated at 18,140 metric tons (20,000 tons) per year, hydraulically pumped from a settlement pond by the Ohio River. Gravel production is approximately one-third that of sand (Cloverport Sand and Gravel, pers. comm.).

8.8.4 Limestone and Shale

Limestone and shale are not developed as resources in the immediate site vicinity. Shale from the lower part of the Hardinsburg Sandstone has been used at Cloverport for the manufacture of brick and roofing tile. Similar shale found in the Buffalo Wallow Formation, the upper member of the Glen Dean Limestone, and in the Big Clifty Sandstone Member of the Golconda Formation, may be suitable for lightweight aggregate and terra cotta products (Clark and Crittenden, 1965; Crittenden and Hose, 1965).

High-purity limestone has been quarried from the Glen Dean Limestone along the Ohio River, and from the Haney Limestone Member of the Golconda Formation near Hardinsburg, within Breckinridge County. Although there are no quarries currently operating in the immediate area, it is a potential resource in areas where the overburden is light.

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Soils

9.0 SOILS

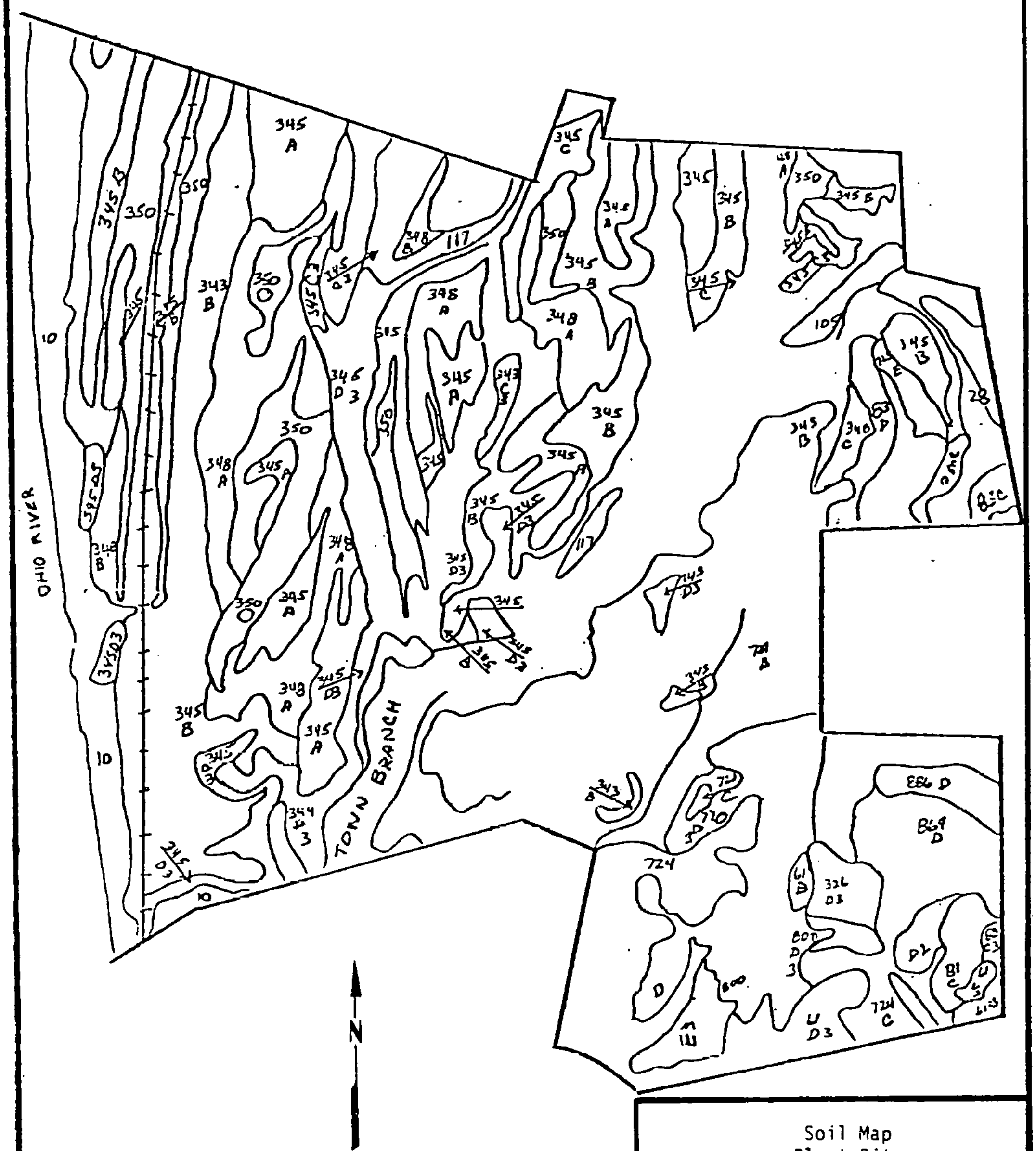
9.1 INTRODUCTION

Both the proposed plant site and waste disposal areas are covered by soils that either developed in the alluvial deposits or formed out of the weathered bedrock. Figure 9.1 and 9.2 are soil maps of the proposed site and southern waste disposal area, respectively.

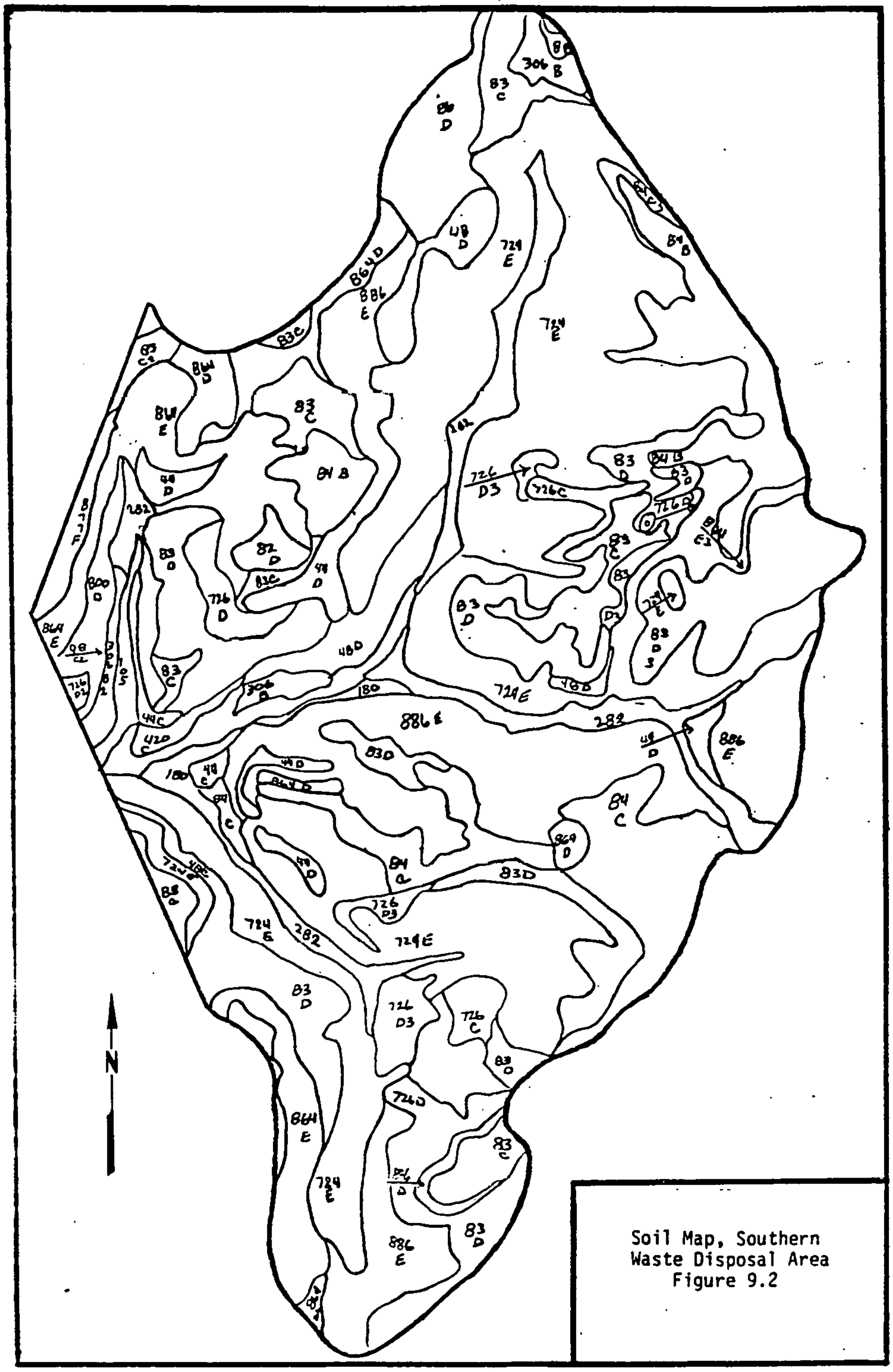
Deep alluvial soils cover the western half and northeastern quarter of the plant site area. These loamy soils are found on nearly level to strongly sloping stream terraces. Their permeability rate is moderate, except in the fragipan, if it exists, where the rate is slight. The fragipan is a loamy, brittle, subsurface horizon that is very low in organic matter content and clay, but is rich in silt or very fine sand. The acidity of these soils varies from slight to moderate. The major soil series included are Wheeling, Weinbach, Sciotoville, Melvin, and Huntington.

The southeastern quarter of the plant site area is overlain by shallow residual soils. These soils are found on strongly sloping to steep slopes. Their acidity varies from slight to moderate and the permeability rate is generally moderate. The soil series found in these upland areas are Weikert, Gilpin, and Wellston.

These series are also found, with others included, in the waste disposal area, where residual soils predominate (Figure 9.2). The area is largely characterized by small ridges and valleys, but some wide bottom lands are present. These bottoms are found parallel to the trunk of Bull



Soil Map
Plant Site
Figure 9.1

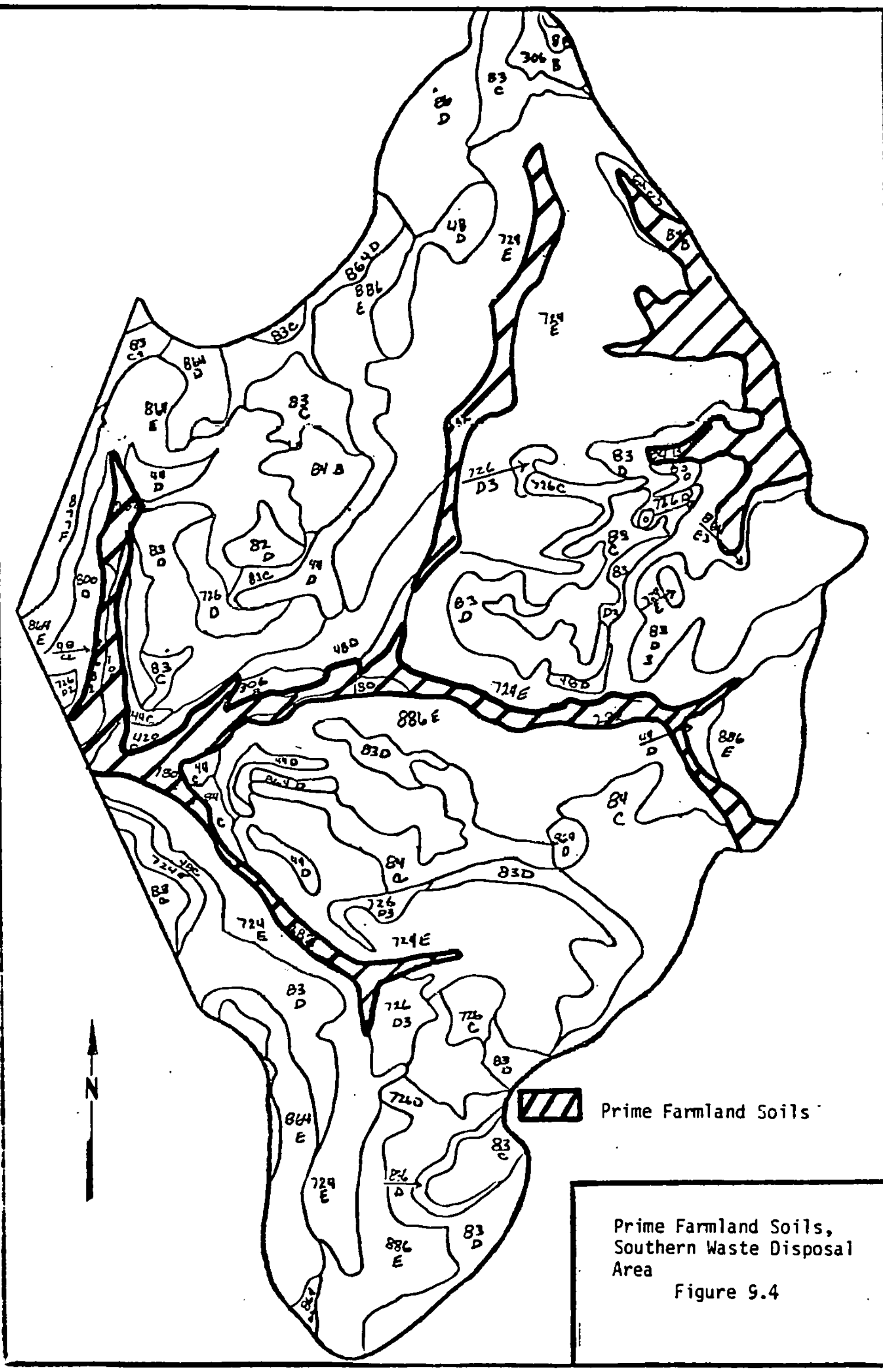


Soil Map, Southern
Waste Disposal Area
Figure 9.2

Creek which drains this area. The Cuba, Captina, Lindside, Melvin, and Markland soil series are found in these lowlands.

These soils, except for Markland, and the Zanesville series are classified as prime farmland soils. Also, the deep alluvial soils that are found in the proposed plant site area have this classification. Figures 9.3 and 9.4 delineate the areas covered by the Kentucky Prime Farmland Soils classification.

Prime Farmland Soils
Plant Site
Figure 9.3



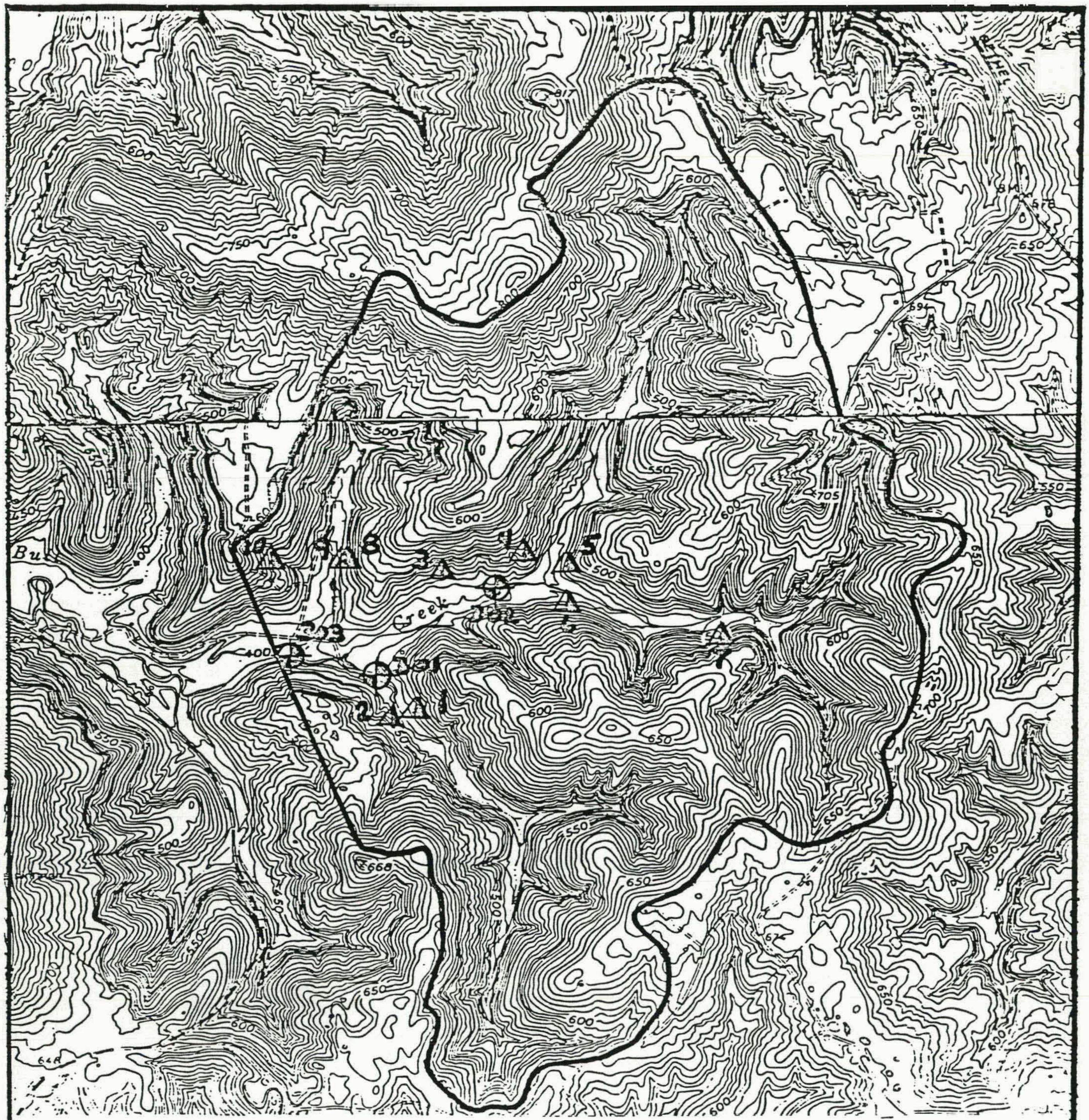
Prime Farmland Soils, Southern Waste Disposal Area
Figure 9.4

9.2 BACKGROUND AND OBJECTIVES

Several geotechnical and geological drilling investigations have been performed on the proposed site in the recent past. A total of 51 borings were drilled in the plant site in 1974 and 1975. Then in late 1980 and early 1981, 18 borings were put down in the plant site and 3 in the waste disposal area.

Ten hand soil samples were also taken in early 1981 in the proposed waste disposal area. Figure 9.5 shows their location. Disturbed and undisturbed samples were taken at each location. The soil series sampled are as follows: 1) Shelocta, 2) Weikert-Gilpin complex, 3) Elk, 4-7) Weikert-Gilpin complex, 8-9) Caneyville, 10) Gilpin. Samples 3, 6, and 10 were sent to Commonwealth Technology Laboratory for physical and chemical testing. Refer to Tables 9.1 and 9.2 for the results.

The data was gathered to present enough information to assess the potential and availability of the site soils to be used as effective liners for surface impoundments, raw matrials storage areas, and waste disposal areas, as well as their general attenuative properties for ground water protection in the event of the accidental discharge of potential pollutants.



Legend

o Primary Boring Location
Δ Hand Auger Location

Reference:

U. S. G. S. 7.5 minute quadrangle sheets for Rome, Ind.-Ky.(1970) and Mattingly, Ky.-Ind.(1970).

Boring & Hand Soil Sample Locations in Waste Disposal Area

Figure 9.5

Table 9.1 Soil Analyses

TEST RESULTS - CHEMICAL PARAMETERS

SAMPLE ID	HOLE 3	HOLE 6	HOLE 10
Depth Below Surface From Which Samples Tested	6-10, 18-22"	7-11, 14-18"	6-10, 20-24"
Water (paste) pH	4.3	4.3	5.6
SMP Buffer pH	5.9	6.5	6.9
Moisture (% of dry wt)	23.1	21.8	23.6
Organic Matter (% of dw)	0.5	0.3	0.4
Sulfate (% of dw)	0.30	0.06	0.09
Total Iron (% of dw)	3.13	2.39	2.39
Total Arsenic (% of dw)	0.0012	0.0013	0.0010
Total Barium (% of dw)	0.0040	0.0035	0.0044
Total Calcium (% of dw)	0.12	0.40	0.17
Total Chromium (% of dw)	0.0016	0.0014	0.0012
Total Lead (% of dw)	0.0015	0.0011	0.0014
Total Silver (% of dw)	0.00004	0.00002	0.00002
Total Mercury (% of dw)	0.000004	0.000004	0.000002
Total Selenium (% of dw)	<0.00002	<0.00002	<0.00002

TEST RESULTS - CATION (SODIUM) EXCHANGE CAPACITY

SAMPLE ID	HOLE 3	HOLE 6	HOLE 10
Exchangeable K (meq/100 gm)	0.30	0.20	0.02
Exchangeable Mg (meq/100 gm)	1.73	0.56	0.32
Exchangeable Ca (meq/100 gm)	7.63	4.55	8.77
Cation Exchange Capacity (meq/100 gm)	21	17	24
Base Saturation (%)	43	31	39

Table 9.1 Continued

TEST RESULTS - PHYSICAL PARAMETERS

SAMPLE ID	HOLE 3	HOLE 6	HOLE 10
Depth Below Surface From Which Samples Tested	22-26"	28-32"	26-30"
Moisture (% of dry wt)	24.8	20.6	23.3
Wet Unit Wt. (pcf)	122.6	134.7	123.7
Dry Unit Wt. (pcf)	98.2	111.7	100.3
Liquid Limit (%)	35	30	29
Plastic Limit (%)	25	24	21
Plasticity Index	10	6	8
Permeability (cm/sec)	5.2×10^{-7}	7.1×10^{-7}	2.6×10^{-7}

Table 9.2 Results of Mineralogical Analyses (Semi-Quantitative)

Location	Parameters
Hole No. 3	>40% kaolinite
	>30% mica (illite)
	<15% hydroxy-Al montmorillonite
	<10% montmorillonite
	<5% quartz
Hole No. 6	>50% kaolinite
	<20% montmorillonite
	<15% hydroxy-Al montmorillonite
	<10% mica
	<5% quartz
	<1% feldspar
Hole No. 10	>50% kaolinite
	>20% mica
	>15% hydroxy-Al montmorillonite
	<10% montmorillonite
	<5% quartz

NOTE: Same samples tested as for chemical parameters.

9.3 METHODOLOGY

The soil survey in Breckinridge County has not been published, so the following discussion was developed from unpublished county data and soil descriptions from other county soil surveys with similar soils.

The information gathered from the borings was not used in this discussion, but will be presented and interpreted in a later report.

Two sampling techniques were used to collect the hand soil samples. The disturbed samples were taken with a hand auger, which has three curved blades that cut into the soil when turned. The soil remains inside the triangle of blades when the auger is removed from the hole. A thin-walled, seamless shelby tube was used to collect the undisturbed samples. The tube is pushed down past the soil until full, then removed from the hole with the sample in tact.

A shelby tube and jar containing disturbed sample from each of three locations were taken over to Commonwealth Technology Laboratory for physical and chemical testing. The physical tests included the samples behavior under varying moisture conditions, permeability, and grain size analysis. The samples were also tested for cation exchange capacity, pH, total organic and metal content, and clay mineral content.

9.4 SAMPLING LOCATIONS

The hand soil sampling locations were chosen to give samples for testing and visual inspection of the major soil types in the waste disposal area. Figure 9.5 is a plot of sampling locations.

9.5 DISCUSSION OF SURFICIAL SOILS

The Wheeling, Weinbach, Sciotoville, Melvin, and Huntington soil series are located in the western half and northeastern quarter of the proposed plant site. These series are found on nearly level to gently sloping stream terraces and have moderate permeability rates. See Table C for a list of their selected properties.

The Wheeling soils vary from a silty clay loam to a fine sandy loam. They are found on slopes ranging from 0 to 20 percent, are slightly acidic, and have a moderate natural fertility. Their permeability rates are moderate, except in the fragipan where it is slow.

The Weinback soils have a silt loam texture. They are found on nearly level slopes, are acidic, and have a moderately low natural fertility. Their permeability rates are moderate, except in the fragipan where it is slow.

The Sciotoville soils have a silt loam texture. They are located on nearly level ground, are acidic, and have a moderate natural fertility. Their permeability rates are moderate, except in the fragipan where it is slow.

The Melvin soils have a silt loam texture. They are found on nearly level slopes, are slightly acidic, and have a moderate natural fertility. Their permeability rates are moderate. The Huntington soils have the same characteristics as the Melvin.

Gilpin, Wellston, Caneyville, Zanesville, and Shelocta soil series cover the southeastern quarter of the proposed plant site area and 85 percent of the proposed waste disposal area. The other 15 percent of the waste disposal area is covered by lowland soils, such as, Cuba, Captina, Lindside, Melvin and Markland. Table 9.3 contains a list of their selected properties.

The Gilpin soils consist of a silt loam. These soils are found on uplands and form by deposition of loess over weathered sandstone. Loess is a wind blown silt or fine sand deposit. These soils are acidic and have moderate permeability rates.

The Wellston soils range in texture from a silt loam to a silty clay loam. These soils are closely associated with the Gilpin soils and form in the same manner. They have moderate permeability rates and are acidic.

The Caneyville soils have a silt loam or silty clay texture. These soils are found on upland slopes and are formed in residuum derived from limestone.

The Zanesville silt loams are found on 2 to 6 percent slopes, are acidic, and develop from loess deposits overlying sandstone and shale. The permeability rates are moderate at the surface, but decrease significantly with depth at the fragipan.

The Shelocta soils, which are gravelly silt loams in the disposal area, are found at the base of the steep slopes. These soils are slightly to moderately acidic and have moderate permeability rates.

The Cuba soils have a silt loam texture. They are deep, acidic, well-drained soils that are found in the bottoms.

The Markland soils have a silty clay texture. These soils are found on sloping sides of stream terraces. The permeability rates are slow and the acidity range from acidic to basic.

The ten hand soil samples were taken on the ridge slopes of the south-

Table 9.3 Selected Soil Properties

Mapping Unit Symbol	Soil Series	Prime Farmland	USDA Texture	Range of Slopes	Reaction	Permeability (in/hr)	Permeability ($cm/sec \times 1.0^{-4}$)	Source
10	Huntington	Yes	Silt Loam	6-12%	6.1-7.8	0.6-2.0	4.2-14.1	Alluvial Soil
44D;D2	Shelocta	No	Gravelly Silt Loam	12-20%	5.6-6.0	0.6-2.0	4.2-14.1	Colluvium derived from Upland Soils
61C;C1,2	Crider	No	Silt Loam	6-12%	Acidic			
61D3		No	Silty Clay Loam					
83C;C1,2	Wellston	No	Silt Loam	6-12%	5.6-6.0	0.6-2.0	4.2-14.1	Loess & material weathered from bedrock
83D;D1,2		No	Silt Loam	12-20%				
83D3		No	Silty Clay Loam	12-20%				
84F;B1,2,3	Zanesville	Yes	Silt Loam	2-6%	4.5-5.5	0.6-2.0	4.2-14.1	Loess & material weathered from bedrock
105	Lindside	Yes	Silt Loam	2-6%	4.5-5.5	0.6-2.0	4.2-14.1	Alluvial Soil
117	Melvin	Yes	Silt Loam	Level	6.1-6.5	0.6-2.0	4.2-14.1	Alluvial Soil
180	Cuba	Yes	Silt Loam		Acidic			
306B;B1,2	Captina	Yes	Silt Loam	2-6%	5.6-6.0	0.6-2.0	4.2-14.1	Alluvial Soil
343B	Wheeling	Yes	Fine Sandy Loam	2-6%	5.1-6.0	2.0-6.3	14.1-44.5	Alluvial Soil
345A		Yes	Silt Loam	0-2%				
345B		Yes	Silt Loam	2-6%				
345C		No	Silt Loam	6-12%				
345C3		No	Silty Clay Loam	6-12%				
345D3		No	Silty Clay Loam	12-20%				
348A;A1	Sciotoville	Yes	Silt Loam	0-2%	6.1-6.5	0.6-2.0	4.2-14.1	Alluvial Soil
348B;B1,2		Yes	Silt Loam	2-6%				
350	Weinbach	Yes	Silt Loam	Level	5.6-6.0	0.6-2.0	4.2-14.1	Alluvial Soil
420C	Markland	No	Silty Clay Loam	6-12%	5.6-6.0	0.6-2.0	4.2-14.1	Sediment deposited in slack water
726C;C1,2	Caneyville	No	Silt Loam	6-12%	4.5-6.0	0.6-2.0	4.2-14.1	Residuum derived from limestone
726D;D1,2		No	Silt Loam	12-20%				
726D3								
800C;C1,2	Wellston	No	Silt Loam	6-12%	5.6-6.0			Loess & material weathered from bedrock
800D3		No	Silty Clay Loam					
864D;D1,2	Gilpin	No	Silt Loam	12-20%	4.5-5.0	0.6-2.0	4.2-14.1	Residuum derived from sandstone and shale
886	Weikert-Gilpin							

ern waste disposal area. Continuous samples were collected to a depth of 5 feet or bedrock, whichever was reached first. The depth to bedrock for 7 of the locations was 2-3 feet. Bedrock was not reached at sample 1. It was found at 6 inches and 4.5 feet for sample 8 and 10, respectively. The texture of the soil samples ranged from clay to sandy silt. The silty clay texture was predominant.

Samples 3, 6 and 10 were sent to Commonwealth Technology's lab for physical and chemical testing. Sample 3 was located midway up the slope, 6 was located at the base of another slope and 10 was located near the top of still another slope. The county soil survey map indicated that the Elk soil series was sampled at location 3, Weikart Gilpin at 6, and the Gilpin at location 10. Tables 9.1 and 9.2 list selected physical and chemical characteristics of these soils.

9.6 PRIME FARMLAND SOILS

Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses (the land could be crop land, pasture land, range land, forest land, or other land, but not urban built-up land or water), (U.S. Soil Conservation Service, 1979). Most prime soils are found on slopes of 6 percent or less.

The soils overlying the alluvial deposits of the proposed plant site, except for the soils with the map symbol 345C, 345C3, and 345D3, are classified as prime farmland soils. These soils cover approximately 70 percent of the proposed area. The Zanesville silt loams, 84B and 83B, which are found on 2 to 6 percent slopes in the uplands of the proposed waste disposal area and the Cuba, Captina, Lindside, and Melvin lowland soils are also classified as prime farmland soils. None of the ridge soils in the southeastern quarter of the plant site or the disposal area have this classification. Figure 9.3 and 9.4 denote prime farmland soil areas.

9.7 REFERENCES

U.S. Soil Conservation Service. Soil Survey. Kentucky county soil surveys as follows: 1967, Henderson; 1970, unpublished, Breckinridge and Meade; 1974, Daviess and Hancock; 1980, Mclean and Muhlenberg.

U.S. Soil Conservation Service. Unpublished report with update. 1979, Prime Farmland Soils of Kentucky.

Surface Water

10.0 SURFACE WATER

10.1 INTRODUCTION

Major water bodies on or bordering the proposed site include the Ohio River, Town Creek and Bull Creek (Figure 10.1). The Ohio River fronts the site from river mile (RM) 705.6 to 707.4. At this point the river is approximately 425 meters (1400 feet) wide with a maximum depth of 19 meters (62 feet) at a normal pool elevation of 116.73 meters (383 feet) MSL. The river is a major transportation artery for barges carrying materials to points throughout the Ohio and Mississippi Valleys. It accepts pollution from many sources, both point and non-point, as it flows the 1578 kilometers (981 miles) from Pittsburg to the Mississippi River. At Cannelton, 22.5 kilometers (14 miles downstream of the site, the total drainage area of the Ohio River is about 251,204 Km^2 (97,000 mi^2) (USGS, 1980).

The river is controlled by a series of high-lift dams and associated locking facilities. Near the site, the old wicker-type dam at Addison (RM 703) was dismantled and replaced in 1975 by the present high-lift dam at Cannelton (RM 720.7). This raised the water levels in the Cannelton Pool by 7.6 meters (25 feet), from 109.11 to 116.73 meters (358 to 383 feet) MSL. Thus, many areas such as the backwaters in Town and Bull Creek, have been inundated for only a short time. The raising of the water level has brought about many changes, including new habitat for aquatic and semi-aquatic fauna and flora, a reduction in current, and associated changes in water quality. These points are developed further in this and other chapters.

The section of the Ohio River main stem which includes the site, from

Figure 10.1 Surface Water and Sediment Quality Stations.

just upstream of Brandenburg, Kentucky (RM 645.8) to the Cannelton Lock and Dam (RM 720.7), has been classified as an "effluent limited" segment (Commonwealth of Kentucky, 1975). These segments include waters in which the application of effluent limitations (best practicable technology for industry and secondary treatment for publicly owned works) will probably result in the achievement of desired water quality.

Water quality of water bodies of the proposed site are under the jurisdiction of standards of Kentucky Division of Water (401 KAR 5:031) promulagated in December, 1979 (Table 10.1). Criteria, which in many instances are the same as the Kentucky standards, are also set by the Ohio River Valley Sanitation Commission ORSANCO (1976). The latter criteria are under review and revisions are expected soon. Further criteria for toxic substances were set by the USEPA (1980). In many instances, either sufficient data are lacking or bioassay results of "representative" aquatic organism are required to set numerical limits for toxic substances.

Table 10.1. Surface Water Standards for Kentucky (401 KAR 5:031)[a,b]

Parameter	Standard
Alkalinity	Less than a 25% reduction; if levels are below 20 mg/l $CaCO_3$, no reduction allowed[c]
Ammonia, un-ionized	0.05[c]
Arsenic	0.050[c]
Barium	1[d]
Chloride, total	250[d]
Chlorine, total residual	0.01[c]
Coliform, fecal (per 100 ml)	200[e,f], 400[e,g]
Color (Pl-Co units)	75[d]
Cyanide, free	0.005[c]
Dissolved solids, total	750[h,d]
Fluoride, total	1[d]
Flow (cfs)	--[h]
Hydrogen sulfide, undissociated	0.002[c]
Methylene blue active substances	0.5[d]
Nitrate-N, total	10[d]
Oxygen, dissolved	4 (instantaneous)[c]; 5 (daily average)[c]
pH (units)	6.0 - 9.0[c]
Phthalate esters	0.003[c]
Phenols	0.005[c]
Radionuclides (pCi/l)	
Gross total alpha particle activity (including radium-226 but excluding radon and uranium)	15
Radium-226 plus radium-228	5
Total gross beta particle activity	50

Table 10.1 Continued.

Parameter	Standard
Radionuclides (pCi/l) (Continued)	
Tritium	20,000
Strontium-90, total	8
Sulfate, total	250[d]
Suspended solids, total	--[h,c]
Temperature (°C)	Increase above ambient not to exceed 2.8°; not to exceed monthly levels given below[c,i] Jan 10.0 Jul 31.7 Feb 10.0 Aug 31.7 Mar 15.6 Sep 30.6 Apr 21.1 Oct 25.6 May 26.7 Nov 21.1 Jun 30.6 Dec 13.9
Toxic substances[c]	
Noncumulative and nonpersistent	0.1 x 96 hr LC50
Others, including pesticides	0.01 x 96 hr LC50
Trace elements, unfiltered, as total (μg/l)	
Beryllium	11 (soft water)[j,c] 1100 (hard water)[k,c]
Cadmium	4 (soft water)[j,c] 12 (hard water)[k,c]
Chromium	0.100[c]
Copper	1000[d]
Iron	1000[c,l]
Lead	50[d]
Manganese	50[d]
Mercury	0.05[c]
Selenium	10[d]
Silver	50[d]
Zinc	5000[d]

Table 10.1 Continued.

Parameter	Standard
Mixing Zones[i]	(a) No pollutants in excess of 0.44 x 94 hr LC50 for representative indigneous aquatic organism
	(b) Not interfere with spawning or nursery areas, fish migration, public water supply intakes, bathing areas, nor preclude free passage of aquatic life
	(c) Not exceed 1/3 width or cross-sectional area of receiving stream, where possible, and in no case exceed 1/2 of this volume
	(d) Must not adversely alter legitimate uses of receiving water or adversely affect an established aquatic community

[a]Units are mg/l unless noted otherwise

[b]Most stringent use standard is presented

[c]Warmwater aquatic habitat

[d]Domestic water supply source

[e]Recreational waters (during recreation season)

[f]Monthly geometric mean based on at least 5 samples a month

[g]In more than 10% of all samples taken during the month

[h]Shall not adversely affect aquatic community

[i]Decided on a case by case basis

[j]0-75 mg/l $CaCO_3$

[k]Greater than 75 mg/l $CaCO_3$

[l]For low flow streams, daily average is 3.5 mg/l when it is established that there will be no damage to aquatic life

10.2 BACKGROUND AND OBJECTIVES

Surface water quality and hydrologic data are available from several sources. Both the U.S. Geological Survey (USGS) and the Ohio River Valley Water Sanitation Commission (ORSANCO) operate water quality stations near the Cannelton Lock and Dam. The former agency also collects hydrologic (flow) and biological data as part of the National Stream Quality Accounting and Pesticide Network. Also, the U.S. Army Corps of Engineers maintains daily records of locking activities and gage elevations.

Other recent data collected in proximity to the site are available from U.S. EPA (in press). This includes data from the Ohio River, RM's 705-722, which encompasses the proposed site, and a limited data set from Town Creek.

The primary objective of the present water quality baseline survey was to obtain site-specific data from the Ohio River, Town Creek and Bull Creek. As there is an existing data base on the river, the site data can be compared to it to determine if any major differences exist between the data bases. If they do exist, investigations may then be conducted into the probable causes. As little information is available on the creeks, baseline conditions will be determined by the present work.

As they are an important component of the chemical environment in an aquatic ecosystem, it is also necessary to gather information from the sediments as well as the water and biota. The sediments act as a sink for many materials adsorbed to suspended mater. These materials are in turn taken up by benthic organisms and projected into the food chain. Thus, while they are constantly being moved downstream and the exact source of materials in them can be difficult to determine, the sediments are a useful and necessary indicator of the overall quality of the aquatic environment.

10.3 METHODOLOGY AND SOURCES

Water samples were taken by a simultaneous grab at a depth of 0.5 m (1.6 feet). Bottles and preservative used for the various parameters were:

Parameter	Bottle Volume(ml)	Bottle Type	Preservative
Organics	4000	Glass	None
Cyanide	500	Polyurethane	Sodium hydroxide
Coliforms	250	Polyurethane	None
Metals	1000	Polyurethane	Nitric acid
Others	1000	Polyurethane	None

Sediment samples were taken with a Wildco 2400 series piston corer with a polyurethane liner. The sediments were immediately transferred to 1-liter glass jars. In the creeks, sediments were taken directly in the glass jar as composites of main sediment types. All sample bottles were immediately placed on ice and then shipped to Howard Laboratories in Dayton, Ohio.

In-situ meter readings for dissolved oxygen (Yellow Springs Instrument, YSI, 33), specific conductance (YSI 57), pH (LaMotte Chemical) and air and water temperature (YSI 33) were taken in conjunction with water sample collection. Several other random sets of meter readings were collected on the Ohio River throughout the course of each survey. The pH meter was standardized using 4.0 and 7.0 buffer solutions and the DO meter by calibrating atmospheric oxygen to air temperature as specified by the instrument manufacturers.

Flow in the creeks was determined by the velocity profile method. A transect was established at right angles to the stream course and current measured with a Marsh McBirney 201 current meter at regular intervals across the transect at 0.6 of the total depth if the total depth was less than 0.6 m (2 feet) and at 0.2 and 0.8 of the total depth if it was greater than 0.6 m (2 feet). Flow was calculated by:

$$\text{Flow (cfs)} = \frac{(V_i + V_{i+1})}{(2)} \times \frac{(D_i + D_{i+1})}{(2)} \times W$$

Where V_i = velocity at point i (fps)

V_{i+1} = velocity at next point across transect

D_i = total depth at point i (feet)

D_{i+1} = total depth at next point across transect

W = interval width (feet)

F = flow (cfs)

On a single occasion in the winter, the flow was measured directly from the outlet pipe below the concrete ford at Town Creek. Flow was then calculated by the area of the vertical plane of the water at the end of the pipe multiplied by the average velocity measured within that area.

Cubic feet can be transposed to cubic meters by:

cubic feet x 0.028 = cubic meters

and to liters by:

cubic feet x 28.32 = liters

10.4 SAMPLING LOCATIONS, FREQUENCY AND RATIONAL

Water quality was taken at Ohio River Stations 2 and 3 and the upper portions of Town (St. T) and Bull (St. B) Creeks (Figure 10.1) during each of the quarterly surveys. In-situ meter readings were taken in conjunction with the water quality sampling. In addition, 24 hour meter readings were taken on the Ohio River at Stations 2 and 3 during each quarterly survey. These were begun at 0500 hours and taken every four hours until 0100 hours of the following day.

Due to the substantial data base at Cannelton, water quality sampling of the Ohio River was limited to a quarterly basis at two of the three biological stations. Once construction begins, Station 1 will be utilized as a control.

Flows were taken quarterly at Stations T and B. On the Ohio River, daily discharge and stage levels for 1980 were obtained from the Louisville District Corps of Engineers to determine site conditions during each survey. However, as discharge is measured below the dam, it is not directly applicable to conditions at the site (U.S. Army Corps of Engineers Louisville District, personal communication with Dave Leist, December 5, 1980). Flow is measured above the dam on a monthly basis by the U.S. Geological Survey.

10.5 RESULTS AND DISCUSSION

10.5.1 Ohio River

10.5.1.1 Low flow

The updated 7-day 10-year low flow of the Ohio River in the Cannelton Pool reach is 368 m^3 (13,000 cfs) (ORSANCO, personal communication with John Keys, January 5, 1980). The lowest discharge on record at Cannelton was 280 m^3 (10,000 cfs) on August 25, 1976 (U.S. Geological Survey, 1980).

10.5.1.2 Flood flows

The greatest flood on record was the 1937 flood, when discharge peaked at 39,921 m^3 (1,410,000 cfs) at Evansville (U.S Geological Survey, 1980). Since the Cannelton Lock and Dam has been in operation, the maximum daily discharge was 17,469 m^3 (617,000 cts) on December 15, 1978. The maximum gage height of 121.2 m (397.8 feet) MSL was recorded on the same day (U.S. Geological Survey, 1980).

10.5.1.3 Site drainage

The site area to the east of Route 144 drains into Town Creek; the area to the west of the road drains directly into the Ohio River (Figure 10.2). Most of the proposed plant site area, 4.64 Km^2 (682 acres) is cultivated; 2.76 Km^2 (407 acres) is wooded; 0.54 Km^2 (133 acres) is pasture; 0.37 Km^2 (92 acres) is oldfield; a small amount of other acreage is either developed or underwater (see Table 6.1). The majority of the proposed waste areas is forested (Table 6.1). Town Creek has a total drainage basin of about 17.6 Km^2 (6.8 square miles) (Dames and Moore, 1975). Bull Creek has a total drainage basin of about 13 K m^2 (5 square miles) (Commonwealth of Kentucky, 1975).

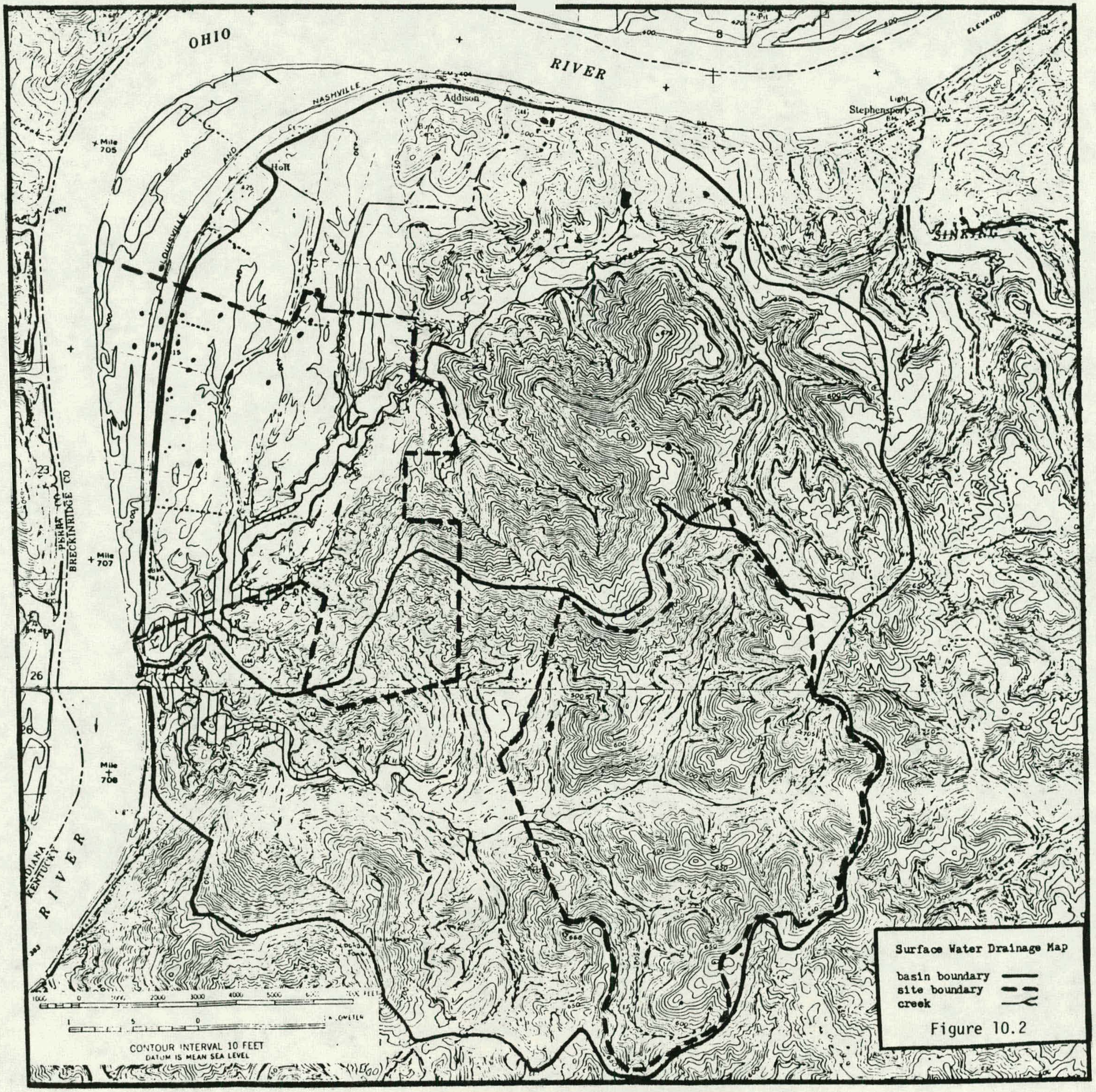

OHIO
RIVER
NASHVILLE
Addison
Stephensport
Holt
Mile 705
Mile 707
Mile 708
BRECKINRIDGE CO
PERRY
INDIANA
KENTUCKY
RIVER
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
Surface Water Drainage Map
basin boundary
site boundary
creek

Figure 10.2

10.5.1.4 100-Year and 500-year flood elevations

The adjusted 100-year flood elevation projected at the site is estimated to be 125.42 m (411.5 feet) MSL, 1929 Datum, (U.S. Army Corps of Engineers, personal communication with Mr. Robertson, March 17, 1981). The area that would be inundated by such a flood is depicted in Figure 10.3. No data was available on the 500-year flood elevation. Also, no floodway map has been produced for this area (National Flood Insurance Agency, personal communication with Maynard Long, March 24, 1981).

10.5.1.5 Surface water users

There are no surface users for some distance downstream of the proposed site (ORSANCO, 1980). Most of the downstream towns use the alluvial aquifer as a potable water source (see Section 11.6.5). Although water from the river probably recharges the alluvial aquifer at points of constant pumping, the water is filtered through the alluvial materials (sand, gravel, silty clays). The nearest downstream municipalities utilizing the Ohio River as a source or portable water are Evansville (RM 791.5) on the Indiana side and Henderson (RM 803.2) on the Kentucky side.

10.5.1.6 Discharges

Discharges within 80 kilometers (50 miles) upstream of the site on the Kentucky side either on the Ohio River or its tributaries include the Hardinsburg STP and three smaller dischargers. These domestic wastes enter the Sinking Creek basin and eventually the Ohio River at RM 700.9 (Kentucky Division of Water, personal communication with Ken Pidgeon, January 6, 1981). The Hardinsburg STP has a design flow of 416.4 m^3/day (110,000 gpd) and receives secondary treatment. The other three discharges are either domestic or animal wastes of less than 75.7 m^3/day (20,000 gpd).

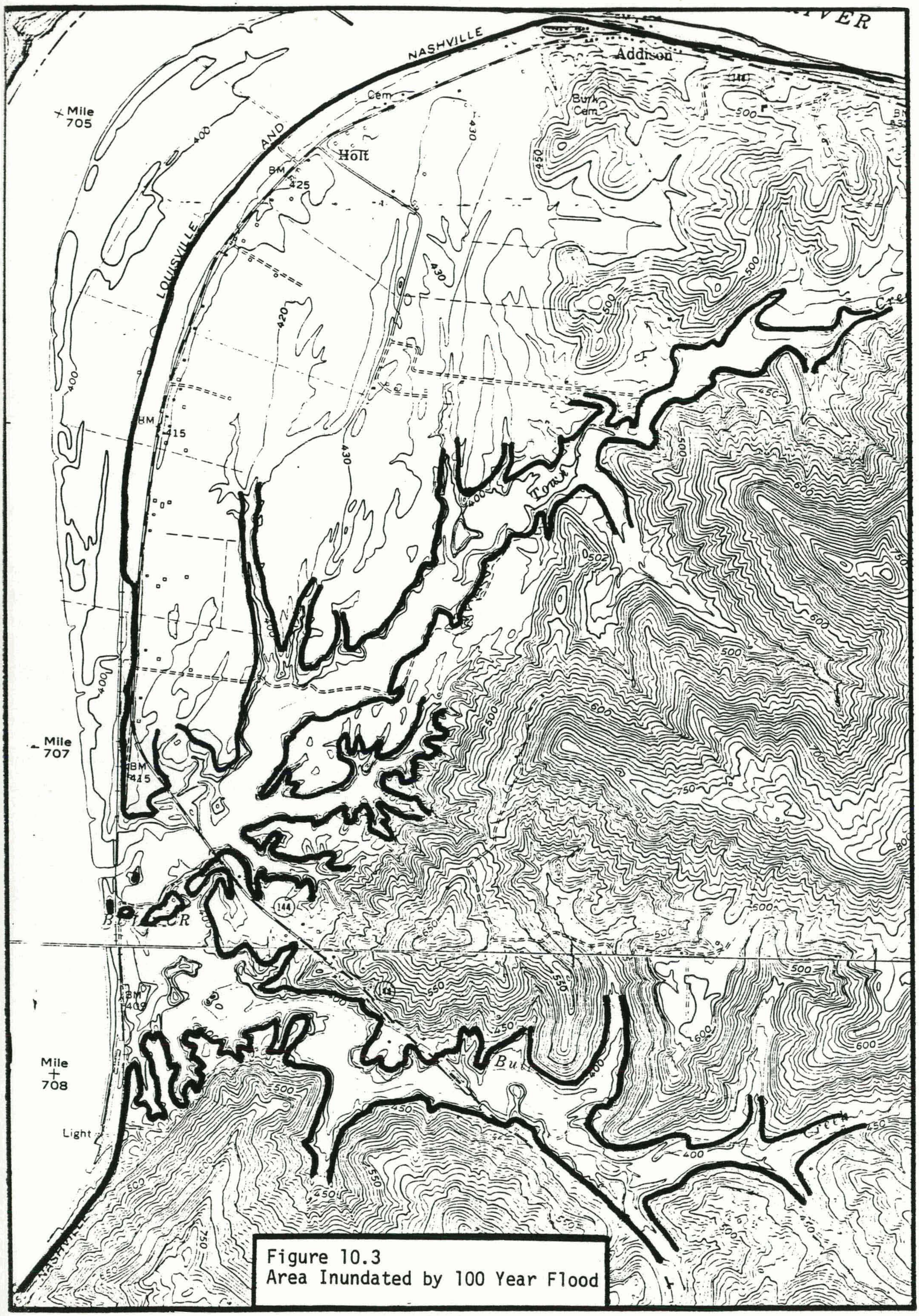


Figure 10.3
Area Inundated by 100 Year Flood

either domestic or animal wastes of less than 75.7 m^3/day (20,000 gpd). On the Indiana side there are five relatively small sanitary waste dischargers in Perry and Crawford Counties in addition to a larger STP facility at Leavenworth (RM 664) (Indiana State Board of Health, personal communication with David Cooper, March 12, 1981).

10.5.1.7 Water quality

Quarterly water quality data, (Tables 10.2 - 10.6), indicated that the waters are generally of good quality. They can be best described as well oxygenated, with moderate hardness and nutrient levels and low in trace metals and organic substances. Conditions at the site were comparable to those described by the historical data at Cannelton (Tables 10.7 and 10.8).

Standard violations occurred with fecal coliforms and several trace elements, including manganese, mercury, and iron (Table 10.9). Fecal coliforms are generally highest in the Ohio River downstream of Cincinnati and Louisville (ORSANCO, 1980). Several violations of the fecal coliform public recreation standard were recorded at Cannelton during 1979 (ORSANCO, 1980). They attributed these high values to high flow conditions during the summer of 1979, causing greater sewer overflows and urban runoff and decreased retention time in the Louisville to Cannelton reach. In the present study, the greatest concentrations were also found in the summer, but a review of USGS and ORSANCO data from Cannelton revealed that high fecal coliform values are highly variable throughout the year.

The most commonly violated standard was that for manganese. This element is high in waters of much of the Ohio River Valley (ORSANCO 1980, USGS, 1980). Also, the standard is for the taste and odor tainting of potable water (U.S. EPA, 1977). It is not an element that is considered highly toxic to aquatic life (U.S. EPA, 1977), and neither Kentucky (or ORSANCO) has a standard (or criteria) for aquatic life.

Mercury, a highly toxic element with a standard for aquatic life of only 0.05 g/l, was in non-compliance in only one sample in the Ohio River

Table 10.2 Summary of water quality collected from the Ohio River, Bull Creek, and Town Creek, 1980 - 81.[a,b,c,d]

Parameter	Ohio River Station 2	Ohio River Station 3	Bull Creek	Town Creek
pH	(6.8 - 7.9)	(6.1 - 7.9)	(7.0 - 7.7)	(7.0 - 7.8)
Dissolved Oxygen (mg/l)	9.2(5.6 - 13.0)	9.2(5.2 - 13.2)	8.1(5.0 - 11.4)	7.6(5.2 - 11.2)
Conductivity (umho/cm)	313(235 - 390)	304.8(210 - 390)	297.5(215 - 350)	318.3(265 - 380)
Water Temperature (°C)	17.2(1.2 - 28.0)	17.3(1.5 - 28.0)	16.0(0.5 - 28.0)	13.9(1 - 25)
Air Temperature (°C)	19.2(0.6 - 35)	21.0(5.0 - 36.0)	20.3(0 - 33.0)	17.6(0 - 32)
Total Coliform (per 100 ml)	(<20 - 3,900)	6,424.8(69 - 25,000)	1,900(200 - 4,600)	1628(240 - 2,600)
Fecal Coliform (per 100 ml)	(<1 - 1,300)	(<1 - 1,400)	189.3(3 - 600)	290(10 - 800)
Suspended Solids	52.3(5 - 183)	32.5(2 - 102)	6.5(1 - 11)	14.8(2 - 32)
Total Dissolved Solids	270(152 - 356)	262(152 - 328)	241(216 - 260)	258(216 - 328)
BOD	2.5(1 - 4)	2.3(2 - 3)	1.8(1 - 3)	(<1 - 4)
TOC	4.3(1 - 8)	4.3(2 - 7)	6.8(2 - 14)	(<1 - 14)
COD	19.5(2 - 37)	9.3(5 - 13)	32(21 - 44)	21.5(8 - 41)
Dissolved Organic Carbon	4.5(1 - 8)	4.0(2 - 6)	(<1 - 14)	(<1 - 14)
Alkalinity	96.5(58 - 178)	82.0(57 - 115)	186.3(158 - 235)	185(155 - 242)
Total Phosphorus as P	(<0.01 - 0.12)	(<0.01 - 0.14)	(<0.01 - 0.09)	(<0.01 - 0.02)
Total Nitrogen (TKN)	3.4(0.68 - 8.0)	2.95(0.54 - 5.3)	5.8(0.06 - 12.2)	2.93(0.06 - 7.20)
Ammonia as N	0.31(0.18 - 0.40)	0.28(0.15 - 0.38)	0.4(0.03 - 0.71)	0.20(0.03 - 0.27)
Chloride	30.5(15 - 44)	19.6(15 - 30)	6.7(3 - 12)	9.18(5 - 15)
Fluoride	0.36(0.24 - 0.607)	0.19(0.137 - 0.27)	(<0.01 - 0.776)	0.14(0.11 - 0.16)
Cyanide	(<0.002 - 0.02)	(<0.002 - 0.02)	(<0.002 - <1.0)	(<0.002 - 0.019)
Oil and Grease	(<1.0 - 6.0)	(<1.0 - 5.0)	(<1.0 - 2.0)	(<1.0 - 4.0)
Total Residual Chlorine	<0.1	(<0.1 - 0.1)	(<0.1 - 0.1)	(<0.1 - 0.2)
Aluminum	2.19(0.117 - 7.99)	1.49(0.052 - 5.18)	0.15(0.067 - 0.2)	(<0.001 - 0.47)
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025 -
Boron	0.46(0.207 - 0.70)	0.11(0.055 - 0.2)	0.54(0.262 - 0.8)	0.24(0.08 - 0.44)
Barium	0.18(0.004 - 0.693)	0.18(0.004 - 0.506)	0.15(0.006 - 0.58)	0.17(0.01 - 0.628)
Beryllium	<0.001 -	<0.001	<0.001	(<0.001 - <0.002)
Bismuth	(<0.002 - <0.01)	(<0.002 - 0.02)	(<0.002 - <0.01)	(<0.002 - <0.01)
Bromine	(0.002 - 0.380)	(<0.001 - 1.0)	(<0.01 - 0.5)	(<0.01 - 0.575)
Cadmium	<0.001	(<0.001 - 0.001)	<0.001	(<0.001 - 0.001)
Cobalt	<0.001	<0.001	(<0.001 - 0.002)	(<0.001 - 0.001)
Total Chromium	(<0.001 - 0.004)	(<0.001 - 0.006)	(<0.001 - 0.001)	(<0.001 - 0.003)
Copper	0.068(0.005 - 0.188)	(<0.001 - 0.005)	0.005(0.003 - 0.007)	(<0.001 - 0.055)
Iron	1.40(0.21 - 4.02)	0.84(0.11 - 2.51)	0.38(0.329 - 0.423)	0.50(0.212 - 0.659)
Gallium	(<0.003 - <0.007)	(<0.003 - <0.007)	(<0.003 - <0.007)	(<0.003 - <0.007)
Germanium	(<0.007 - <0.01)	(<0.007 - <0.01)	(<0.007 - 0.01)	(<0.007 - <0.01)
Mercury	<0.0001	(<0.0001 - 0.0002)	(<0.0001 - 0.0002)	(<0.0001 - 0.0001)
Lanthanum	(<0.003 - <0.005)	(<0.003 - <0.005)	(<0.003 - <0.005)	(<0.003 - <0.005)
Magnesium	13.3(9.3 - 16.3)	13.1(9.3 - 16.2)	8.82(5.79 - 13.40)	13.2(9.2 - 21.3)
Manganese	0.073(0.015 - 0.118)	0.05(0.016 - 0.085)	0.23(0.153 - 0.508)	0.16(0.028 - 0.367)
Molybdenum	(<0.001 - <0.002)	(<0.001 - 0.001)	(<0.001 - 0.009)	(<0.001 - <0.002)
Nickel	(<0.001 - 0.012)	(<0.001 - 0.006)	(<0.001 - 0.006)	(<0.001 - 0.018)
Lead	(<0.001 - 0.004)	(<0.001 - 0.004)	(<0.001 - 0.02)	<0.001
Rubidium	(<0.01 - <0.02)	(<0.01 - <0.02)	(<0.01 - <0.02)	(<0.01 - <0.02)
Antimony	(<0.001 - 0.176)	(<0.001 - 0.012)	(<0.001 - 0.053)	(<0.001 - 0.199)
Selenium	(<0.0025 - 0.01)	(0.0025 - 0.007)	(<0.0025 - 0.005)	(<0.0025 - 0.005)
Tin	(<0.005 - 0.075)	(<0.005 - 0.19)	(<0.005 - 0.585)	(<0.001 - <0.01)
Strontium	0.03(0.017 - 0.042)	0.03(0.015 - 0.052)	0.018(0.015 - 0.022)	0.028(0.023 - 0.038)
Titanium	(<0.007 - <0.01)	(<0.001 - 0.01)	(<0.001 - <0.01)	(<0.001 - <0.01)
Uranium	<0.01	(<0.01 - <0.011)	(<0.01 - <0.011)	(<0.01 - <0.011)
Vanadium	(<0.001 - 0.002)	(<0.001 - 0.001)	(<0.001 - 0.003)	(<0.001 - <0.02)
Tungsten	<0.02	<0.02	<0.02	<0.02
Zinc	0.03(0.006 - 0.047)	0.02(0.004 - 0.029)	0.015(0.005 - 0.027)	(<0.001 - 0.026)
Zirconium	(<0.005 - <0.01)	(<0.005 - <0.01)	(<0.005 - <0.01)	(<0.005 - <0.010)
Silver	<0.001	<0.001	<0.001	<0.001
Phenols (µg/l)	<2.0	<2.0	(<2.0 - 3.0)	<2.0
Aliphatic Hydrocarbons (µg/l)	<5.0	<5.0	(<5.0 - 44.0)	(<5.0 - 15.0)
Arylamines (µg/l)	(<0.1 - <1.0)	(<0.1 - <1.0)	(<0.1 - <1.0)	(<0.1 - <1.0)
Mono & Polycyclic Hydrocarbons (µg/l)	(<0.01 - <0.02)	(<0.01 - <0.02)	(<0.01 - <0.02)	(<0.01 - <0.02)
Sulfur Compounds: Thiophenes & Mercaptans (µg/l)	(<1.0 - <4.0)	(<1.0 - <4.0)	(<1.0 - <4.0)	(<1.0 - <4.0)
Chlororganics (µg/l)	(<0.006 - 0.017)	(<0.006 - 0.021)	(<0.006 - 0.03)	(<0.006 - 0.033)
Chloramines (µg/l)	(<100.0 - 200.0)	<100.0	(<100.0 - 150.0)	(<10.0 - 150.0)

[a]All values are in milligrams per liter (mg/l) unless otherwise noted.

[b]See Figure 10.1 for sampling locations.

[c]Values are means and (ranges); means not calculated when one or more observations reported as a less than (<) value.

[d]Four observations per station; May, July and October, 1980 and January, 1981.

Table 10.3. Surface Water Quality Data of the Breckinridge Site, Spring, 1980.

	Sta. 2 5-15-80	Sta. 3 5-15-80	Sta. B 5-15-80	Sta. T 5-18-80
Total Coliform (per 100 ml)	330	330	800	2,600
Fecal Coliform (per 100 ml)	45	38	100	800
	mg/L	mg/L	mg/L	mg/L
Suspended Solids	9	2	1	5
Total Dissolved Solids	152	152	216	216
BOD	4	3	3	4
TOC	6	7	9	11
COD	37	7	31	41
Dissolved Organic Carbon	7	6	12	11
Alkalinity	58	57	162	157
Total Phosphorus as P	0.022	<0.010	<0.010	<0.010
Total Nitrogen (TKN)	4.04	5.10	10.10	7.20
Ammonia as N	0.32	0.38	0.71	0.27
Chloride	15	15	3	5
Fluoride	0.607	0.137	0.776	0.150
Cyanide	<0.002	0.004	0.007	<0.002
Oil & Grease	6.0	5.0	2.0	<1.0
Total Residual Chlorine	<0.1	0.1	0.1	0.1
Aluminum	0.478	0.55	0.20	0.47
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025
Boron	0.70	0.20	0.80	0.44
Barium	0.004	0.004	0.006	0.010
Beryllium	<0.001	<0.001	<0.001	<0.001
Bismuth	<0.010	0.020	<0.010	<0.010
Bromine	<0.01	1.00	<0.01	<0.01
Cadmium	<0.001	<0.001	<0.001	<0.001
Cobalt	<0.001	<0.001	0.002	0.001

Table 10.3. Continued

	Sta. 2 5-15-80	Sta. 3 5-15-80	Sta. B 5-15-80	Sta. T 5-18-80
	mg/L	mg/L	mg/L	mg/L
Total Chromium	<0.001	0.002	0.001	0.003
Copper	0.006	0.005	0.007	0.002
Iron	0.614	0.480	0.329	0.505
Gallium	<0.007	<0.007	<0.007	<0.007
Germanium	<0.007	<0.007	<0.007	<0.007
Mercury	<0.0001	<0.0001	<0.0001	<0.0001
Lanthanum	<0.005	<0.005	<0.005	<0.005
Magnesium	9.30	9.30	8.00	10.00
Manganese	0.076	0.046	0.116	0.127
Molybdenum	<0.001	<0.001	<0.001	<0.001
Nickel	0.012	0.006	0.006	0.018
Lead	<0.001	0.004	<0.001	<0.001
Rubidium	<0.020	<0.020	<0.020	<0.020
Antimony	<0.020	<0.020	<0.020	<0.020
Selenium	<0.0025	<0.0025	<0.0025	<0.0025
Tin	0.023	0.012	0.102	<0.001
Strontium	0.019	0.022	0.016	0.027
Titanium	<0.01	<0.01	<0.01	<0.01
Uranium	<0.01	<0.01	<0.01	<0.01
Vanadium	<0.001	<0.001	<0.001	<0.001
Tungsten	<0.020	<0.020	<0.020	<0.020
Zinc	0.047	0.029	0.021	0.026
Zirconium	<0.005	<0.005	<0.005	<0.005
Silver	<0.001	<0.001	<0.001	<0.001
	ug/L	ug/L	ug/L	ug/L
Phenols (1)	<2.0	<2.0	<3.0	<2.0
Aliphatic Hydrocarbons	<5.0	<5.0	44.0	<5.0
Arylamines	<0.1	<0.1	<0.1	<0.1
Mono & polycyclic Hydrocarbons (2)	<0.01	<0.01	<0.01	<0.01
Sulfur Compounds:				
Thiophenes and Mercaptans (3)	<1.0	<1.0	<1.0	<1.0
Chlororganics (4)	0.017	0.020	0.030	0.033
Chloramines	<100.0	<100.0	<100.0	<10.0

Table 10.4. Surface Water Quality Data of the Breckinridge Site, Summer, 1980.

	Sta. Z 7-15-80	Sta. 3 7-15-80	Sta. B 7-15-80	Sta. T 7-15-80	Sta. T 7-19-80
Total Coliform (per 100 ml)	3,900	25,000	2,000	1,900	2,100
Fecal Coliform (per 100 ml)	1,300	1,400	600	120	140
	mg/L	mg/L	mg/L	mg/L	
Suspended Solids	183	107	11	32	
Total Dissolved Solids	320	292	248	216	
BOD	3	2	1	1	
TOC	8	6	14	14	
COD	23	12	32	22	
Dissolved Organic Carbon	8	6	14	14	
Alkalinity	76	78	158	155	
Total Phosphorus as P	<0.010	<0.010	<0.010	<0.010	
Total Nitrogen (TKN)	8.00	5.30	12.20	3.58	
Ammonia as N	0.40	0.15	0.37	0.23	
Chloride	20.80	20.20	3.60	4.70	
Fluoride	0.30	0.27	0.11	0.11	
Cyanide	<0.002	<0.002	<0.002	<0.002	
Oil & Grease	<1.00	<1.00	<1.00	<1.00	
Total Residual Chlorine	<0.10	<0.10	0.10	0.20	
Aluminum	7.99	5.18	0.162	0.21	
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025	
Boron	0.520	0.055	0.700	0.162	
Barium	0.019	0.014	0.007	0.011	
Beryllium	<0.001	<0.001	<0.001	<0.001	
Bismuth	<0.002	<0.002	<0.002	<0.002	
Bromine	0.13	0.11	0.02	0.02	
Cadmium	<0.001	0.001	<0.001	0.001	
Cobalt	<0.001	<0.001	<0.001	<0.001	

Table 10.4. Continued

	Sta 2	Sta 3	Sta B	Sta T
	mg/L	mg/L	mg/L	mg/L
T. Chromium	0.002	0.006	<0.001	<0.001
Copper	0.005	<0.001	0.003	<0.001
Iron	4.020	2.510	0.418	0.659
Gallium	<0.003	<0.003	<0.003	<0.003
Germanium	<0.010	<0.010	<0.010	<0.010
Mercury	<0.0001	<0.0001	<0.0001	<0.0001
Lanthanum	<0.005	<0.005	<0.005	<0.005
Magnesium	11.400	11.400	5.790	9.200
Manganese	0.118	0.085	0.153	0.028
Molybdenum	<0.001	<0.001	<0.001	<0.001
Nickel	<0.001	<0.001	<0.001	<0.001
Lead	<0.001	<0.001	<0.001	<0.001
Rubidium	<0.020	<0.020	<0.020	<0.020
Antimony	0.176	0.012	0.053	0.199
Selenium	<0.0025	<0.0025	<0.0025	<0.0025
Tin	0.075	0.190	0.585	<0.010
Strontium	0.017	0.033	0.015	0.025
Titanium	<0.007	<0.007	<0.007	<0.007
Uranium	<0.011	<0.011	<0.011	<0.011
Vanadium	<0.001	<0.001	<0.001	0.005
Tungsten	<0.020	<0.020	<0.020	<0.020
Zinc	0.031	0.019	0.006	0.007
Zirconium	<0.006	<0.006	<0.006	<0.006
Silver	<0.001	<0.001	<0.001	<0.001
	ug/L	ug/L	ug/L	ug/L
Phenols (1)	<2.0	<2.0	3.0	<2.0
Aliphatic Hydrocarbons	<5.0	<5.0	44.0	<5.0
Arylamines	<0.1	<0.1	<0.1	<0.1
Mono & polycyclic hydrocarbons (2)	<0.01	<0.01	<0.01	<0.01
Sulfur Compounds:				
Thiophenes and Mercaptons (3)	<4.0	<4.0	<4.0	<4.0
Chlororganics	0.017	0.021	0.010	0.033
Chloramines	200.0	<100.0	150.0	150.0

Table 10.5. Surface Water Quality Data of the Breckinridge Site, Fall, 1980.

	Sta. 2 10-10-80	Sta. 3 10-10-80	Bull Creek 10-9-80	Town Creek 10-9-80
Total Coliform (per 100 ml)	<20	300	4,600	1,300
Fecal Coliform (per 100 ml)	<20	<7	54	380
	mg/L	mg/L	mg/L	mg/L
Suspended Solids	12	14	7	20
Total Dissolved Solids	356	328	260	328
BOD	1	2	2	<1
TOC	1	2	2	<1
COD	13	13	21	8
Dissolved Organic Carbon	1	2	2	<1
Alkalinity	178	115	235	242
Total Phosphorus as P	0.12	0.14	0.09	0.02
Total Nitrogen (TKN)	0.98	0.84	0.88	0.86
Ammonia as N	0.18	0.26	0.53	0.25
Chloride	42.0	27.0	12.0	15.0
Fluoride	0.292	0.189	0.104	0.125
Cyanide	0.020	0.020	0.024	0.019
Oil & Grease	<1.0	<1.0	1.0	<1.0
Total Residual Chlorine	<0.10	<0.10	<0.10	<0.10
Aluminum	0.193	0.174	0.103	0.211
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025
Boron	0.207	0.060	0.262	0.290
Barium	0.693	0.506	0.580	0.628
Beryllium	<0.001	<0.001	<0.001	<0.001
Bismuth	<0.002	<0.002	<0.002	<0.002
Bromine	0.380	0.475	0.500	0.575
Cadmium	<0.001	<0.001	<0.001	<0.001
Cobalt	<0.001	<0.001	<0.001	<0.001

Table 10.5. Continued

	Sta. 2 10-10-80	Sta. 3 10-10-80	Bull Creek 10-9-80	Town Creek 10-9-80
	mg/L	mg/L	mg/L	mg/L
T. Chromium	0.002	<0.001	<0.001	<0.001
Copper	0.071	<0.001	0.006	0.055
Iron	0.212	0.240	0.423	0.630
Gallium	<0.003	<0.003	<0.003	<0.003
Germanium	<0.009	<0.009	<0.009	<0.009
Mercury	<0.0001	<0.0001	<0.0001	<0.0001
Lanthanum	<0.003	<0.003	<0.003	<0.003
Magnesium	16.300	16.200	8.070	12.300
Manganese	0.015	0.016	0.155	0.367
Molybdenum	0.001	0.001	0.009	<0.001
Nickel	<0.001	<0.001	<0.001	<0.001
Lead	<0.001	<0.001	<0.001	<0.001
Rubidium	<0.010	<0.010	<0.010	<0.010
Antimony	<0.001	<0.001	<0.001	<0.001
Selenium	<0.0025	<0.0025	<0.0025	<0.0025
Tin	<0.010	<0.010	<0.010	<0.010
Strontium	0.036	0.052	0.018	0.023
Titanium	<0.001	<0.001	<0.001	<0.001
Uranium	<0.010	<0.010	<0.010	<0.010
Vanadium	0.002	0.001	0.003	0.001
Tungsten	<0.020	<0.020	<0.020	<0.020
Zinc	0.006	0.004	0.005	<0.001
Zirconium	<0.010	<0.010	<0.010	<0.010
Silver	<0.001	<0.001	<0.001	<0.001
	ug/L	ug/L	ug/L	ug/L
Phenols (1)	<2.0	<2.0	<2.0	<2.0
Aliphatic Hydrocarbons	<5.0	<5.0	<5.0	12.0
Arylamines	<1.0	<1.0	<1.0	<1.0
Mono & polycyclic hydrocarbons (2)	<0.02	<0.02	<0.02	<0.02
Sulfur Compounds:				
Thiophenes and Mercaptons (3)	<1.0	<1.0	<1.0	<1.0
Chlororganics	<0.006	<0.006	<0.006	<0.006
Chloramines	<100.0	<100.0	<100.0	<100.0

Table 10.6. Surface Water Quality Data of the Breckinridge Site, Winter, 1981.

	Sta. 2 1-15-81	Sta. 3 1-15-81	Bull Creek 1-15-81	Town Creek 1-15-81
Total Coliform (per 100 ml)	27	69	200	240
Fecal Coliform (per 100 ml)	<1	<1	3	10
pH (S.U.)	7.35	7.25	7.30	7.30
	mg/L	mg/L	mg/L	mg/L
Suspended Solids	5	7	1	2
Total Dissolved Solids	252	276	240	272
BOD	2	2	1	2
TOC	2	2	1	2
COD	5	5	44	15
Dissolved Organic Carbon	2	2	<1	2
Alkalinity	74	78	190	186
Total Phosphorus as P	0.12	0.11	<0.02	<0.02
Total Nitrogen (TKN)	0.68	0.54	0.06	0.06
Ammonia as N	0.33	0.32	0.03	0.03
Chloride	44.0	30.0	8.0	12.0
Fluoride	0.24	0.18	<0.01	0.16
Cyanide	<0.002	0.005	0.011	0.004
Oil & Grease	<1.0	<1.0	<1.0	4.0
Total Residual Chlorine	<0.10	<0.10	<0.10	<0.10
Aluminum	0.117	0.052	0.067	<0.001
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025
Boron	0.400	0.120	0.400	0.080
Barium	0.019	0.190	0.017	0.022
Beryllium	<0.001	<0.001	<0.001	<0.001
Bismuth	<0.002	<0.002	<0.002	<0.002
Bromine	0.002	<0.001	0.013	0.002
Cadmium	<0.001	<0.001	<0.001	<0.001
Cobalt	<0.001	<0.001	<0.001	<0.001

Table 10.6. Continued

	Sta. 2 1-15-81	Sta. 3 1-15-81	Bull Creek 1-15-18	Town Creek 1-15-81
	mg/L	mg/L	mg/L	mg/L
T. Chromium	0.004	0.001	0.004	0.002
Copper	0.188	0.005	0.004	0.001
Iron	0.747	0.110	0.356	0.212
Gallium	<0.003	<0.003	<0.003	<0.003
Germanium	<0.009	<0.009	<0.009	<0.009
Mercury	<0.0001	0.0002	0.0002	0.0001
Lanthanum	<0.003	<0.003	<0.003	<0.003
Magnesium	16.200	15.500	13.400	21.300
Manganese	0.083	0.058	0.508	0.112
Molybdenum	<0.002	<0.002	<0.002	<0.002
Nickel	<0.001	<0.001	<0.001	<0.001
Lead	0.004	<0.001	0.020	<0.001
Rubidium	<0.010	<0.010	<0.010	<0.010
Antimony	<0.001	<0.001	<0.001	<0.001
Selenium	0.010	0.007	0.005	0.005
Tin	<0.005	<0.005	<0.005	<0.005
Strontium	0.042	0.015	0.022	0.038
Titanium	<0.010	<0.010	<0.010	<0.010
Uranium	<0.010	<0.010	<0.010	<0.010
Vanadium	<0.001	<0.001	<0.001	<0.001
Tungsten	<0.020	<0.020	<0.020	<0.020
Zinc	0.030	0.023	0.027	0.024
Zirconium	<0.010	<0.010	<0.010	<0.010
Silver	<0.001	<0.001	<0.001	<0.001
	ug/L	ug/L	ug/L	ug/L
Phenols (1)	<2.0	<2.0	<2.0	<2.0
Aliphatic Hydrocarbons	<5.0	<5.0	12.0	15.0
Arylamines	<1.0	<1.0	<1.0	<1.0
Mono & polycyclic hydrocarbons (2)	<0.02	<0.02	<0.02	<0.02
Sulfur Compounds:				
Thiophenes and Mercaptons (3)	<1.0	<1.0	<1.0	<1.0
Chlororganics(4)	<0.006	<0.006	<0.006	<0.006
Chloramines	<100.0	<100.0	<100.0	<100.0

Table 10.7 Water quality data from the ORSANCO manual sampling station at Cannelton Lock and Dam, Ohio River, Mile 720.7, November 1975 - August 1980 [a,b,c]

Parameters	Mean	Max	Min	No Observation
Alkalinity	84	84	84	1
Ammonia - N	<0.16	1.97	<0.05	92
Ammonia - N, unionized	0.002	0.007	0.001	32
Biochemical oxygen demand	2.36	7.4	0.4	50
Calcium	58.69	65.9	51.5	2
Chemical oxygen demand	11.28	22.0	4	7
Coliforms, fecal (per 100 ml)	543.41	9,400	0	102
Coliforms, total (per 100 ml)	6934.42	91,000	0	86
Conductivity (μmhos)	355.32	650	130	98
Cyanide	<9.54	<50	<0.01	97
Dissolved solids	220.28	403	81	98
Flow (cfs)				
Flouride	0.31	0.31	0.31	1
Hardness, total	139.81	193	109	22
Kjedahl nitrogen, total	<0.59	2.2	<0.1	92
Magnesium	9.78	14.0	7.8	8
Nitrite & nitrate nitrogen	1.06	1.96	0.02	92
Oxygen, dissolved	8.81	14.0	4.9	98
pH (units)		7.8	6.5	98
Phenolics (μg/l)	<2.90	19	<2	87
Phosphorus, total	<0.30	2.89	<0.05	92
Potassium	3.0	3.0	3.0	1
Sodium	17.83	37.0	8.0	16
Sulfate	72.68	156	42	87
Suspended solids	67.24	579	<10	83
Temperature (°C)	16.37	30.5	0.0	98
Trace elements, total (μg/l)				
Arsenic	<8.82	<10	<5	17
Barium	<187.50	<200	<100	32
Cadmium	<4.29	28	<1	45
Chromium	<23.18	<30	4	34
Copper	<25.36	160	4	47
Iron	2690.81	15,000	160	47
Lead	<26.89	410	<5	47
Manganese	149.89	560	30	31
Mercury	<0.63	6	<0.5	46
Nickel	<78.94	100	<10	32
Selenium	<5.31	<10	<5	16
Silver	<15.56	<30	<1	16
Zinc	<45.53	260	10	47

[a] Data reduced from ORSANCO "Quality Monitor"
[b] Units are mg/liter unless specified otherwise
[c] Absolute value assumed for one or more observation(s), but the mean is less than (<) the absolute value calculated

Table 10.8. U. S. Geological Survey[a] Water Quality Data from Cannelton[b].

CONSTITUENT	CONSTITUENT (MG/L OR UNIT SHOWN)				
	SAMPLE SIZE	MEAN	STANDARD DEVIATION	RANGE	
TEMPERATURE, WATER (DEG C)	59	16.66	8.52	2.50	30.00
STREAMFLOW (CUBIC FT/SEC)	55	164881.73	155018.74	17200.00	631000.00
TURBIDITY (JTU)	43	49.98	57.68	1.00	220.00
SPECIFIC CONDUCTANCE (MICROMHOS)	59	351.76	66.52	174.00	495.00
PH (STANDARD UNITS)	59	7.31	0.39	6.50	8.40
BICARBONATE ION	44	75.34	13.77	43.00	113.00
CARBONATE ION	40	0.00	0.00	0.00	0.00
NITROGEN, KJEDAHL, TOTAL	55	0.81	0.46	0.27	2.50
NITRITE+NITRATE, TOTAL	57	1.23	0.25	0.83	2.00
PHOSPORUS, TOTAL	58	0.18	0.14	0.03	0.93
HARDNESS, TOTAL	59	134.92	24.14	67.00	190.00
HARDNESS, NONCARBONATE	59	70.80	15.86	32.00	110.00
CALCIUM, DISSOLVED	59	37.34	6.76	19.00	53.00
MAGNESIUM, DISSOLVED	59	9.76	1.94	4.80	14.00
SODIUM, DISSOLVED	59	16.27	5.41	6.10	29.00
POTASSIUM, DISSOLVED	59	2.75	0.62	1.80	3.90
CHLORIDE, DISSOLVED	59	21.59	7.04	8.00	42.00
SULFATE, DISSOLVED	59	66.12	15.76	36.00	110.00
FLOURIDE, DISSOLVED	59	0.21	0.10	0.10	0.40
SILICA, DISSOLVED	58	4.66	1.87	0.20	6.60
COLIFORM, FECAL (COL/100 ML)	53	1841.91	6359.22	3.00	46000.00
STREPTOCOCCI, FECAL (COL/100 ML)	50	829.88	1794.10	1.00	8300.00
PHYTOPLANKTON, TOTAL (CELLS/ML)	44	5100.00	6188.84	120.00	27000.00
DISSOLVED SOLIDS, ROE 180 DEG C	59	215.24	45.43	117.00	330.00
DISSOLVED SOLIDS, SUM OF CONST	59	197.29	39.99	103.00	300.00
SEDIMENT, CLAY-SILT (PERCENT)	33	97.36	9.51	48.00	100.00
SEDIMENT, SUSPENDED	34	138.32	191.20	5.00	803.00

	DURATION TABLE OF DAILY SPECIFIC CONDUCTANC					
DAILY SPECIFIC CONDUCTANCE IN MICROMHOS AT 25 DEG C, THAT WAS EQUALLED OR EXCEEDED FOR THE	1%	5%	10%	25%	50%	75

Table 10.8 Continued

	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
ARSENIC TOTAL (UG/L AS AS)	26	1.730769	1.185165	0.000000	5.0000
ARSENIC DISSOLVED (UG/L AS AS)	25	0.760000	0.830662	0.000000	3.0000
BARIUM, TOTAL RECOVERABLE (UG/L AS BA)	10	59.999998	61.463629	0.000000	200.0000
BARIUM, DISSOLVED (UG/L AS BA)	11	33.636364	59.037738	0.000000	200.0000
CADMIUM TOTAL RECOVERABLE (UG/L AS CD)	23	29.608695	113.658076	0.000000	
CADMIUM DISSOLVED (UG/L AS CD)	24	3.666666	5.887840	0.000000	27.0000
CHROMIUM, TOTAL RECOVERABLE (UG/L AS CR)	24	12.499999	4.423259	9.999986	20.0000
CHROMIUM, DISSOLVED (UG/L AS CR)	26	4.846154	6.920649	0.000000	20.0000
COBALT, TOTAL RECOVERABLE (UG/L AS CO)	24	2.166667	3.212295	0.000000	11.0000
COBALT, DISSOLVED (UG/L AS CO)	25	0.120000	0.439697	0.000000	2.0000
COPPER, TOTAL RECOVERABLE (UG/L AS CU)	24	24.374998	17.749005	3.000000	75.0000
COPPER, DISSOLVED (UG/L AS CU)	25	6.920000	3.365511	2.000000	18.0000
IRON, TOTAL RECOVERABLE (UG/L AS FE)	24	2975.833089	3075.385993	190.000000	11000.0000
IRON, DISSOLVED (UG/L AS FE)	25	27.199999	24.241837	0.000000	100.0000
LEAD, TOTAL RECOVERABLE (UG/L AS PB)	24	17.499999	12.860455	0.000000	44.0000
LEAD, DISSOLVED (UG/L AS PB)	25	2.000000	2.533114	0.000000	9.0000
MANGANESE, TOTAL RECOVERABLE (UG/L AS MN	24	138.583323	133.297283	20.000000	530.0000
MANGANESE, DISSOLVED (UG/L AS MN)	25	21.399999	37.722672	0.000000	190.0000
MERCURY TOTAL RECOVERABLE (UG/L AS HG)	26	0.246154	0.240384	0.000000	0.8000
MERCURY DISSOLVED (UG/L AS HG)	25	0.244000	0.238188	0.000000	0.7000
SELENIUM, TOTAL (UG/L AS SE)	26	0.153846	0.367946	0.000000	1.0000
SELENIUM, DISSOLVED (UG/L AS SE)	25	0.040000	0.200000	0.000000	1.0000
SILVER, TOTAL RECOVERABLE (UG/L AS AG)	12	0.083333	0.288675	0.000000	1.0000
SILVER, DISSOLVED (UG/L AS AG)	13	0.000000	0.000000	0.000000	0.0000
ZINC, TOTAL RECOVERABLE (UG/L AS ZN)	24	57.083331	36.053001	20.000000	160.0000
ZINC, DISSOLVED (UG/L AS ZN)	25	10.040000	14.037094	0.000000	60.0000

[a] Data Summary for 1974-1980 received from Dave Leist of the USGS, July 8 and December 12, 1980.

[b] Units mg/l unless noted otherwise.

TABLE 10.9 Surface water quality standards' violations at water bodies of the Breckinridge site, 1980-81.[a]

Parameter	Location	Date	Concentration	Ky. Standard[b]	% of Total Samples Exceeding Standard
Fecal Coliform	Ohio River	7-15-80	1300	400	25
(per 100 ml:	St. 2				25
	Ohio River	7-15-80	1400		25
	St. 3				25
	Bull Creek	7-15-80	600		
	Town Creek	5-18-80	80		
Chlorine, total	Ohio River	5-18-80	0.1	0.01	25
residual	St. 3				
(mg/l	Bull Creek	5-18-80	0.1		50
	Bull Creek	7-15-80	0.1		
	Town Creek	5-18-80	0.1		50
	Town Creek	5-18-80	0.2		
Iron, total	Ohio River	7-15-80	4.0	1.0	25
(mg/l)	St. 2				
	Ohio River	7-15-80	2.5		25
	St. 3				
Mercury	Ohio River	1-15-81	0.2	0.05	25
ug/l)	St. 2				
	Bull Creek	1-15-81	0.2		25
	Town Creek	1-15-80	0.1		25
Manganese	Ohio River	5-15-80	76	50	75
(ug/l)	St. 2				
		7-15-80	118		
		1-15-80	83		

TABLE 10.9 Continued.

Parameter	Location	Date	Concentration	Ky. Standard[d]	%of Total Samples Exceeding Standard
Manganese (ug/l)	Ohio River St. 3	7-15-80	85	50	50
		1-15-81	58		
	Bull Creek	5-15-80	116		100
		7-15-80	153		
		10-9-80	155		
		1-15-81	508		
	Town Creek	5-15-80	127		75
		10-9-80	367		
		1-15-81	112		

a. Total of 4 observations per station.
b. See Table 10.1 for explanation.

However, ORSANCO (1980) states that mercury continues to be a problem in many areas of the river, and no sources have presently been identified. Four of the eight samples taken by ORSANCO in 1980 (through August) at Cannelton contained at least 0.5 g/l. Three Station (RM's 705, 717, 722) sampled by U.S. EPA (in press) in May, 1980 contained 1.8 - 2.6 μg/l. Thus, mercury is a problem in the Ohio River that appears to be getting worse with time (ORSANCO 1980).

Iron exceeded the Kentucky standard on two occasions in the Ohio River. A review of the historical data revealed that it is frequently in violation in the Ohio River Valley. Sources probably include mining and industrial activities.

U.S. EPA (in press) found little thermal or dissolved oxygen stratification in the river from July 9 to September 8, 1979 and from April 30 to June 6, 1980. However, the summer of 1979 was unusually wet, and profiles during the hot, dry summer of 1980 were not made.

Results on the 24-hour sampling showed little diurnal variation for dissolved oxygen, specific conductance, of pH (Table 10.10). Conductance generally showed slight increases throughout the day, and during the winter this increase was more pronounced. As expected, both water and air temperature generally peaked during the afternoon readings. Although there was little diurnal variation for pH, readings were usually slightly higher in the daylight hours.

Table 10.10. 24-Hour In-Situ Readings from Ohio River Stations 2A and 3A, May, July, October 1980 and January, 1981.

Time (hours)	Air Temp. (^oC)								Water Temp. (^oC)							
	Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter	
0500	14	14	25	25	15	15	3	3	18	18	28	28	20.5	20.5	1.5	1.5
0900	18	18	29	28.5	16.5	16.5	0	0	18.5	18.5	28	28.5	21.0	21	1	1
1300	27.5	27.5	36	35	26	26	1.5	1.5	19	19	28.5	29	22	23	1.5	1
1700	22	22.5	31	31	25	25	1	1.0	19	19	28.5	28.5	22	22.5	1	1
2100	17	17	23	23	20	20	0	0	19	18	28	28	22	21	1	1
0100	--	15	--	22	20.5	20.5	-2	-2	18	--	--	28	21	21	1	1

Time (hours)	Dissolved Oxygen (mg/l)								Specific Conductance (umhos/cm^2)							
	Spring		Summer		Fall		Winter		Spring		Summer		Fall		Winter	
0500	7.5	7.6	5.6	5.6	9.3	9.4	13.1	13.2	262	260	390	385	410	400	220	220
0900	8.1	8.0	5.6	5.7	9.3	9.0	13.0	13.0	277	268	394	388	395	390	225	222
1300	7.4	7.6	5.6	5.6	10.6	9.7	13.1	13.0	273	272	398	405	410	390	222	220
1700	7.8	7.8	5.7	5.7	10.2	10.0	13.0	13.0	277	284	395	400	400	400	252	250
2100	8.4	8.3	5.6	5.6	10.6	10.2	13.0	13.0	287	289	--	--	400	400	250	250
0100	--	8.0	--	5.6	9.7	10.2	13.3	13.2	--	280	--	--	390	390	285	288

Table 10.10. Continued

Time (hours)	pH (units)							
	Spring		Summer		Fall		Winter[a]	
0500	6.8	6.9	6.9	6.9	7.3	7.5	--	--
0900	7.1	6.8	7.1	7.1	7.5	7.2		
1300	6.8	7.1	7.0	7.0	7.8	7.8	--	--
1700	6.9	6.8	7.2	7.0	7.9	7.8	--	--
2100	6.9	6.7	7.0	7.0	7.7	7.5	--	--
0100	--	6.8	--	7.0	7.4	7.5	--	--

[a] Buffers and pH probe frozen

10.5.2 Town Creek

10.5.2.1 Water Quality

Quarterly water quality samples taken on the upper position of Town Creek indicated that some differences existed between the creek and Ohio River (Table 10.2). The most noticeable differences were the higher levels of alkalinity and manganese and lower levels of suspended solids, chloride, iron and aluminum. These differences are because Town Creek is a headwater stream fed by springs from the limestone strata.

Although water quality was generally excellent, with low amounts of trace metals and organics, a few violations of Kentucky water quality standards did occur. Foremost among these was manganese, which averaged more than 4 times the drinking water standard. Other violations, including fecal coliform, total residual chlorine, and mercury were less severe and less frequent. Although several chlorine values exceeded the standard, these values were near the laboratory detection limits. Chlorine usually arises from water or wastewater treatment and would not be expected in this headwater stream.

10.5.2.2 Flow

Owing to the unusually dry year, Town Creek had flows less than 1 cfs on all four dates, with the maximum flow of 0.02 m^3 (0.7 cfs) occuring in May (Table 10.11). The 7-day 10-year low flow is 0.0 cfs (Commonwealth of Kentucky, 1975). Previously hydrologic studies of Town Creek found that maximum water levels would be caused by Ohio River flooding (Dames & Moore, 1975).

10.5.3 Bull Creek

10.5.3.1 Water Quality

Quality of the water in Bull Creek, as in Town Creek, was generally

Table 10.11 Seasonal Flow Data from Town and Bull Creeks, 1980-81[a].

	Spring	Summer	Fall	Winter
Bull Creek	0.008 (0.3)	<0.003(<0.1)	<0.003(<0.1)	0.003(0.1)
Town Creek	0.02(0.7)	0.008(0.3)	<0.003(<0.1)	0.008(0.3)

[a] Presented as m^3/sec and (cfs)

excellent. Standards violations that occurred were for the same parameters as in Town Creek. Also, while suspended solids were lower than at any of the four water quality stations, aliphatic (straight chain) hydrocarbons were the highest. This can probably be explained by presence of the oil-bearing Big Clifty Sandstone strata in this area (Clark and Crittendon, 1965).

10.5.3.2 Flow

Flow was even lower in Bull Creek than in Town Creek for the dates of measurement, only exceeding 0.003 m^3 (0.1 cfs) in May (Table 10.11). It should be noted that on both creeks, a partial barrier is located just upstream of the measurement location. On Bull Creek this is a series of road culverts, and on Town Creek it is a concrete ford. These partial barriers tend to backup water behind them, preventing a complete free-flow situation. The 7-day 10-year low flow of Town Creek is 0.0 cfs (Commonwealth of Kentucky, 1975).

10.6 SEDIMENT QUALITY

Sediment collected in the spring and fall of 1980 from the Ohio River Town Creek and Bull Creek contained some aliphatic hydrocarbons and the trace elements aluminum, iron, manganese (Table 10.12). Concentrations of most metals were much higher in the fall, when the percent dry weight was less. In the river, this is probably due to the near-normal pool stages that prevailed throughout the year (Table 10.13), allowing finer suspended materials containing adsorbed heavy metals to settle. Chromium and bromine were unexplained exceptions to this phenomena.

Cobalt, chromium, copper, nickel and zinc were present in higher levels than in two polluted Illinois rivers (Mathis and Cummings, 1973; Anderson and Brower, 1978). Zinc was also greater than the U.S. EPA (1976) guideline of 50 ppm for sediments. Cadmium and lead were generally within the upper range of those reported for uncontaminated waters in the fall and were low in the spring. Arsenic and copper were higher than values reported from the lower Green River (Southern Company Services, Inc., 1980). Mercury, while similar to values in the Green River, was substantially lower than from sediments in the Ohio River just downstream of Cincinatti (U.S. Army Corps of Engineers, 1978). Of the metals discussed above, cadmium and mercury most frequently exceed the standard or criteria in the water column.

In the creek sediments, several of the metals, including cadmuim, mercury, magnesium, nickel and zinc were less concentrated than in river sediments. These elements were not generally lower in the water column of the creeks as compared to the river. In fact, those elements that were elevated in the creek waters, aluminum and manganese, did not show this same tendency in the sediments.

Table 10.12 Sediment quality, Ohio River, Bull Creek, Town Creek, 1980.[a]

	Ohio River Station 2		Ohio River Station 3		Bull Creek		Town Creek	
Parameter	Spring[b]	Fall[c]	Spring	Fall	Spring	Fall	Spring	Fall
Aluminum	13,550	24,400.0	8,390	33,900.0	7,880	19,500.0	5,240	20,600.0
Arsenic	1.25	5.9	2.01	6.6	2.41	11.3	8.43	5.6
Boron	0.77	<0.27	<0.20	24.50	<0.21	9.12	<0.11	8.52
Barium	11.00	1,283.0	6.03	1,054.0	4.05	468.0	8.55	887.0
Beryllium	0.86	4.64	0.64	5.55	0.42	1.98	0.52	3.36
Bismuth	<0.30	<0.25	<0.50	<0.25	<0.50	<0.30	0.24	0.54
Bromine	784	3.64	438	19.20	327	7.44	289	65.18
Cadmium	0.17	0.59	0.27	1.64	0.09	0.70	0.07	0.67
Cobalt	16.20	19.2	18.02	35.8	15.80	20.3	14.82	27.5
Total Chromium	30	7.87	33	18.0	23	18.2	21	8.41
Copper	5.90	26.46	22.50	59.95	2.80	12.1	3.70	15.06
Iron	24,000	31,800	32,200	35,160	30,700	23,739	35,700	25,600
Gallium	<0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.2	<0.3
Germanium	<0.6	<0.2	<0.3	<0.3	<0.3	<0.2	<0.2	<0.2
Mercury	0.022	0.044	0.040	0.141	0.012	<0.0007	0.009	0.028
Lanthanum	12.40	11.21	9.60	8.32	8.70	6.80	6.80	7.40
Magnesium	3,260	6,400.0	4,870	4,810.0	1,400	1,450.0	1,310	1,650.0
Manganese	779	1,240.0	108	1,410.0	724	1,450.0	2,070	1,200.0
Molybdenum	0.093	<0.10	0.057	0.2	0.053	<0.10	0.073	<0.10
Nickel	60	23.29	69	56.40	14	25.8	28	21.8
Lead	0.33	16.3	0.38	30.5	0.23	8.08	0.20	13.7
Rubidium	<0.7	<0.4	<0.5	<0.4	<0.5	<0.4	<0.2	<0.4
Antimony	<1.9	4.23	<0.8	19.90	<0.8	2.31	<0.5	2.04
Selenium	<0.085	<0.29	<0.045	<0.55	<0.045	<0.14	<0.043	<0.13
Tin	9.35	40.8	9.79	65.1	3.85	50.0	1.47	46.1
Strontium	121	110.0	102	86.0	61	59.4	52	52.0
Titanium	15.14	583.0	4.91	900.0	2.89	339.0	0.46	560.0
Uranium	<5.0	<2.8	<2.9	<0.9	<2.9	<3.2	<1.7	<1.4
Vanadium	9.2	32.5	14	62.8	25.1	42.7	19	49.1
Tungsten	<0.9	<0.8	<0.7	<0.7	<0.7	<0.9	<0.4	<0.8
Zinc	162	95.6	269	290.0	44	50.2	43.50	64.7
Zirconium	<2.2	<1.9	<1.8	<1.4	<1.8	<2.6	<0.9	<1.8
Silver	0.47	<0.21	0.19	0.47	0.19	<0.067	0.13	<0.13
Phenols (1)	<10.0	<8.0	<10.0	<8.0	<10.0	<8.0	<10.0	<8.0
Aliphatic Hydrocarbons	4,400	4,200.0	1,400	1,900.0	3,700	3,800.0	6,200	2,600.0
Arylamines	42	12.0	16	22.0	12	46.0	37	28.0
Mono & Polycyclic Hydrocarbons (2)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.03	<0.02	<0.04
Sulfur Compounds Thiophenes and Mercaptans (3)	<26	<20.0	<21	<20.0	<25	<22.0	<28	<29.0
Chlororganics (4)	16.93	2.64	4.18	3.08	7.75	8.32	31.09	4.18
Chloramines	<7.26	<1.90	<4.29	<1.70	4.80	6.20	<2.84	<1.80
Dry Weight	77.47%	59.47%	64.14%	28.28%	67.43%	56.05%	71.11%	74.34%

[a]Results in mg/kg dry weight.

[b]May 15-18, 1980.

[c]October 8-9, 1980.

Table 10.13. 1980 Upper Gage Readings from Cannelton Lock & Dam. Zero Elevation is 374.0 MSL.[a]

DAY	JAN	FEB	MAR	APR	MAY	JUN
1	9.1	9.3	9.2	9.0	9.0	9.3
2	9.2	9.2	9.0	9.3	9.0	9.2
3	9.1	9.0	9.4	9.3	9.0	9.2
4	9.3	9.3	9.3	8.9	9.5	8.9
5	9.1	9.4	9.2	8.9	9.6	9.1
6	9.1	9.0	9.0	8.9	9.2	9.0
7	9.0	9.2	9.0	8.9	9.4	9.2
8	8.9	9.5	9.0	8.9	9.2	9.5
9	9.2	9.4	9.0	9.0	9.3	9.4
10	9.1	9.5	9.1	9.0	9.5	9.0
11	9.2	9.1	9.0	8.8	9.7	9.0
12	8.9	9.2	8.9	9.0	9.7	9.0
13	9.1	9.5	9.0	9.0	9.5	9.1
14	9.2	9.5	9.0	9.0	9.4	9.1
15	9.1	9.0	9.1	9.4	8.8	9.2
16	9.0	9.8	9.0	9.4	9.2	9.3
17	9.1	9.8	9.3	9.1	9.4	9.2
18	9.0	9.4	9.1	9.4	9.3	9.0
19	9.0	9.8	8.9	9.7	9.4	9.3
20	9.1	9.3	8.9	9.2	9.1	9.3
21	9.1	9.4	9.0	9.0	9.0	9.3
22	9.1	9.3	8.8	9.0	9.0	9.2
23	9.4	9.4	10.2	9.0	9.0	9.4
24	9.0	9.2	11.2	9.1	9.1	9.5
25	9.0	9.2	11.8	9.0	9.3	9.7
26	9.5	9.2	12.2	9.4	9.4	9.7
27	9.8	9.4	11.6	9.4	9.2	9.3
28	9.1	9.2	9.9	9.4	9.0	9.1
29	9.1	9.1	9.1	9.2	9.4	9.2
30	9.2	-	8.9	9.1	9.2	9.2
31	9.2	-	9.1	-	9.4	-

Table 10.13. Continued

DAY	JULY	AUG	SEPT	OCT	NOV	DEC
1	9.3	9.9	9.2	9.5	10.2	9.2
2	9.5	9.9	9.0	9.3	10.2	9.1
3	9.3	9.9	9.0	9.3	10.2	9.2
4	9.3	10.0	9.1	9.6	9.3	9.1
5	9.3	10.0	9.2	9.8	9.3	9.1
6	9.3	10.0	9.3	10.0	9.2	9.2
7	9.0	9.8	9.5	10.1	9.3	9.5
8	9.2	10.0	9.2	10.2	9.3	9.4
9	9.4	9.9	9.0	10.8	9.1	9.1
10	9.1	10.1	9.3	10.5	9.1	9.5
11	8.9	9.9	9.2	10.1	9.4	9.3
12	9.5	9.1	9.2	9.7	9.3	9.2
13	9.4	8.9	9.7	9.7	9.3	9.2
14	9.3	9.0	9.5	9.5	9.5	9.3
15	9.0	9.0	9.4	9.6	9.2	9.2
16	9.1	9.1	9.2	9.9	9.3	9.1
17	9.2	9.0	9.2	10.0	9.4	9.1
18	9.2	9.1	9.3	11.0	9.1	9.2
19	9.1	9.2	9.2	9.3	9.3	9.3
20	9.2	8.9	9.0	9.4	9.4	9.2
21	9.0	9.0	9.4	9.4	9.1	9.4
22	9.1	9.0	9.2	9.6	9.1	9.3
23	9.2	9.4	9.2	9.4	9.4	9.0
24	9.0	8.9	9.5	9.6	9.4	9.0
25	9.3	9.2	9.3	10.2	9.2	9.4
26	9.1	9.2	9.7	10.4	9.1	9.5
27	9.2	9.1	9.5	10.4	9.0	9.5
28	9.1	9.2	9.5	10.5	9.0	9.2
29	9.1	9.1	9.5	10.5	9.0	9.1
30	10.0	9.0	9.5	10.4	9.2	9.3
31	9.8	9.1	--	10.2	9.2	9.5

[a] Source U. S. Army Corps of Engineers, Louisville District (1981).

As might be expected, concentrations of metals in the sediments were greater than those in the water and fish. This tendency of increased metal levels from water to fish tissue to sediments has been reported by several others (Mathis and Cummings, 1973; Enk and Mathis, 1975).

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Ground Water

11.0 GROUND WATER

11.1 INTRODUCTION

The proposed plant site and waste disposal areas in Breckinridge County, Kentucky were evaluated with respect to ground water utilizing available sources. Particular attention was given to the physical aquifer characteristics and existing chemical conditions in the plant area and the occurrence of bedrock ground water in the waste disposal areas. In the following section ground water conditions will be discussed for both regional and site specific conditions: methodology, samplings methods, locations and rationale, and water quality.

11.2 BACKGROUND AND OBJECTIVES

Subsurface investigations at the site were performed in 1974 and 1975 in which some preliminary ground water investigations were done. This early work was primarily for foundation design and for development of a ground water supply. Water level data for four observation wells were obtained as well as water quality data from existing domestic wells. Most of the sampled wells are no longer operational. Further foundation and ground water investigations were conducted in 1980 and early 1981. Field reconnaissance and ground water sampling was performed in 1980-81; additionally, eight observation wells were installed at the plant site and three in the southern waste disposal area.

The objectives of this study were to delineate the existing ground water characteristics of the region and site vicinity utilizing existing site specific information, literature and field investigations. Particular attention was given to delineating bedrock flow and alluvial aquifer characteristics.

11.3 METHODOLOGY AND SOURCES

Ground water data was obtained during a geotechnical investigation from installed observation wells in the plant and waste areas. Identification of surface expression of ground water was obtained during field reconnaissance by Dames & Moore personnel. Water levels are from observation wells utilizing the wetted tape method. This is the most accurate method when done carefully. River elevations were supplied by the Corp of Engineers and Cannelton Lock and Dam. Water quality was analyzed by Howard Laboratories in Dayton, Ohio. Sampling was performed by Dame's and Moore personnel at selected wells and springs. References utilized in this section are noted in 11.8.

11.4 SAMPLING LOCATION, FREQUENCY AND RATIONALE

Water quality sampling locations are shown on Figure 11.1. Sampling was conducted seasonally to reflect temporal variations in ground water quality. The domestic wells utilized were selected on their proximity to the site. During the early phases of this investigation there were no wells installed at the site proper. Springs were sampled to determine background water quality in the bedrock aquifers. Ground water in the bedrock generally occurs as flowing water in solutional cavities and along bedding planes of which spring and seeps are surface expressions. The springs utilized were selected on proximity to the site and their different geologic origin.

11-5

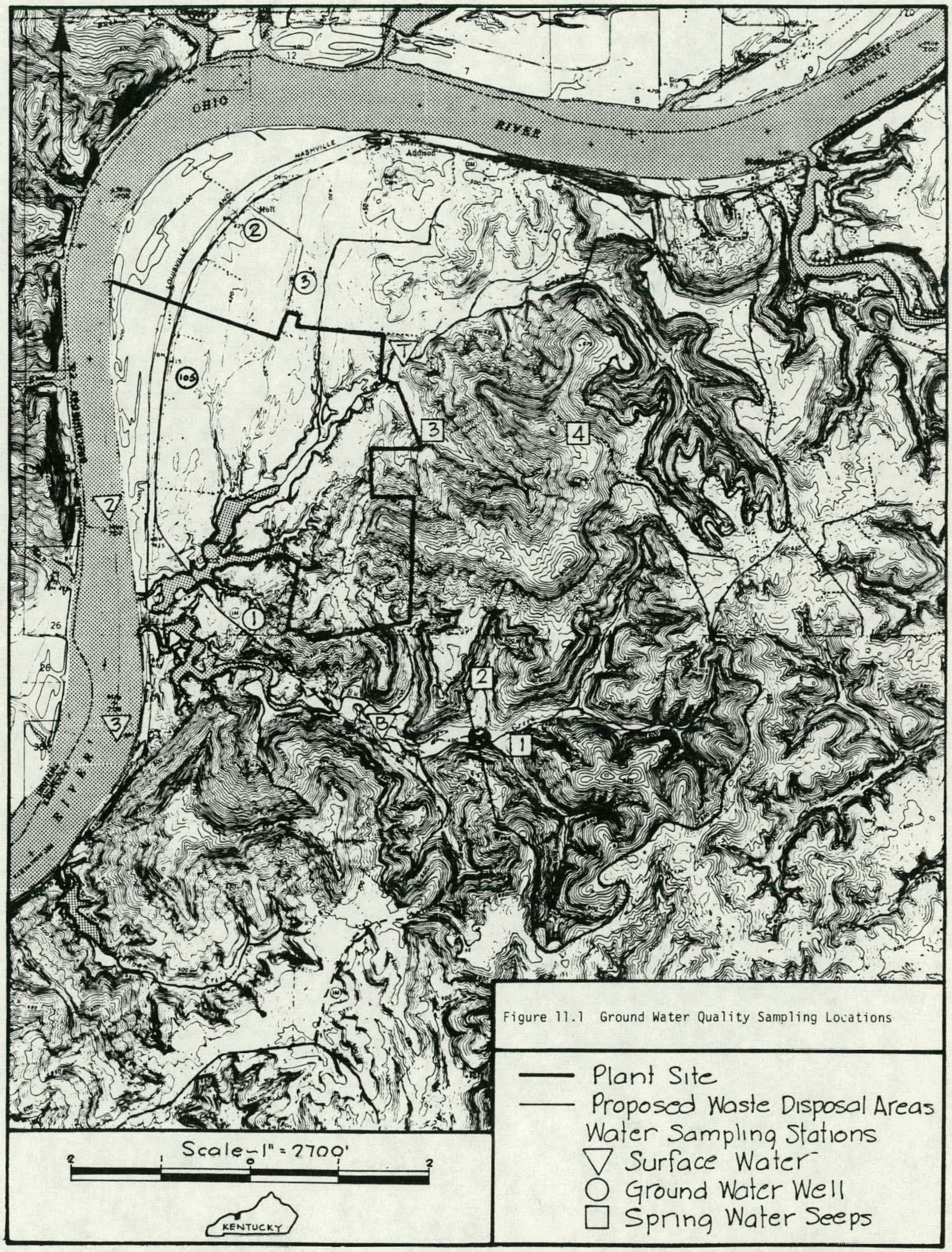


Figure 11.1 Ground Water Quality Sampling Locations

11.5 QUALITY ASSURANCE

The quality control (QC) process within the Lexington (LX) office is intended to promote a check and review system of the procedures, and resultant measurements, used and determined by our staff to carry out their assigned work. It is primarily applicable to the technical quality of work being performed in the field, laboratory and office.

The LX QC plan is administered by Project Management (PM) who direct respective Principal Investigators (PI). The PM is advised by the Principal-In-Charge (PIC)/Managing Principal-In-Charge (MPIC). This administrative set-up results in the enhancement of the uniformity, continuity and integrity of the technical quality of all LX QC projects.

In conjunction with QC management procedure above, the LX office uses a sign-off procedure which is completed at regular intervals during the course of our projects. The sign-off procedure may be initiated by principle personnel assigned to the project and from which designated work has originated. Upon completion of each task, project personnel must sign-off their work and submit it to the next highest professional level for review. The completed work is reviewed, possibly several times, and approved by the respective PM, PIC or specified technical reviewer for overall technical content and quality. This procedure also assures overall project quality on a relatively long term basis. In the event that additional questions arise during the eventual completion of a project the originator of work may be easily identified, then consulted, through our sign-off policy.

In general, the methods, procedures and guidelines for field sampling, laboratory analysis of samples, and for data analysis is adopted from standard references supplied by the U.S. Environmental Protection Agency, the U.S. Geological Survey, American Public Health Association, American Water Works Association and the Water Pollution Control Federation. There are also special references which may be used for highly specialized cases, or situations when state-of-the-art expertise is required.

Before field sampling is initiated the principal (PIC, PM, PI) personnel assigned to the project attend a project meeting in which the important objectives and goals pertaining to the technical make-up is discussed. Potential technical problems are discussed, and (final) plans for completing the field sampling activities are transmitted to the PI.

Sample collecting activities in the field are quality controlled from the initial set-up of the project to its completion. Preparation for field sampling activities is done by compiling a field equipment check list for that equipment necessary to complete all specified work tasks according to predetermined methods and procedures. The equipment list serves as a check by which qualified field personnel may inventory, and see that all equipment is calibrated and standardized, if necessary, and in good working order.

Records of maintenance, calibration and standardization are kept on file for all special mechanical and electrical devices.

During sample collecting, field logs are maintained to document daily progress. Records of all sampling parameters, client, location, data, time, collector(s) name, sampler type, preservative and volume, and other observations is made. Every reasonable attempt is made to assure that the field collections are of high quality, and will produce reliable data.

Specific QC practices are carried out by the PI, and are reviewed by the PM, when the field memo for the respective project is completed. This review process is a check on difficulties which occurred in the field and what, if any, methods or procedures were aborted/modified. All alterations, if any, are recorded and placed in the respective job files.

11.6 REGIONAL AQUIFERS

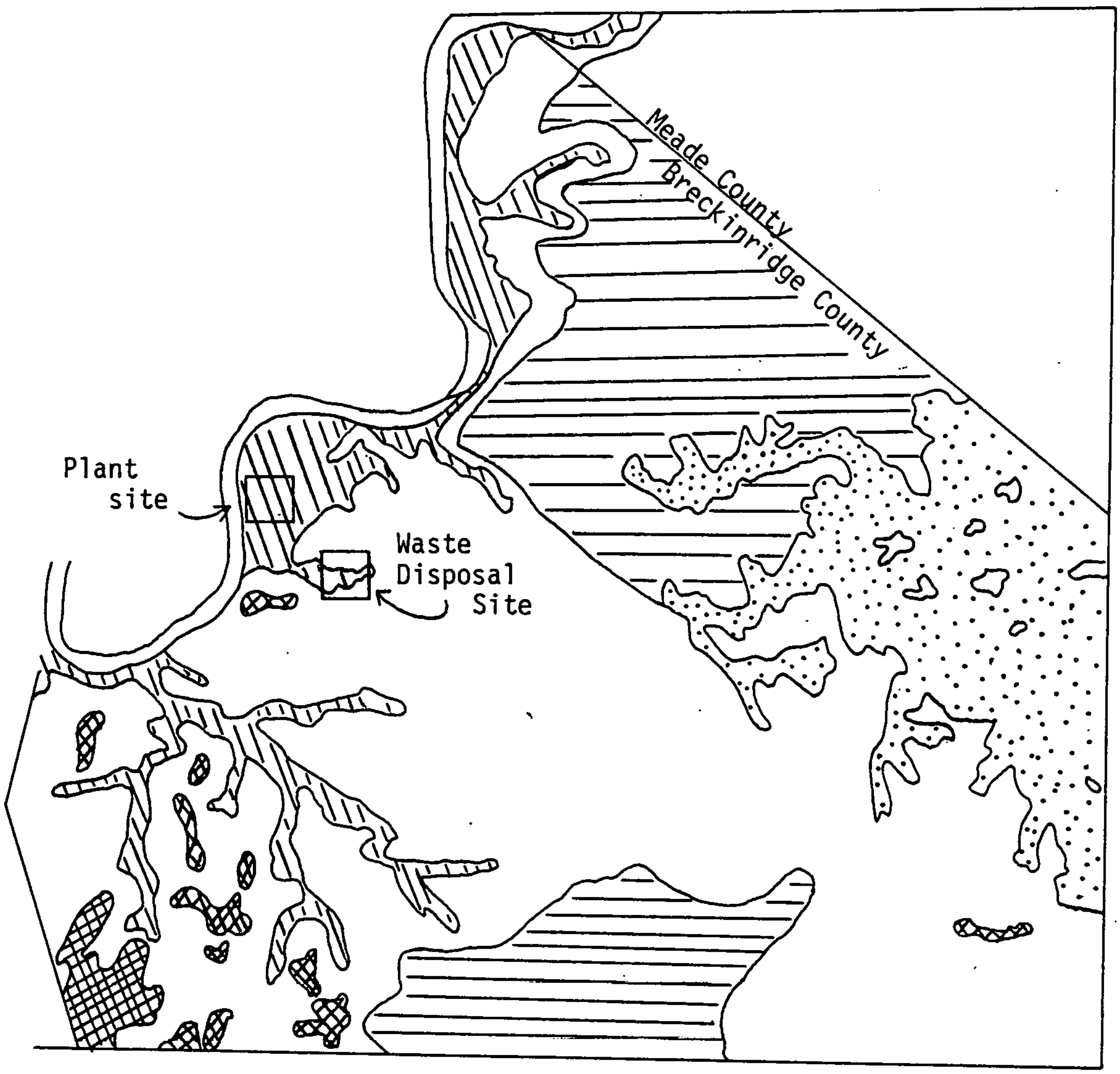
Water is available from three interconnected and interrelated parts of the hydrological system in Breckinridge County. Water is found on the surface, in the Mississippian bedrock and in the alluvial deposits along the Ohio River and its tributaries (Figures 11.2 and 11.3).

11.6.1 Alluvial Aquifers

The Ohio River alluvial plain is one of the major groundwater aquifers in the central United States. It has been estimated that the alluvium stores over four trillion liters (one trillion gallons) of water over the length of the aquifer (E.H. Walker, 1957). The aquifer is situated in the broad, u-shaped trough of the Ohio River. This trough is partly filled with clay, silt, sand, gravel and some boulders in the deeper portions. The alluvial plain is relatively flat with a gentle slope to the river.

The aquifer sediments are composed of glacial outwash deposits overlain by recent alluvium. The coarse fining upward fill material was deposited during the retreat of glacial activity in the Ohio River drainage area. Relatively thin finer grained recent alluvial deposits overly the glacial outwash. The aerial extent and thickness of the aquifer varies due to erosion of the glacial material, variation with distance from the valley walls, and inclusion of impermeable units from tributary streams. Generally the maximum thickness of the saturated zone increases downstream and across the valley toward the river.

Wells completed within the alluvial aquifer yield large quantities of water suitable for public water supply systems with as much as 5000 gpm to



Water in Recent and Pleistocene Alluvium
(Drilled wells in Alluvium may yield several hundred gallons a minute.

Water in Pennsylvanian Rocks.

Water in Mississippian Rocks of Meramec Age.
(Most wells inadequate for domestic use)

Water in Mississippian Rocks of Chester Age
(Wells yield enough for domestic purposes (>500 gpd) at depths in excess of 150 feet.

Water in Mississippian Rocks of Meramec Age.
(Most wells yield more than 500 gallons per day)

Figure 11.2 Availability of Groundwater

SOURCE: Brown & Lambert, 1963

SYSTEM	SERIES	FORMATION OR GROUP	THICKNESS (IN FEET)	SECTION	WATER-BEARING CHARACTER
QUATERNARY	Recent and Pleistocene	Alluvium	0-120		Yields several hundred gallons per minute to drilled wells in alluvium in the Ohio River valley. Yields as much as 5,000 gpm (gallons per minute) to compound horizontal wells. Nearly all wells furnish more than 500 gpd (gallons per day), enough water for a domestic supply with a power pump. Alluvium in stream valleys tributary to the Ohio River is fine grained and thin; most wells do not furnish enough for a bailer or bucket (less than 100 gpd).
PENNSYLVANIAN		Caseyville sandstone	0-100		Yields enough water for a domestic supply with a power pump (more than 500 gpd) to wells in lowland areas bordering streams. Wells in upland generally are inadequate (yields less than 100 gpd).
	Chester	Leitchfield / Buffalo Wallow	0-125		Yield little or no water to wells.
	Chester	Tar Springs sandstone			Sandstone formations yield enough water for a domestic supply with bailer or bucket (more than 100 gpd) in lowland areas bordering streams and in broad upland areas where there is a substantial saturated thickness in perched water bodies. Deep wells that tap the sandstone formations near perennial stream level furnish enough for a domestic supply with a power pump (more than 500 gpd). Close to outcrop areas, particularly near major escarpments, yields from perched water bodies generally are low and not dependable. Minor spring horizons occur near the base of most of the sandstones on discontinuous layers of shale. The most prominent springs are those which discharge from the base of the Big Clifty sandstone. These are the "dripping springs" of the Dripping Springs escarpment. Many of these springs go dry during the late fall and summer, and very few are adequate for a domestic supply with a power pump.
	Chester	Glen Dean limestone	50-70		
	Chester	Hardinsburg sandstone	30		Limestone formations yield small to adequate supplies from solution openings. In lowland areas bordering streams some wells furnish enough for a domestic supply with a power pump (more than 500 gpd). Most in upland areas are inadequate for a domestic supply with a bailer or bucket (less than 100 gpd). Deep wells that encounter solution openings in limestone may produce more than 5 gpm, but most deep wells are inadequate for a domestic supply with bailer or bucket (less than 100 gpd). Where karst is formed on the Paoli limestone, some wells yield more than 5 gpm from solution openings in the Paoli and the underlying Ste. Genevieve limestone. Close to outcrop areas, particularly near major escarpments, yields from perched water bodies generally are inadequate during dry periods. Springs occur at the base of many of the limestones where they crop out on escarpments and hillsides. Adjacent to large upland areas, flows are as much as 1,000 gpm and low flows are more than 5 gpm from some springs.
	Chester	Haney limestone[2]	35		
	Chester	Big Clifty sandstone[2]	75		
	Chester	Beech Creek ls.[2]	10		

Figure 11.3 Columnar section at site

SOURCE: Brown and Lambert, 1963

compound horizontal wells. Such large quantities are replenished by induced infiltration from the river.

Medium values for hydraulic conductivity and transmissibilities for the Ohio River alluvial aquifer are 18.8 meters/day (460 gpd per square foot) and 648 cubic meters/day (52,150 gpd per foot) (Gallagher and Price, 1966).

Alluvium in the tributaries are generally thin, fine grained and yield small quantities of water.

11.6.2 Bedrock Aquifers

Perched water tables are common in the Mississippian Chester Age formations which consist of alternating layers of sandstone, limestone and shale. Perched water is commonly found in sandstones underlain by shale or in limestones that contain discontinuous shale lens. Water is also available in water-filled cavities between two lithologic units as sheet water (Brown and Lambert, 1963).

Solutional openings in some lower Chester limestones are well formed with flows of as much as 6.3×10^{-3} cubic meters/sec (100 gpm). Generally, drilled wells are adequate for domestic supplies when installed in a saturated sandstone formation. Wells in limestones are less dependable and yields will vary with the number and quality of solutional cavities penetrated.

11.6.3 Recharge and Discharge

Recharge to the alluvial aquifers is derived from three sources: water entering the aquifer during floods, seepage from bedrock and precipiitation. Recharge to the aquifer is greatest in the winter and early spring when precipitation infiltration is usually greatest and stream flows are high. During floods low lands are indunated and if a direct contact with the aquifer is available recharge is rapid. More commonly an overlying impermeable unit is present resulting in very slow recharge rates. Primary recharge to the alluvial aquifers is accomplished through inflow from the bedrock along the valley walls and precipitation infiltration.

Groundwater usually seeps into the river and helps maintain river flow. During floods this situation is reversed and recharge to the aquifer is localized near the river.

Recharge from precipitation to the alluvial aquifer in Louisville, Kentucky is estimated at 1136 cubic meters/day to 1893 cubic meters/day (0.3 to 0.5 million gallons per day) and recharge from bedrock inflow at 757 cubic meters/day (0.2 million gallons a day) (Whitesides and Ryder, 1969).

Recharge to bedrock aquifers is accomplished through infiltration of rainfall through the soil, by flow from streams or other surface flow and by flow of surface water through sinkholes and jointing.

11.6.4 Water Quality

Chemical and physical quality of the water in the alluvial aquifer varies over the length of the Ohio River and is related to depth, composition of the alluvium and type of rock and quality of water entering the aquifer from the bedrock. Water in the allivial aquifer in Breckinridge County is a predominantly calcium-magnesium, bicarbonate type with some sulfate and chloride (Gallagher, 1963). The fresh-saline interface is at

61 meters (200 feet) mean sea level below the aquifer along the Ohio River (Hopkins, 1966). Groundwater quality in the Mississippian rocks is determined by the geologic source and length of time water has been in contact with the rocks. The water is generally a calcium bicarbonate type.

11.6.5 Water Uses

Ground water use in Breckinridge County is primarily used for principal and small domestic supplies. Cloverport is the chief user of ground water from the alluvial aquifer (Mull, Cushman and Lambert, 1971), withdrawing 4900 cubic meters a day (1.3 million gallons a day) from three horizontal wells. Domestic wells within the site vicinity are shown in Figure 11.4. These wells are installed in the alluvial aquifer.

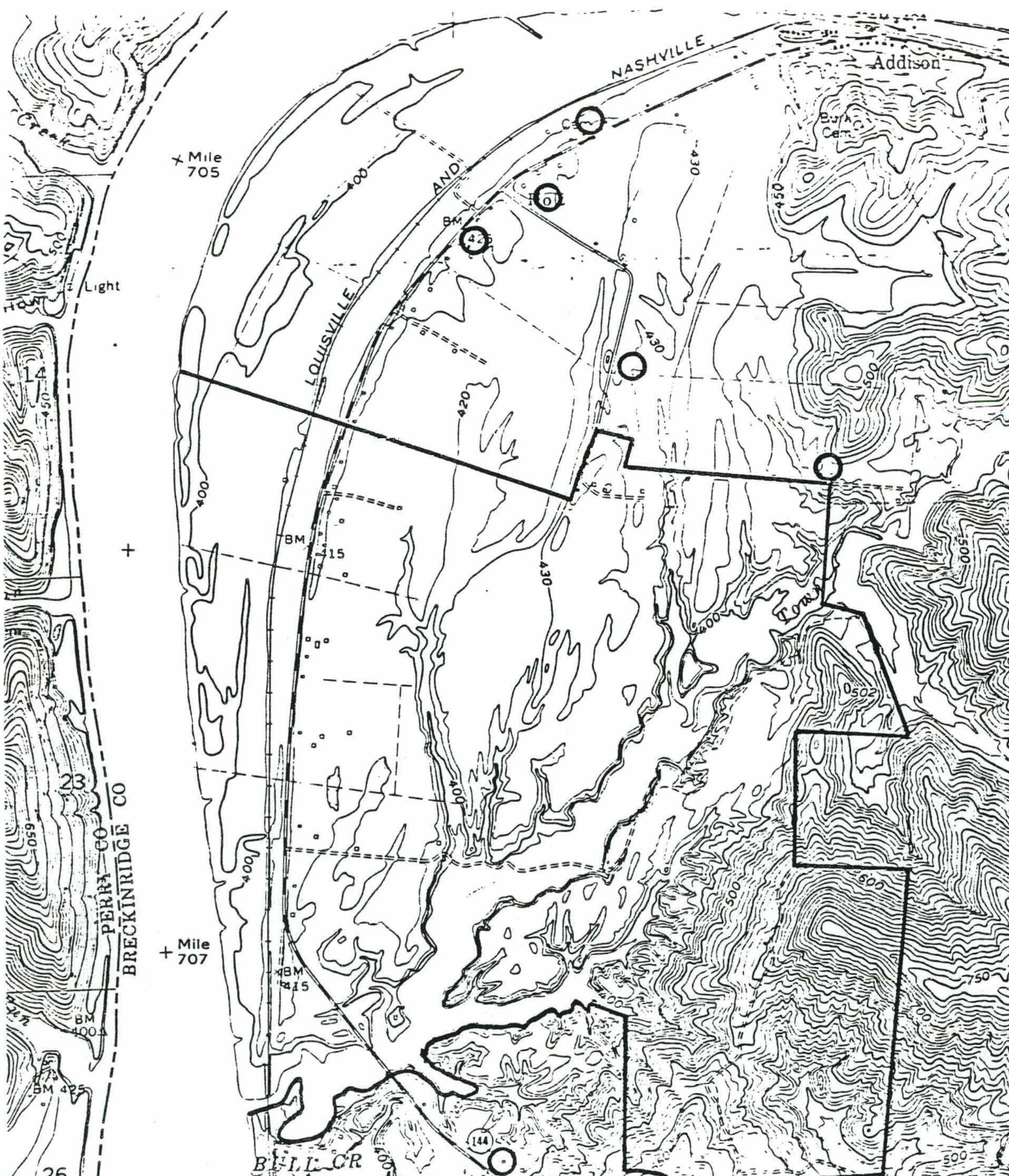


Figure 11.4. Domestic wells at the plant site
1 inch = 2000 feet

11.7 SITE CONDITIONS

11.7.1 Alluvial Aquifers

The alluvium beneath the plant portion of the facility consists of a clayey to sandy silt layer underlain by the alluvial aquifer. The thickness of the surficial clay layer ranges from 4.3 to 7.6 meters (14 to 25 feet) across the site (Figure 11.5) and acts to confine the aquifer near the river. The alluvial aquifer consists of a fine to coarse sand with some gravel grading to gravel at the base. The thickness of the aquifer averages above 33.5 meters (110 feet) tapering to 16.8 meters (55 feet) under the river and, reaches a maximum in excess of 46 meters (150 feet) in the ancestoral Ohio River channel underlying the site.

Ground water elevations obtained in February, 1981 show a relatively flat, gently sloping gradient toward the river. Preliminary data from water elevations indicate an influence on the southern edge of the site from the Town Creek backwater. Ground water elevations range from 385.4 feet at the eastern edge of the site to an Ohio River elevation of 383.4 feet indicating a hydraulic gradient of 3.3×10^{-4} (1.8 ft/ mile). Ground water elevations for February and March, 1981, are shown on Table 11.1. Locations of observation wells at the site are shown in Figure 11.6.

Hydraulic conductivity values for the alluvial aquifer were obtained utilizing the Hazen formula from geotechnical data (Dames & Moore, 1976), and in situ values obtained from falling head permeability tests. These values, 4×10^{-2} cm/sec and 2×10^{-4} cm/sec, respectively, are compared with other values for the alluvial aquifer in Table 11.2. The value from the Hazen equation will be used in this report to represent site specific hydraulic conductivities. Those values from in situ permeability

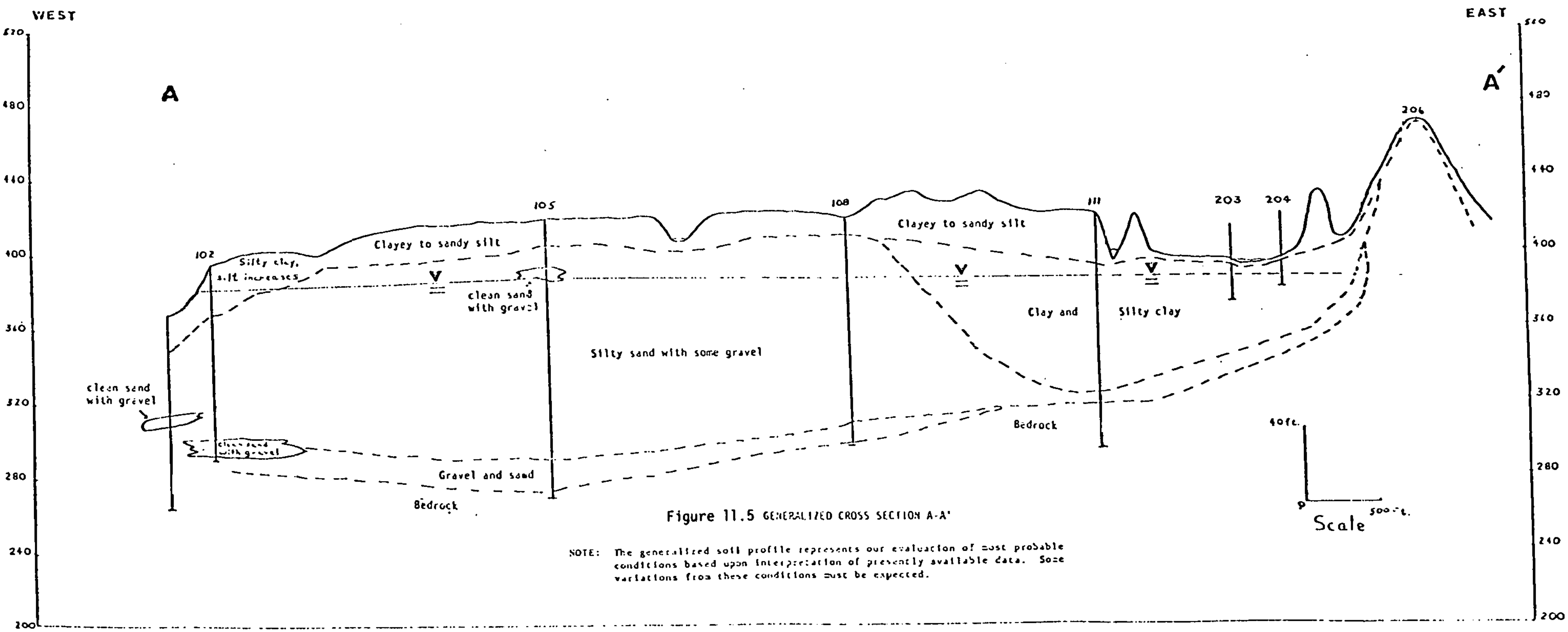


Figure 11.5 GENERALIZED CROSS SECTION A-A'

NOTE: The generalized soil profile represents our evaluation of most probable conditions based upon interpretation of presently available data. Some variations from these conditions must be expected.

Table 11.1 Water Levels

Observation Well	Surface Elevation	Groundwater Elevation March, 11	Groundwater Elevation February, 26
104	421.5	384.9	384.4
105	421.3	385.2	384.7
106	414.5	384.8	384.8
107	417.1	385.1	384.7
108	418.0	385.2	384.8
109	423.7	383.5	383.2
110	426.8	398.4	398.5
111	419.5	385.4	385.2
301	405.6	402.2	401.8
302	417.5	414.0	413.6
303	398.0	397.2	396.7
Ohio River elevation:		383.4	383.9

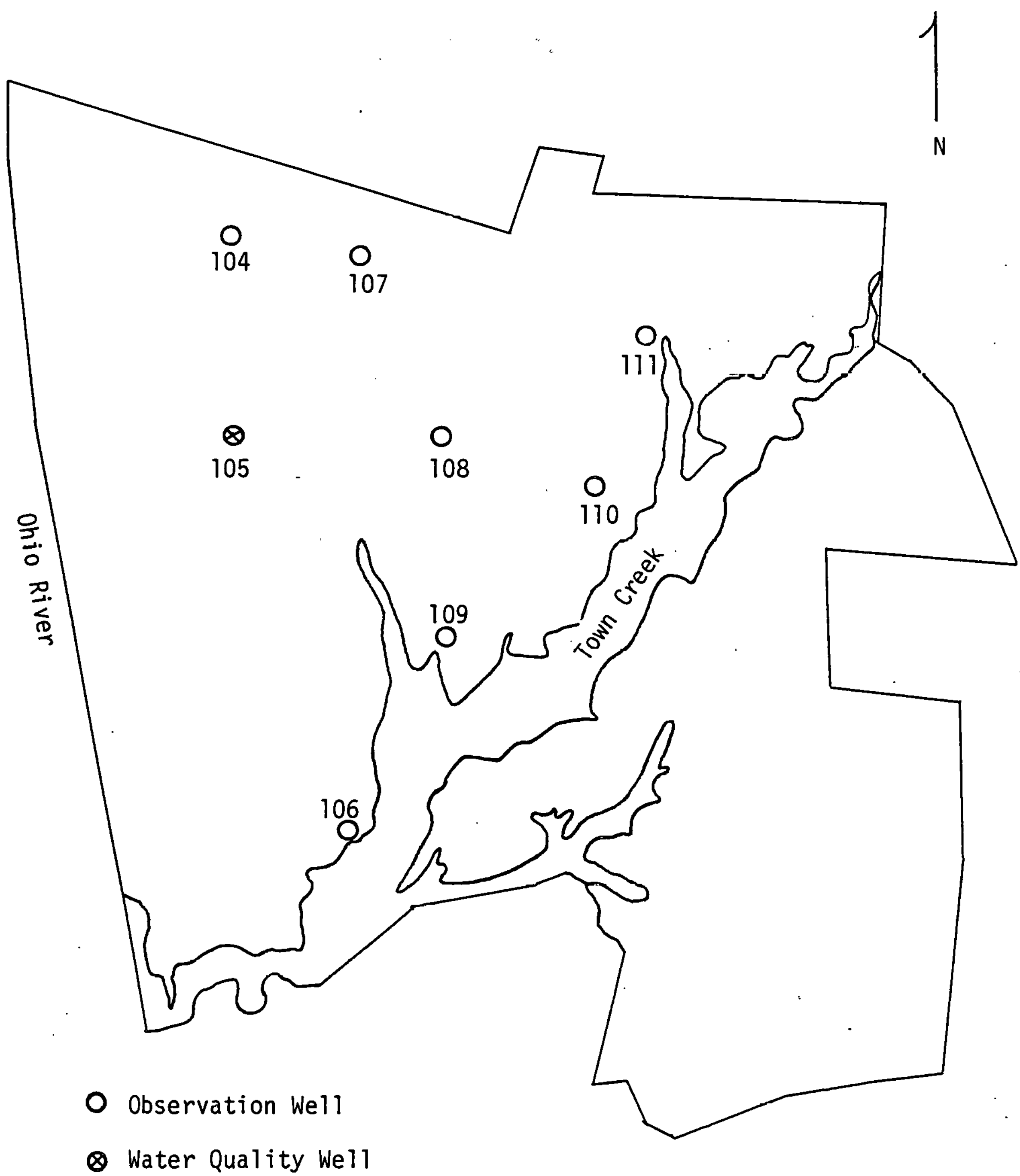


Figure 11.6 Observation Well Locations (Plant Site)

Table 11.2

Hydraulic Conductivity

Reference	Value
Ohio River[1]	0.02 cm/sec
Hawesville[2]	0.07 cm/sec
Hazen equation (Ashland site)	0.04 cm/sec
In situ permeability tests	2×10^{-4} cm/sec

(1) Median value for Ohio River Alluvial Aquifer (Gallagher and Price, 1966)

(2) (Grubbs, 1975)

tests reflect localized conditions existing within the 1.5 meter (5 foot) screen length whereas the values of grain size incorporated into the Hazen equation are more representative of the soils within the site. Additionally, a value of 0.04 cm/sec is in closer agreement with hydraulic conductivities obtained in aquifer pump tests near Hawesville, Kentucky.

Utilizing a hydraulic conductivity value of 0.04 cm/sec (Hazen formula) and an average saturated thickness of the alluvial aquifer of 30.5 meters (100 feet) a transmissivity was calculated at approximately 1052 cubic meters per day (84,700 gallons per day per foot). This value is slightly greater than the median value of 648 cubic meters per day (52,150 gpd per foot) for the Ohio River aquifer.

A perched aquifer is located at the eastern edge of the plant above the thick lake deposit (see observation well 110). In situ permeability tests indicate a value of 1×10^{-3} cm/sec and a ground water elevation of 398 feet msl. Neither direction of flow nor areal extent of this perched zone is known at this time.

Recharge to the aquifer is primarily from the valley wall and precipitation. The Ohio River and Town Creek locally recharge the aquifer during flood conditions. Discharge is to the Ohio River and Town Creek.

The Bull Creek alluvium in the waste disposal area consists of interbedded clays and sands. The water table ranges from 414.0 to 397.2 (March 11, 1981) indicating a gradient of 6×10^{-3} (30 ft/mile). Locations of observation wells are shown on Figure 11.7 and water elevations on Table 11.1. Recharge to the Bull Creek aquifer is primarily from bedrock seepage.

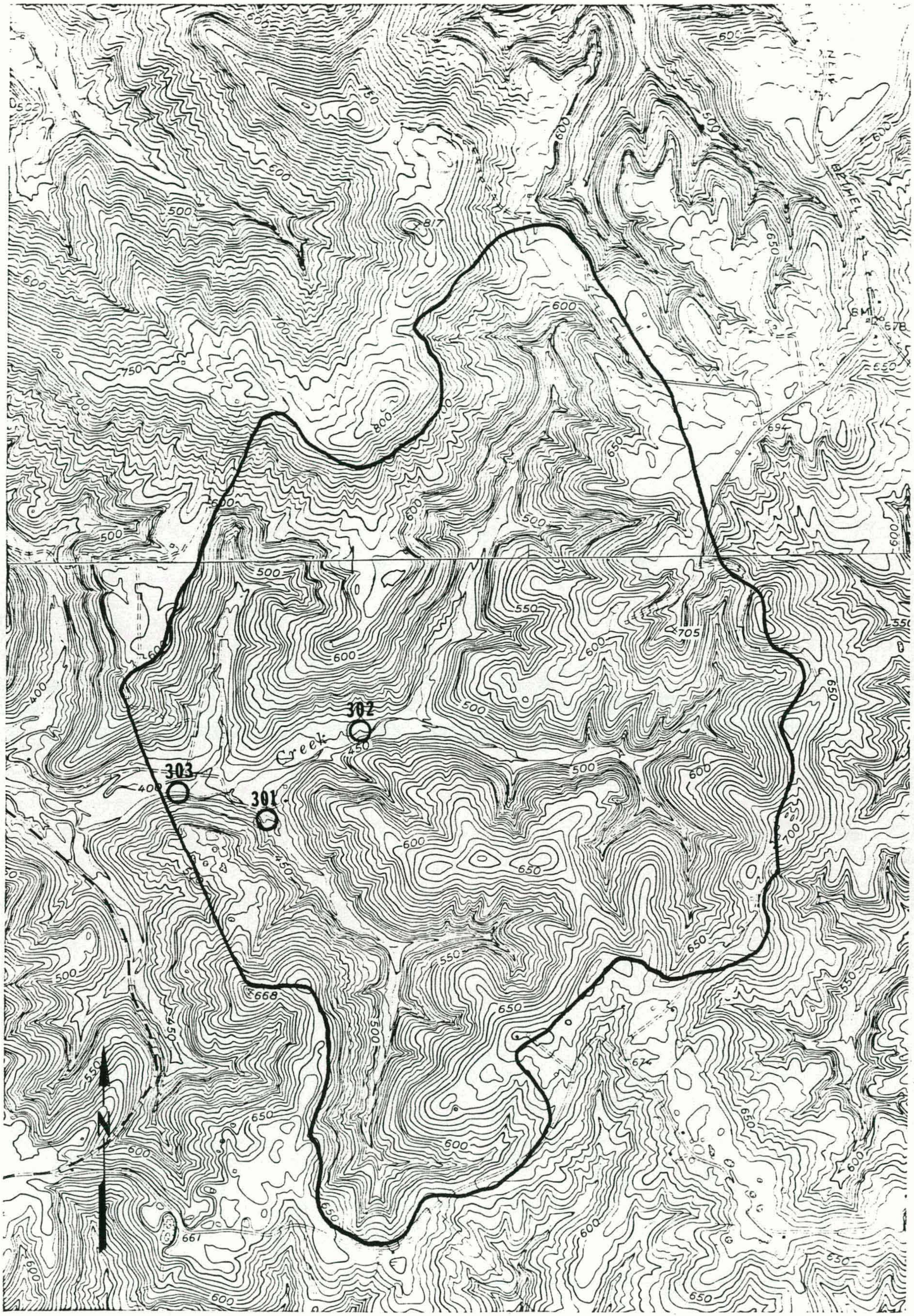


Figure 11.7 Observation wells in waste disposal area

11.7.2 Bedrock Aquifers

Numerous seeps and springs are located within the stratigraphic column at the site. These are commonly found at bedding planes and lithologic contacts. Generally the springs at higher elevations were dry during the summer months except those in the Big Clifty Sandstone, which are the most prominent in the Mississippian Chester series. Some springs show well developed solutional conduits with entrances of several feet. Locations of known springs in the site vicinity are shown on Figure 11.8. Boring 303 performed during the geotechnical investigation in the southern waste disposal area penetrated the Beechcreek Limestone which acts as an aquifer and is under artesian pressure.

11.7.3 Water Quality

Ground water quality data collected from wells and springs of the site area are presented in Tables 11.3 and 11.4.

Water from Well #1 differed in several respects from waters of domestic Wells #2 and #3. Odor, turbidity, color, total dissolved solids, notrogen compounds and several trace elements, including aluminun, barium, iron and manganese were higher than in the other two wells. Possible explanations are that: 1) the holding tank and well casing are worn; 2) the water of the alluvial aquifer differs from that of the alluvial aquifer of Wells #2 and #3; and 3) local surface conditions differ, causing surface recharge in the immediate area surrounding the well to degrade the water quality. Elevated levels of trace elements are probably due to explanations 1 and 2 above.

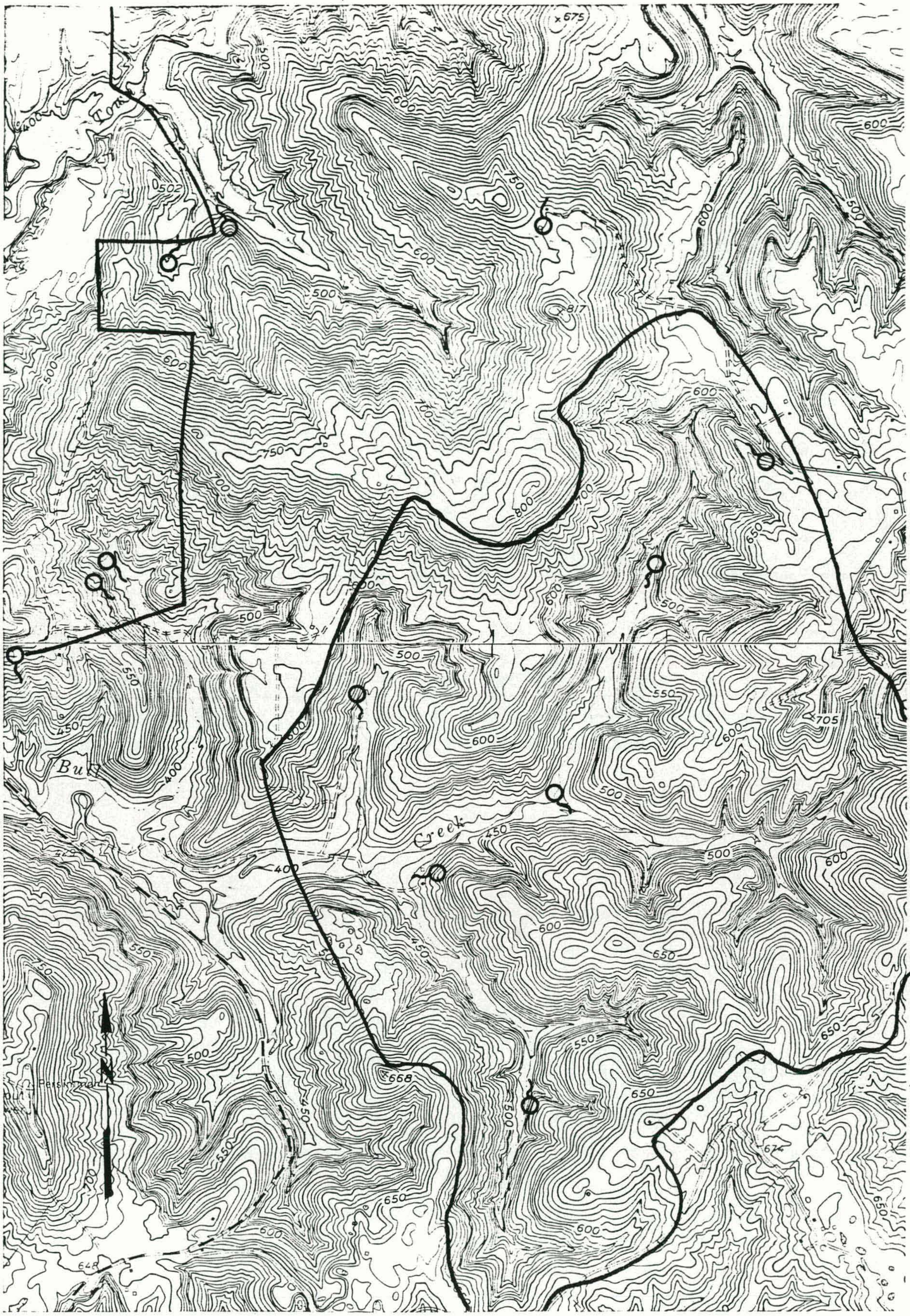


Figure 11.8 Located springs in vicinity

Table 11.3 Ground Water Quality of Wells of the Breck·nridge Site.[a]

Parameter	Well #3		Well #1			Well #2	Well #105	Well #303
Date	2-2-81	10-9-80	5-23-80	10-9-80	2-19-81	5-23-80	2-27-81	2-2-81
Total Coliform (per 100 ml)	<1	<2	<9	3	<1	10	<2	>16
Fecal Coliform (per 100 ml)	<1	<1	<2[c]	<1	<1	10[c]	<2[c]	<20[c]
pH (S.U.)	7.19	6.68	7.30	6.90	7.60	6.55	7.45	7.70
Density	1.00	1.052	0.993	1.084	0.99	0.994	0.99	1.00
Odor (TON)	1	1	4	8	4	1	32	1
Turbidity (NTU)	1.7[c]	0.8	32.0[c]	19.0[c]	24.0[c]	2.1[c]	190[c]	1,800.0[c]
Color (CU)	5	1	18[c]	2	10	0	40[c]	750[c]
Taste[b]								
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Suspended Solids	<1	<1	4	49	7	<1	376	7,500
Total Dissolved Solids	224	188	444	492	588	204	116	3,150
TOC	8	11	17	25	2	12	27	70
Ammonia as N	<0.02	0.11	2.55	3.14	2.[illegible]	0.46	0.82	3.90
Nitrate	2.36	2.32	0.35	<0.02	0.[illegible]	3.90	0.55	<0.02
Cyanide	<0.002	0.083	<0.002	0.105	<0.[illegible]2	<0.002	0.002	<0.002
Fluoride	0.98	0.182	0.005	0.923	<0.10	0.092	0.36	7.70
Sulfate	21.0	9.5	4.00	3.3	4.60	2.80	5	23.00
Ortho-Phosphate	<0.02	0.06	<0.010	0.22	0.24	<0.010	0.41	0.96
Chloride	5.0	13.0	9	13.0	10.0	2	2	748.0
Hardness as $CaCO_3$	173	184	221	207	271	175	69	211
Alkalinity	173	330	384	291	418	169	61	772
Total Nitrogen	0.06	0.59	3.15	4.80	2.14	2.10	18.90	12.60
Aluminum	<0.010	<0.001	<0.001	0.106	0.085	0.003	119.00	784.000
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025	0.0239	<0.0025	0.004	0.0410
Barium	0.020	0.085	0.127	0.277	0.299	0.001	1.09	1.370
Boron	<0.200	0.200	0.20	0.435	<0.200	0.36	<0.20	0.725
Beryllium	<0.004	<0.001	<0.001	<0.001	<0.004	<0.001	<0.004	<0.004
Bismuth	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bromine	<0.010	1.90	<0.01	0.28	<0.010	<0.01	0.036	2.400
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	0.140
Cobalt	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.005	0.617
Total Chromium	<0.001	<0.001	<0.001	<0.001	<0.010	<0.001	0.615	1.160

Table 11.3 Continued.

Parameter	Well #3		Well #1			Well #2	Well #105	Well #303
Date	2-2-81	10-9-80	5-23-80	10-9-80	2-19-81	5-23-80	2-27-81	2-2-81
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Copper	0.007	0.011	<0.001	<0.001	0.033	0.020	1.442[c]	0.504[c]
Iron	0.097	0.196	3.254[c]	3.490[c]	3.320[c]	0.262	37.00	352.000
Germanium	<0.02	<0.010	<0.007	<0.010	<0.02	<0.007	<0.02	<0.02
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0008
Lanthanum	<0.006	<0.008	<0.005	<0.008	<0.012	<0.005	<0.006	<0.006
Magnesium	20.10	17.90	21	22.00	19.30	14	9.40	104.00
Manganese	0.004	0.005	0.057[c]	0.057[c]	0.114[c]	0.008	0.22[c]	5.590[c]
Molybdenum	<0.001	0.012	0.001	0.033	0.008	<0.001	0.014	0.004
Nickel	<0.001	0.032	<0.001	0.054	<0.001	0.020	0.470	0.570
Lead	<0.001	0.002	<0.001	0.002	0.037	<0.001	0.134	1.050
Rubidium	<0.010	<0.012	<0.020	<0.012	<0.010	<0.020	<0.010	<0.010
Antimony	<0.001	<0.001	<0.020	<0.001	<0.001	<0.020	<0.005	0.063
Selenium	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	0.003
Tin	0.048	0.068	<0.001	0.012	<0.050	<0.001	<0.25	0.379
Titanium	<0.030	<0.001	<0.001	<0.001	0.120	0.003	0.080	<0.030
Uranium	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01
Vanadium	<0.001	<0.001	<0.001	<0.001	0.040	<0.001	0.060	<0.001
Tungsten	<0.01	<0.020	<0.050	<0.020	<0.01	<0.050	<0.01	<0.01
Zinc	0.365	0.644	0.009	0.026	0.033	0.823	0.70	1.760
Zirconium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002
Thorium (pCi/L)	ND[d]	<5	<0.015	<5	ND	<0.015	<5	ND
Radium (pCi/L)	"	<15[c]	<0.005	<15[c]	"	<0.005	<15	"
Organics (ug/L)								
Phenols (1)	<2.0	<3.0	<2.0	<2.0	<3.0	<2.0	8	<3.0
Aliphatic Hydrocarbons	28.0	3,000.0	<1.0	22.0	3,000.0	<1.0	26,000	8,000.0
Arylamines	<0.1	<0.1	<1.0	<0.1	<0.1	<1.0	<0.1	<0.1
Mono & Polycyclic Hydrocarbons	<0.01	<0.01		<0.01	<1.80		<0.01	<0.01
Benzo (a) anthracene			<0.02			0.07		
Benzo (b) fluoranthene			<0.01			<0.01		
Benzo (c) pyrene			<0.02			<0.02		
Sulfur Compounds: (3)								
Thiophenes and mercaptans	<1.0	<3.0	<1.0	<1.0	<3.0	<1.0	13	<3.0
Chlororganics (4)	<0.006	<0.1	0.192	<0.006	<0.1	0.193	13	0.13
Chloramines	<100.0	<100.0	<100.0	<100.0	<100.0	100.0	<100.0	<100.0

[a] See Figure 11.1 for well locations.
[b] Not determined due to bacterial contamination.
[c] Exceeds USEPA Drinking Water Standard.
[d] Not detectable, slightly higher background radiation.

Table 11.4 Ground Water Quality of Springs of the Breckinridge Site.[a]

Parameter	Spring #1			Spring #2		Spring #3		Spring #4
Date	5-23-80	10-9-80	2-2-81	5-23-80	2-2-81	5-23-80	2-23-81	5-23-80
Total Coliform (per 100 ml)	190	320	77	800	520	3,400	140	100
Fecal Coliform (per 100 ml)	71[c]	2[c]	2[c]	160[c]	195[c]	1,200[c]	60[c]	3[c]
pH(S. U.)	6.65	6.51	7.35	6.90	7.72	6.55	7.12	6.40[c]
Density (g/cc)	0.994	0.996	1.00	0.992	1.00	0.992	1.00	0.992
Odor (TON)	1	2	1	1	1	2.5	1	1
Turbidity (NTU)	5.3[c]	29.0[c]	23.0[c]	7.2[c]	16.0[c]	9.5[c]	11.0[c]	1.8[c]
Color (CU)	2	3	15	20[c]	25[c]	20[c]	20[c]	1
Taste[b]								
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Total Suspended Solids	57	57	17	<1	3	5	9	<1
Total Dissolved Solids	296	300	208	260	208	348	264	448
TOC	22	11	6	14	7	15	7	16
Ammonia as N	0.66	0.23	0.04	0.35	0.03	0.49	<0.02	0.49
Nitrate	0.70	<0.02	0.51	0.30	0.20	0.70	1.66	7.80
Cyanide	<0.002	0.019	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Fluoride	1.410	0.340	0.13	0.097	0.10	1.100	<0.10	0.246
Sulfate	22.50	17.1	23.5	55.00	41.50	121.00	164.00	37.00
Ortho-Phosphate	<0.010	0.04	<0.02	<0.010	0.02	<0.010	<0.02	<0.010
Chloride	1	2.0	4.0	3	6.0	5	5.0	35
Hardness as $CaCO_3$	241	179	139	184	137	221	160	265
Alkalinity	248	221	144	156	103	134	79	237
Total Nitrogen	1.40	0.91	0.46	1.10	0.38	1.80	0.28	3.20
Aluminum	0.394	1.130	1.110	0.158	0.623	0.223	0.499	0.003
Arsenic	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025
Barium	<0.001	<0.005	0.017	0.002	0.023	0.001	0.022	<0.001
Boron	<0.20	<0.200	0.715	1.51	<0.200	<0.20	<0.200	<0.20
Beryllium	<0.001	<0.004	<0.001	<0.001	<0.004	<0.001	<0.004	<0.001
Bismuth	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Bromine	1.50	0.260	0.45	0.13	0.250	<0.01	0.150	1.75
Cadmium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001
Total Chromium	<0.001	0.007	0.002	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	0.001	<0.001	0.013	<0.001	0.001	<0.001	0.003	<0.001
Iron	0.362[c]	0.842[c]	1.630[c]	0.208	0.551[c]	0.285	0.235	0.007
Germanium	<0.007	<0.02	<0.010	<0.007	<0.02	<0.007	<0.02	<0.007
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.0001
Lanthanum	<0.005	<0.006	<0.008	<0.005	<0.006	<0.005	<0.006	<0.005

Table 11.4 Continued.

Parameter	Spring #1			Spring #2		Spring #3		Spring #4
Date	5-23-80	10-9-80	2-2-81	5-23-80	2-2-81	5-23-80	2-23-81	5-23-80
Magnesium	14	11.80	22.50	9	7.70	18	16.80	24
Manganese	0.021	0.056[c]	0.188[c]	0.007	0.019	0.020	0.018	0.002
Molybdenum	<0.001	<0.001	0.052	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	0.036	<0.001	0.074	0.031	<0.001	0.014	<0.001	0.009
Lead	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Rubidium	<0.020	<0.010	<0.012	<0.020	<0.010	<0.020	<0.010	<0.020
Antimony	<0.020	<0.001	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
Selenium	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	<0.0025	0.005	<0.002
Tin	<0.001	0.058	<0.010	<0.001	0.152	<0.001	0.222	<0.001
Titanium	0.003	<0.030	<0.001	0.003	<0.030	<0.001	<0.030	<0.001
Uranium	<0.010	<0.010	<0.010	<0.010	<0.01	<0.010	<0.01	<0.010
Vanadium	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tungsten	<0.050	<0.01	<0.020	<0.050	<0.01	<0.050	<0.01	<0.050
Zinc	0.013	0.015	0.020	<0.001	0.020	<0.001	0.020	0.003
Zirconium	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Silver	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Thorium (pCi/L	<0.015	ND[d]	<5	<0.015	ND	<0.015	ND	<0.015
Radium (pCi/L)	<0.005	"	<15[c]	<0.005	"	<0.005	"	<0.005
Organics (µg/L)								
Phenols (1)	<2.0	<2.0	<3.0	<2.0	<3.0	<2.0	<3.0	<2.0
Aliphatic Hydrocarbons	<1.0	15.0	8,000.00	<1.0	7,000.00	<1.0	8,000.00	<1.0
Arylamines	<1.0	<0.1	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0
Mono & polycyclic hydrocarbons:		<0.01	<0.01		<0.01		<0.01	
Benzo (a) anthracene	0.41			<0.02		<0.02		<0.02
Benzo (b) fluoranthene	0.05			<0.01		<0.01		<0.01
Benzo (c) pyrene	0.20			<0.02		<0.02		<0.02
Sulfur Compounds: (3)								
Thiophenes and mercaptans	<1.0	<1.0	<3.0	<1.0	<3.0	<1.0	<3.0	<1.0
Chlororganics (4)	0.156	0.015	<0.1	0.245	0.81	0.054	0.14	0.270
Chloramines	<100.00	<100.00	<100.00	<100.00	<100.00	<100.00	<100.00	<100.00

[a] For location of springs see Figure 11.1.
[b] Not determined due to bacterial contamination.
[c] Exceeds USEPA Drinking Water Standards.
[d] Not detected; higher background radiation.

U.S. Environmental Protection Agency primary (40 CFR 141; 45 FR 57342, August 27, 1980) and secondary (40 CFR 143; 44 FR 42198, January 19, 1981) drinking water standards were exceeded on several occasions in the domestic wells. The most frequent violations occurred for fecal coliform, turbidity, iron, and manganese (See Table 11.2).

Non-compliance with the fecal coliform standard (1/100 ml) probably results from animal wastes in the aquifer recharge area. As discussed previously, the high metals values of Well #3 could result from construction materials or recharge from the Big Clifty Sandstone stratum.

Wells #105 and #303 were drilled in February and January, 1981, respectively, as part of the site investigation. Both wells show high levels of suspended solids and associated high turbidity and color readings. Constituents apparently introduced with the suspended phase included fluoride, sulfate, ortho-phosphate, chloride, total nitrogen, and several trace metals.

Water from the springs exceeded the drinking water standards for fecal coliform and turbidity for all observations. As in the wells, iron and manganese were often in non-compliance. Other trace metals often detected in absolute quantities included aluminum, barium, bromine, copper, nickel, and zinc. Aliphatic hydrocarbons were much higher in the winter samples than for other sampling dates. Conversely, individual PAH compounds were only detectable in the spring samples.

Although the limited data base renders comparisons difficult, there were some apparent differences between the springs. For instance, Spring #1 contained the greatest amounts of suspended solids, while sulfates were elevated at Spring #3.

Data from the springs should be treated with caution due to the dry year and low flows which often made sampling difficult. To obtain sufficient quantities of water, samples were sometimes collected in pools just below the mouth rather than directly in the seepage. This would allow some surface runoff to be included. This could probably account for the high coliform levels at Spring #3, where the pool at the base of the spring is frequented by wildlife, especially deer. Cattle in the aquifer recharge area of Spring #2 probably contribute to the coliform levels found there.