GEOLOGIC SETTING AND WATER QUALITY OF SELECTED BASINS IN THE ACTIVE COAL-MINING AREAS OF OHIO, JUNE 1985 THROUGH DECEMBER 1986

By Allison L. Jones

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CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units rather than the inch-pound terms used in this report, the following conversion factors may be used:

Multiply inch pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
inch (in.)	25.4	millimeter (mm)
square mile (mi^2)	2.590	square kilometer (km^2)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$^{o}F = 1.8 \times {}^{o}C + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

During the initial 18 months of a 7-year study, water-quality data were collected from 20 basins in the active coal-mining areas of Ohio. The study area is mostly within the unglaciated eastern part of Ohio along the western edge of the Appalachian Plateaus physiographic province. The area is underlain by sandstone, shale, coal, and limestone of Mississippian, Pennsylvanian, and Permian age.

One to three long-term surface-water sites were assigned to each basin to document present water quality and changes in water quality over time. A total of 40 sites were sampled twice yearly at low flow. This report contains the results of the first three rounds of sampling. In addition, two to three individual basins are being chosen for intensive study during each year of the project. Additional data from the first five basins are included in this report.

For each of these intensively studied basins, 10 additional surface-water sites were selected for sampling to represent the water quality of the basin in more detail than was possible with one to three samples. Where present, a productive aquifer (that is, an aquifer capable of producing enough water for commercial, light industrial, or public water supplies) was investigated by sampling three to five wells and measuring water levels concurrently. The purpose of this ground-water sampling is to describe any productive aquifer present in areas where coal-mining permits may be issued.

Specific-conductance values for 100 samples ranged from 270 to 2,800 µS/cm. One hundred samples from the long-term surface-water network had a median specific conductance of 760 µS/cm (microsiemens per centimeter at 25 °C) and a range of 270 to 2,800 µS/cm (microsiemens per centimeter at 25 °C) and had a median of 760 µS/cm. pH values ranged from 2.70 to 8.85 and had a median of 7.70. Alkalinity values ranged from 0 to 390 mg/L (milligrams per liter) as $CaCO_3$ and had a median of 122 mg/L.

The initial five basins chosen for intensive study were the Stillwater Creek basin; Symmes, Ice, and Indian Guyan Creeks basin; Moxahala Creek basin; Little Beaver Creek basin; and McMahon, Captina, and Sunfish Creeks basin. In the Stillwater Creek basin, specific conductance ranged from 390 to 3,300 µS/cm, pH ranged from 7.00 to 8.00, and alkalinity ranged from 78 to 372 mg/L as $CaCO_3$. In the Symmes, Ice, and Indian Guyan Creeks basin, the specific conductance ranged from 250 to 465 µS/cm, the pH ranged from 6.70 to 7.90, and the alkalinity ranged from 10 to 182 mg/L as $CaCO_3$. In the Moxahala Creek basin, specific conductance ranged from 520 to 4,600 µS/cm, pH ranged from 3.44 to 9.20, acidity ranged from 9.0 to 465 mg/L as $CaCO_3$, and alkalinity ranged from 2 to 425 mg/L as $CaCO_3$. In the Little Beaver Creek basin, specific conductance ranged from 330 to 1,210 µS/cm, pH ranged from 7.49 to 8.83, and alkalinity ranged from 35 to 257 mg/L as $CaCO_3$. In the McMahon, Captina, and Sunfish Creeks basin, specific conductance ranged from 350 to 1,200 µS/cm, pH ranged from 7.94 to 8.78, and alkalinity ranged from 85 to 192 mg/L as $CaCO_3$.

Chemical analyses for 150 surface-water samples and 17 ground-water samples are presented. At the completion of the 7-year study a large amount of baseline data will have been gathered for use by the Ohio Department of Natural Resources to facilitate permit application and compliance and to study water-quality trends.

INTRODUCTION

Background

Coal has been mined in the eastern third of Ohio since 1804. The first mines were small pick-and-shovel operations in which coal was removed by hand (Eavenson, 1942). Drift mines, tunneled into the coal seams, were developed next. As demand for coal steadily increased, seams too deep for drift mining were reached by vertical shafts (Pfaff and others, 1981). Surface mining began on a small scale in Ohio in 1913. As the supply of easily obtainable coal in the deep coal mines dwindled and its removal became less efficient and less economical, there was a shift to surface extraction. In 1986, 59 percent of all coal produced in Ohio was surface mined (Ohio Department of Natural Resources, 1987).

Coal mining has affected the environment for many years. Only recently have stringent mining and reclamation laws been enacted to help restore and protect the land and water. A need remains to better understand the cumulative effects of coal mining on the quality of water resources in Ohio. Surface-water-quality data have been collected in the past, although over a relatively short period, but data collection has concentrated in areas of abandoned mines. Ground-water-quality data are scarce.

The U.S. Geological Survey began a 7-year study in 1985 in cooperation with the Ohio Department of Natural Resources (ODNR), Division of Reclamation, to obtain baseline hydrologic data for ODNR's evaluation of surface-mining permit application and compliance. The permitting process is designed to prevent future mining from adversely affecting water supplies on which communities and industries depend.

Purpose and Scope

This report presents the results of the first 18 months of the 7-year study (June 1985 through December 1986). The purpose of this report is to (1) describe the hydrogeologic and physiographic settings of the study areas; (2) present surface-water-quality data for 20 actively mined basins in eastern Ohio; and (3) describe the ground-water quality of a productive aquifer, where present, in each of the five basins selected for intensive study. Trends will not be investigated until further data are collected.

Data were obtained from a network of 40 long-term surface-water sites throughout the 20 basins (fig. 1, in pocket), each of which was sampled twice yearly at low flow. In the five intensively studied basins, an additional 10 surface-water sites (short-term) were sampled during the fall low-flow season.

Description of the Study Area

The study area includes all or part of 29 counties located in the coal-bearing area of eastern Ohio (fig. 2, in pocket). This area is mostly within the unglaciated part of Ohio along the western edge of the Appalachian Plateaus physiographic province (Fenneman, 1938), where local relief is as much as 500 feet (Razem and Sedam, 1985). A map characterizing land use of eastern Ohio is shown in figure 3. The entire coal-producing area (approximately 8,350 square miles) is drained by the Ohio River and contributes an average annual runoff of 14 inches (Ohio Department of Natural Resources, 1962).

The study area has been divided into 20 basins, which are listed in downstream order in table 1 and shown in figure 2. The five basins selected for intensive study were the Stillwater Creek basin; Symmes, Ice, and Indian Guyan Creeks basin; Little Beaver Creek basin; Moxahala Creek basin; and McMahon, Captina, and Sunfish Creeks basin.

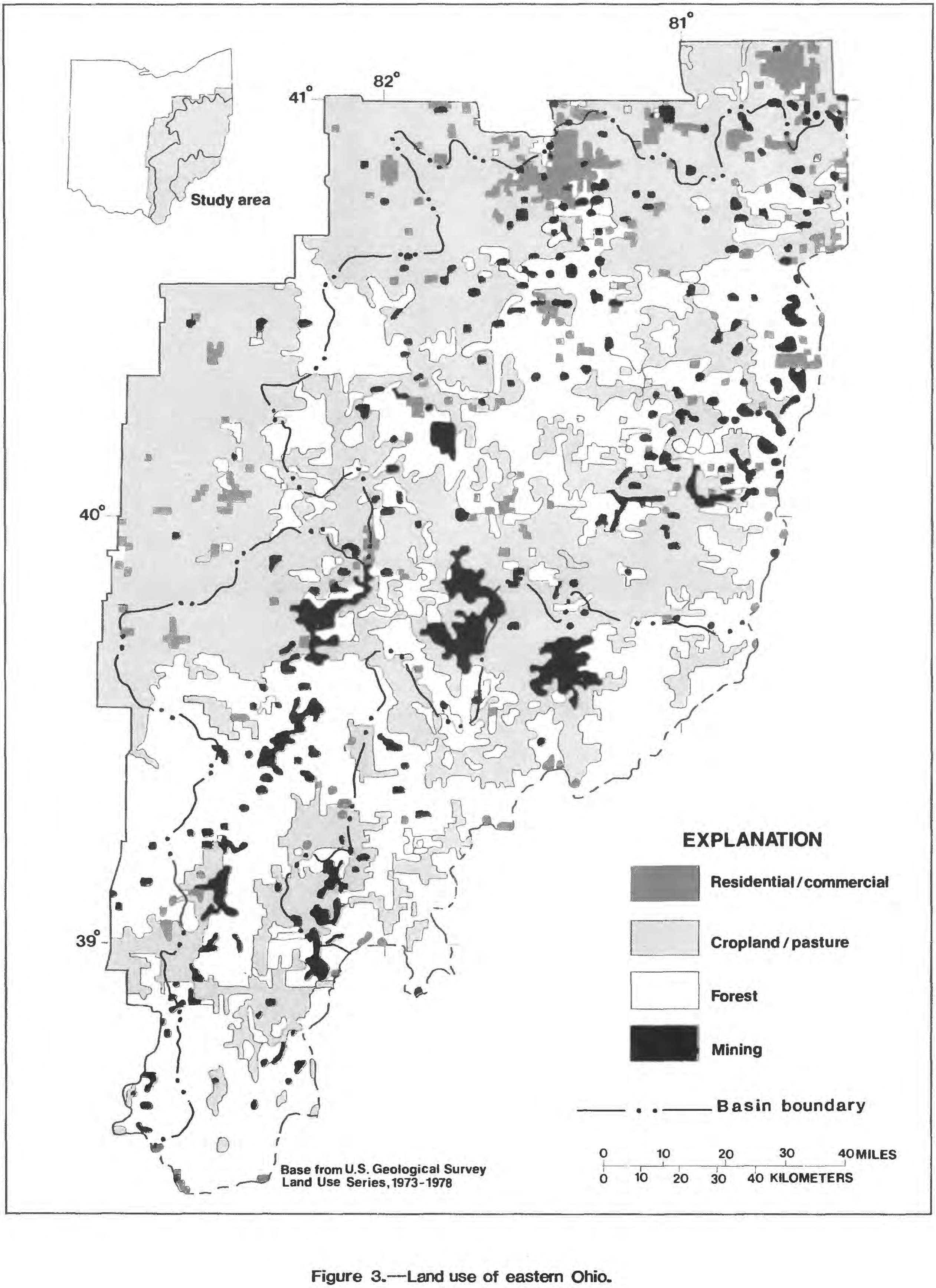


Figure 3.—Land use of eastern Ohio.

Table 1.--Study basins, in downstream order, and assigned identification code

Basin I.D.	Basin name
A	Little Beaver Creek
B	Yellow/Cross Creeks
C	Short/Wheeling Creeks
D	McMahon/Captina/Sunfish Creeks
E	Sandy Creek
F	Conotton Creek
G	Middle Tuscarawas River/Sugar Creek
H	Stillwater Creek
I	Lower Tuscarawas River
J	Walhonding River
K	Upper Wills Creek
L	Lower Wills Creek
M	Upper Muskingum River
N	Middle Muskingum River
O	Moxahala Creek
P	Upper Hocking River
Q	Middle Hocking River
R	Upper Raccoon Creek
S	Lower Raccoon Creek
T	Symmes/Ice/Indian Guyan Creek

The climate is characterized by moderate extremes of humidity and temperature. Mean daily temperatures range from 19.9 °F in January to 80.0 °F in July to the north, and from 28.0 °F to 90.0 °F to the south (Pierce, 1959). Precipitation is greatest in early spring and least in the fall and averages 40 inches per year. Figure 4 shows a contour map of the average annual precipitation in Ohio (Ohio Department of Natural Resources, 1962).

Coal beds are found in a 32-county area of eastern Ohio (Brant and Delong, 1960). The area is underlain by rocks of Mississippian, Pennsylvanian, and Permian age. Rock types are usually present in sequences of (with increasing depth) coal, limestone, calcareous shale, sandstone, and limestone (Brant and Moulton, 1960).

The outcrop pattern (fig. 5) from west to east progresses from older to younger units, which trend north-northeast and dip regionally to the southeast at approximately 30 feet per mile toward the Appalachian basin. The regional trend of the Pennsylvanian System is modified locally by numerous low structural features (Lamborn, 1951).

The oldest formation of Pennsylvanian age is the Pottsville Formation (fig. 6), in which conglomeratic sandstones are dominant. Above this are the Allegheny, Conemaugh, and Monongahela Formations, all of Pennsylvanian age, which comprise alternating beds of shale, sandstone, coal, and thin limestones. The Dunkard Group of Pennsylvanian and basal Permian age is a variable series of rocks composed of beds of red shale (which is the most abundant rock type), limestone, sandstone, and coal. In the south, the limestone and coal are scarce, and the series consists chiefly of shale and sandstone (Collins, 1979).

The proportion of sandstone strata increases with age. The Allegheny Formation is 40 percent sandstone, and the remainder is composed of shale and clay. The Conemaugh Formation is not more than 30 percent sandstone, and the Monongahela Formation consists of shale, limestone, and not more than 15 percent sandstone (Stout and others, 1943). The carbonate content decreases with age in the Pennsylvanian rocks; therefore, the Monongahela Formation contains more carbonate rocks than the Allegheny and Conemaugh Formations (Razem and Sedam, 1985). Deposits of unconsolidated silts, nearly 100 feet thick in some places, are found chiefly in the bottoms of old valleys that now have no major drainage, and in the lower parts of many smaller valleys. In the main valleys, these silts have largely been removed, and the valleys now are filled with sands and gravels, which have been terraced by the present streams. In the valleys that have carried glacial waters (but have not been glaciated), these coarse, fluvial deposits are common and are composed chiefly of glacial outwash (Happ, 1934).

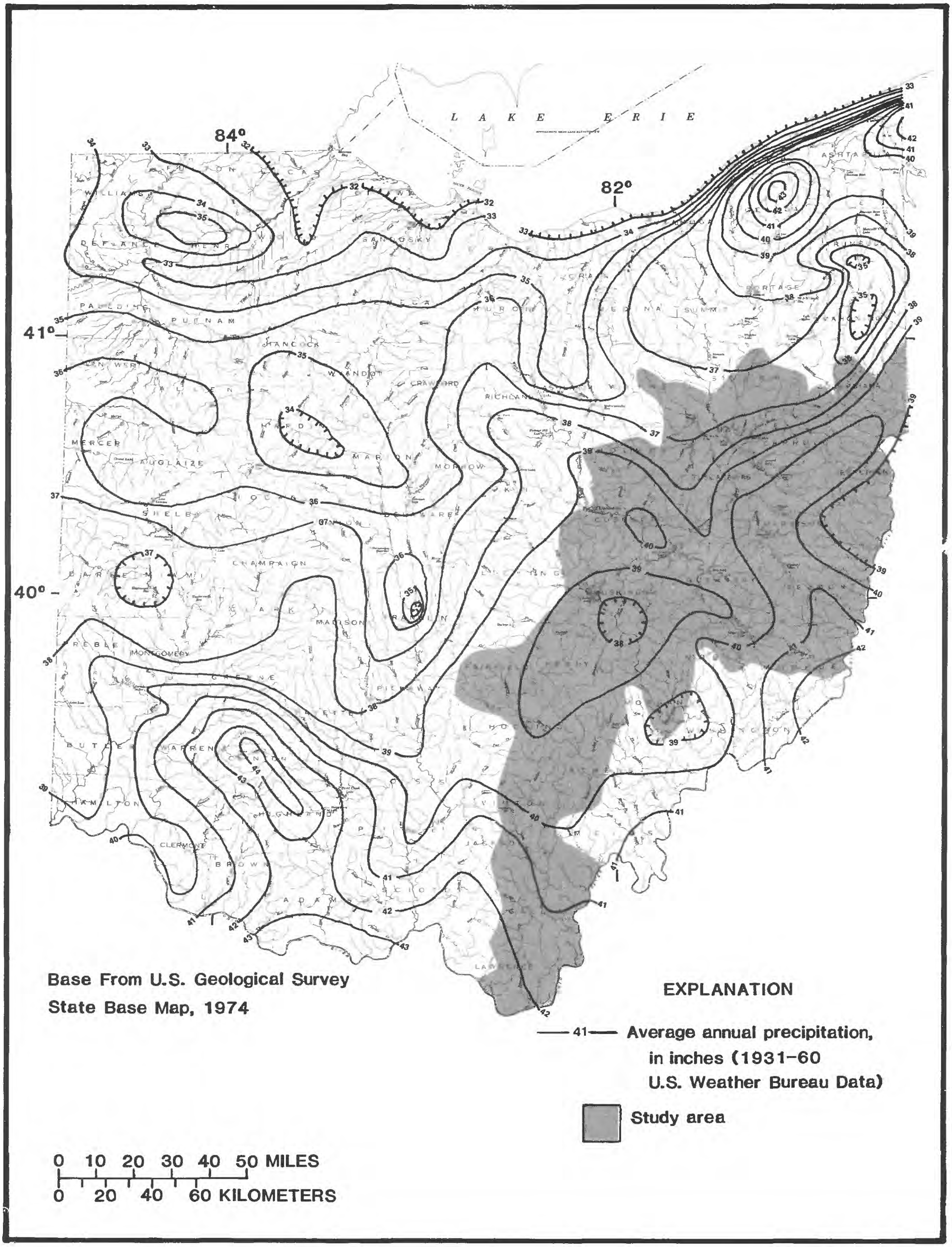


Figure 4.--Average annual precipitation in Ohio.

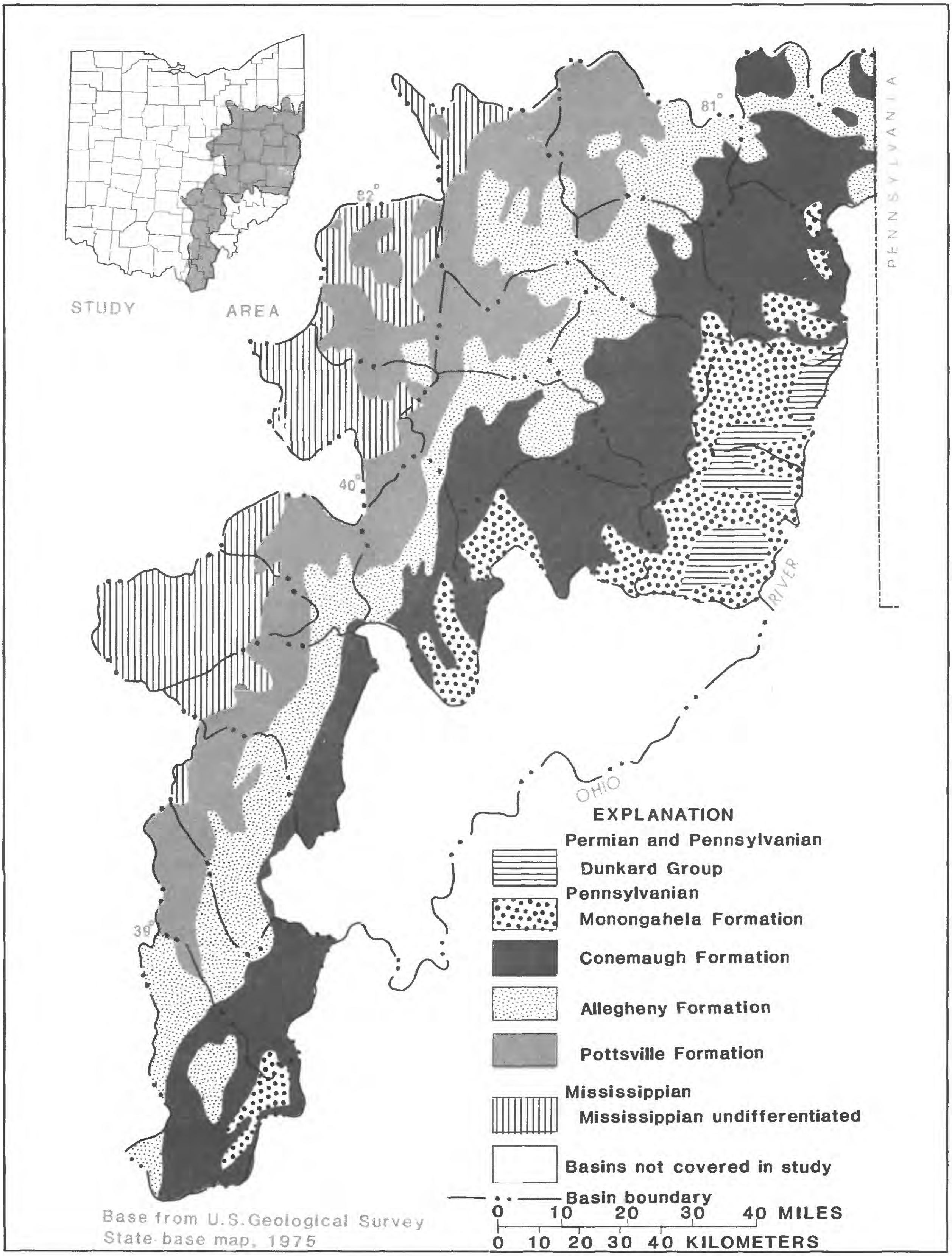


Figure 5.—Surficial geology of study area. (Modified from Collins, 1979).

System	Group, Formation		Description	Important coal beds
Permian	Dunkard Group	Greene	Mostly red shales and thin limestones, localized coals and sandstone bodies. Present only in small areas.	No. 12 Washington
Pennsylva-nian and Permian	Dunkard Group	Washington	Sandstones, shales, and minor coals. Sandstones are typically micaceous, fine to medium grained, and have thin conglomeratic zones. Locally, sandstones may be massively developed.	
Pennsylvanian	Monongahela		Important coal-bearing strata and associated beds of clay, shale, sandstone, and limestone. Sandstones tend to be fine to medium grained, micaceous, and patchy in development. Compared to other Pennsylvanian units, the Monongahela has a smaller proportion of sandstone and a larger proportion of limestone. Limestones tend to be marly, freshwater types. Secondary porosity along fractured surfaces is well developed locally.	No. 11 Waynesburg No. 10 Uniontown No. 9 Meigs Creek No. 8 Pittsburgh
Pennsylvanian	Conemaugh		Thick repetitious succession of shales and patchy sandstones interspersed with thin, discontinuous coals and clays and widespread limestones. The lower limestones are of marine origin, whereas those in the upper part are marly, freshwater types. Secondary porosity along fractured surfaces is well developed locally.	
Pennsylvanian	Allegheny		Repetitious succession of important coal-bearing strata interspersed with several fine to coarse-grained massive, cross-bedded sandstones and thin, persistent limestones. Sandstones, though widespread, have considerable local lateral variation. Solution cavities are developed locally in the limestones.	No. 7 Upper Freeport No. 6A Lower Freeport No 6 Middle Kittanning No. 5 Lower Kittanning No. 4A Clarion No. 4 Brookville
Pennsylvanian	Pottsville		Succession of sandstone, shales, clays, coals, and thin limestones. Locally, sandstones are open-textured, conglomeratic, massive, cross-bedded, and commonly are found as deposits filling old channels in eroded terrains. Lateral gradations include shale and coal. Non-deposition during the Early Pennsylvanian precluded the development of the basal conglomerate of the Sharon Member in most of southeastern Ohio.	No. 3 Lower Mercer No. 2 Quakertown No. 1 Sharon
Pennsylvanian	Pottsville		Thin, discontinuous zone of impure nodular iron ore and ferruginous sandstone. The unit marks the disconformity between Mississippian and Pennsylvanian strata. Age of the deposit is conjectural, but generally it is included at the base of the Pottsville Formation.	
Mississippian	Undifferentiated		Variable sequence of sandstones and shales; Maxville Limestone is present in patches at the top. In places, various units are conglomeratic and sandstones are massive. Lateral and vertical gradation to siltstone and shale is common. Ground-water potential is limited to extreme western areas. Eastward, the section contains salt water. To the north, post-Mississippian erosion has removed part of the section.	

Figure 6.--Generalized geologic column for southeastern Ohio, including relative position of important coal beds (from Razem and Sedam, 1985).

Fifty-two coal beds are recognized and named in Ohio, most of which are thin and discontinuous. Most minable coals are in the Allegheny and Monongahela Formations, and all are highly volatile and bituminous, falling in the medium (1.1 to 3.0 percent) to high (greater than 3.0 percent) sulfur range (Collins, 1978). Mining has traditionally concentrated on the "numbered" coals--Sharon ("No. 1") through Waynesburg ("No. 11")--which still supply most coal mined in Ohio. The Allegheny and Monongahela Formations are especially productive because of their more uniform thickness and distribution; therefore, most mines in Ohio are in parallel bands following the outcrop of these two formations (Pfaff and others, 1981). The lithologic character of the principal units and the relative positions of the important coals are shown in figure 6.

Acknowledgments

The author acknowledges the cooperation of the Ohio Department of Natural Resources, Division of Water; the Muskingum Watershed Conservancy District; the Village of Flushing; and the Village of Lisbon. The author also expresses thanks to area businesses and homeowners in Deersville, Flushing, Lisbon, and Glenford for permitting access to their wells, and to many others throughout eastern Ohio for permitting access to their properties for streamflow measurements.

METHODS OF STUDY

One to three long-term surface-water sites in each of the 20 basins (fig. 1) were sampled three times at low flow. A total of 30 sites were sampled twice the first year (1985), and 40 sites were sampled the second year (1986). In each of the five basins selected for "intensive" study, 10 additional surface-water sites were sampled once.

Onsite measurements of discharge, specific conductance, pH, temperature, alkalinity, and acidity were made at each surface-water site. Discharge was measured by the methods described in Rantz and others (1982). Specific conductance, pH, temperature, and alkalinity were determined by the methods discussed in Skougstad and others (1979). Acidity was determined using the hot-peroxide-treatment method (American Public Health Association, 1975). Water samples for chemical analysis were collected using the equal-transit-rate/equal-width-increment method (U.S. Geological Survey, 1977) for all streams whose water depths were greater than 0.5 foot. These were composited in a churn splitter from which subsamples were drawn. Samples also were sent to the U.S. Geological Survey's National Water Quality Laboratory for analysis of:

Dissolved sulfate;
Total and dissolved iron;
Total and dissolved manganese; and
Total and dissolved aluminum.

Each of the five basins receiving intensive study was examined for the existence of a productive aquifer, that is, an aquifer capable of producing enough water for commercial, light industrial, or public water supplies (excluding unconsolidated deposits along the Ohio River). Where a productive aquifer is present, the ground water was investigated.

At each ground-water sampling site, the following on-site measurements were made:

Water level (when possible);
Specific conductance;
pH;
Temperature; and
Alkalinity.

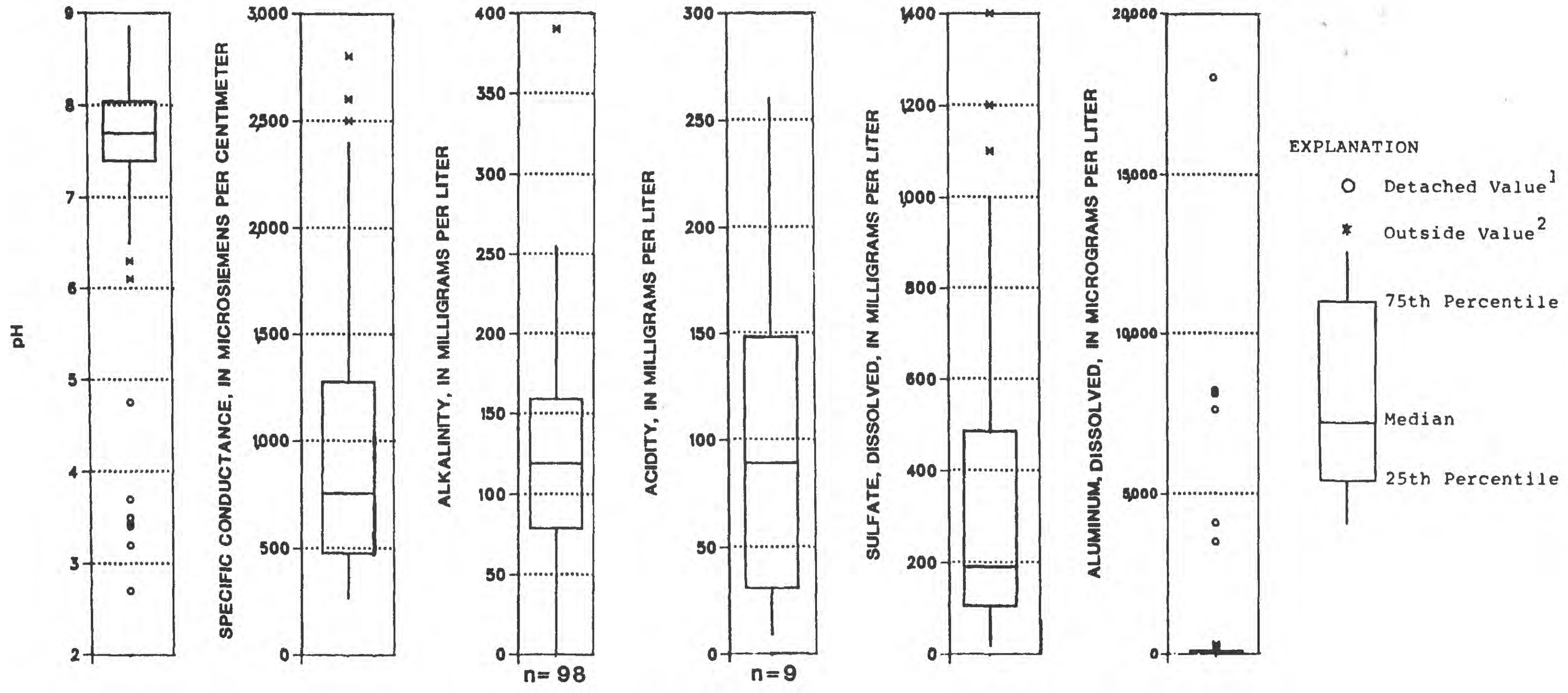
Laboratory analysis included:

Total and dissolved aluminum;
Dissolved sulfate;
Total and dissolved iron;
Total and dissolved manganese;
Dissolved silica;
Dissolved calcium;
Dissolved magnesium;
Dissolved sodium;
Dissolved chloride;
Dissolved potassium;
Total organic carbon; and
Total dissolved solids
(residue on evaporation at 180 °C).

GENERAL WATER QUALITY

Surface Water

The variation in geology throughout Ohio's coal-mining region influences water quality. Basins with limestone bedrock near the surface may buffer acidic mine drainage entering streams, whereas basins without such buffering capacity are more severely affected. Water samples collected from the network of 40 long-term surface-water sites were distributed near the mouths of major streams in the 20 basins (fig. 1). These sites were sampled twice yearly at low flow. Results of chemical analyses are presented in table 2 (at back of report) and in figure 7.



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a >1.5 and ≤3 interquartile ranges from the box.

n=100 samples

Figure 7.—Box plots showing the range, percentiles, and median values of constituents at the long-term surface-water sites.

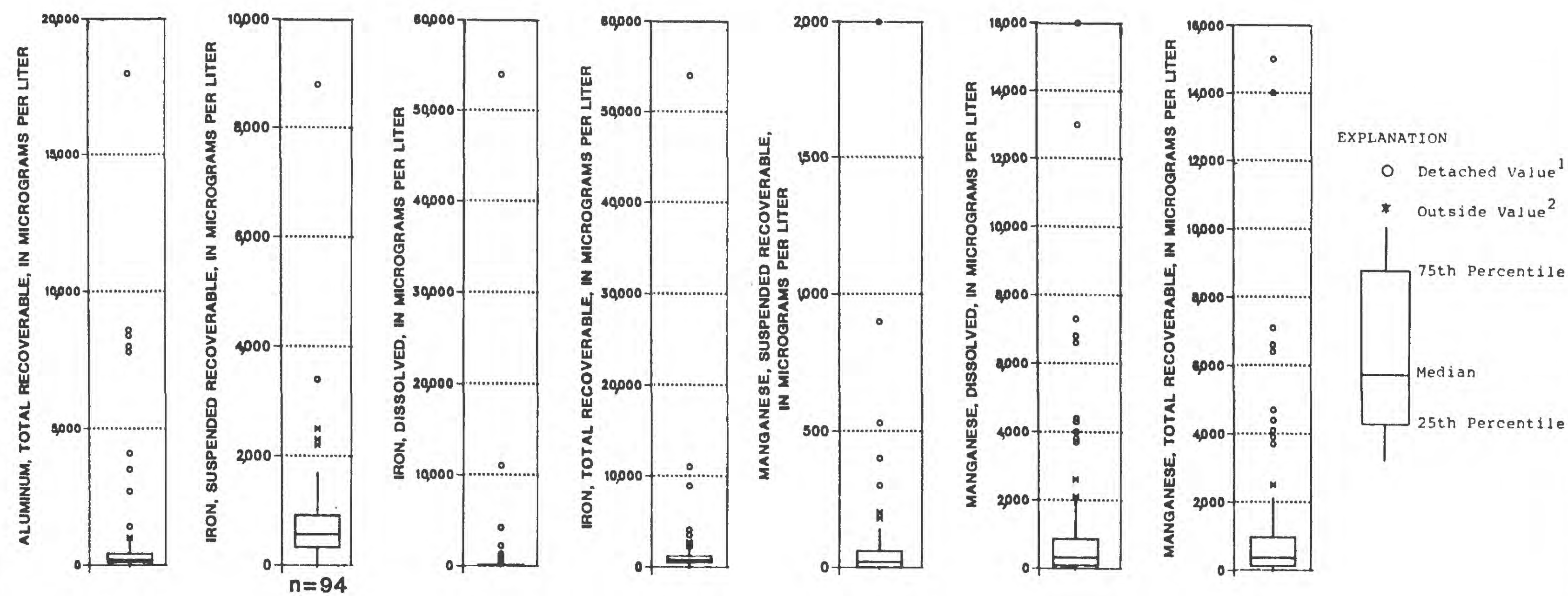


Figure 7.—Box plots showing the range, percentiles, and median values of constituents at the long-term surface-water sites—Continued.

Dissolved-solids concentration is an indicator of general water quality. A rapid method for estimating dissolved-solids concentrations is measurement of specific conductance. Under most conditions, the relation between specific conductance and dissolved-solids concentration is linear. The numerical value for dissolved-solids concentrations, in milligrams per liter (mg/L), generally is 0.55 to 0.75 the value of specific conductance in microsiemens per centimeter at 25 ^{o}C (µS/cm) (Hem, 1985). Elevated ionic concentrations in water produce elevated specific-conductance values. In water with elevated dissolved-sulfate concentrations, an elevated measured specific conductance is likely to indicate acid mine drainage. One hundred samples from the long-term site network had a median specific conductance of 760 µS/cm and a range of 270 µS/cm (at site T-1) to 2,800 µS/cm (at site K-1).

The presence of elevated dissolved-sulfate concentrations in surface water can be an indicator of acid mine drainage. Ferrous sulfides in the sandstones and shales overlying coal beds, as well as in waste coal and spoil itself, are important sources of sulfate. Data have shown that, once sulfate concentrations become elevated, they do not return to their premining levels, even after successful reclamation (Pfaff and others, 1981; Hren and others, 1984). Median sulfate concentration for the long-term network was 190 mg/L, with a range of 17 mg/L (at site M-1) to 1,400 mg/L (at site K-1 and O-2). As would be expected, the highest concentrations were found at sites in basins with active or abandoned coal mines.

Pyrite and marcasite are the sulfur-bearing minerals commonly present in coal and associated strata. Pyrite is the most widespread of all sulfide minerals and is recognized as the major source of acid mine drainage in the eastern United States. These minerals are exposed to air and water during coal mining. The oxidation of pyrite may be characterized by the following reactions:

$$FeS_2(s) + 7/2O_2 + H_2O \longleftrightarrow Fe^{2+} + 2SO4^{2-} + 2H^+ \qquad (1)$$

$$Fe^{2+} + 1/4O_2 + H^+ \longleftrightarrow Fe^{3+} + 1/2\ H_2O \qquad (2)$$

$$Fe^{3+} + 3H_2O \longleftrightarrow Fe(OH)_3(s) + 3H^+ \qquad (3)$$

$$FeS_2(s) + 14Fe^{3+} + 8H_2O \longleftrightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (4)$$

The oxidation of the sulfide in pyrite to sulfate in reaction 1 releases ferrous iron and acidity (as H^+) into the water. In reaction 2, ferrous iron is oxidized to ferric iron, which then hydrolyzes to form additional acidity and ferric hydroxide (reaction 3), an insoluble substance often seen in streams receiving acid mine drainage. In reaction 4, sulfide is again oxidized to produce acidity, sulfate, and ferrous iron (Stumm and Morgan, 1970).

When oxygen is present in a mining environment, the rate of acid drainage production is limited by the rate of iron (Fe^{+2}) oxidation; the higher the pH, the greater the rate of oxidation (Wiram, 1974). At a pH below 4.5, the rate of oxidation would be extremely slow without microbial catalysis by the iron bacteria <u>Thiobacillus</u> and <u>Ferrobacillus ferrooxidans</u>, which thrive in low-pH water (Stumm and Morgan, 1970). Rock texture, porosity, and permeability also are important in determining the amount of oxidizing agents able to reach iron disulfides, particularly in drift mines and strip-mine highwalls (Pfaff and others, 1981).

Elevated concentrations of iron, manganese, and aluminum are considered undesirable contaminants in terms of aquatic biota and human uses. All three metals are dissolved in surface-water samples from all 20 basins to some degree, and all three are known to be found in increased concentrations during and immediately after mining (Dyer and Curtis, 1977).

Concentrations of iron in water depend on the geology of the area and the chemistry of the water system. More than 1,000 to 2,000 μg/L (micrograms per liter) of soluble iron in surface waters generally indicates acidic contamination from mine drainage or other sources (Ward and Wilmoth, 1968). The median concentration of dissolved iron among the long-term sites was 45 μg/L, with a range of less than 10 μg/L (at sites H-1, L-1, and B-2) to 54,000 μg/L (at site Q-2).

Manganese is dissolved from some of the rocks and soils. Small amounts commonly are present in dolomite and limestone and substitute for calcium. Large quantities commonly are associated with elevated iron content and with mine drainage. Manganese is an undesirable impurity in water supplies because of its tendency to deposit black oxide stains. Concentrations of manganese commonly increase after surface mining; manganese commonly is present in concentrations of more than 1,000 μg/L in streams receiving acid mine drainage. Manganese usually stays in solution for greater distances downstream from the pollution source than iron. As the acidity is gradually neutralized, ferric hydroxide precipitates first, followed by manganese (Hem, 1985). Median dissolved-manganese concentration for the long-term network was 320 μg/L, with a range of 10 μg/L (at sites B-1 and D-1) to 16,000 μg/L (at site O-2).

Aluminum is present only in negligible quantities in natural waters except in areas where the waters have been in contact with the more soluble rocks of high aluminum content, such as bauxite and certain shales. Acidic waters also commonly contain large amounts of aluminum (Ward and Wilmoth, 1968). Aluminum in public water supplies is not considered a public-health problem under most conditions, as most people ingest 10 to 100 milligrams per day from all sources (McKee and Wolf, 1963). Concentrations of dissolved aluminum in the long-term network ranged from less than 10 μg/L (at sites N-2 and J-1) to 18,000 μg/L (at site Q-1). The median concentration was 30 μg/L.

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. The principal system regulating pH in natural waters is the carbonate system, which is composed of carbon dioxide, carbonic acid, bicarbonate ion, and carbonate ion. The pH of samples from the long-term network had a median of 7.70 and ranged from 2.70 (at site Q-2) to 8.85 (at site P-2). In general, the long-term network represented the most downstream point available in each basin. Therefore, a neutral pH value was not uncommon because of possible dilution of any acid mine drainage present. Seven samples had a pH of less than 5.0.

"Buffering capacity," the ability to neutralize additions of acids or bases without a change in pH, is controlled by the concentration of alkalinity and acidity present in water (U.S. Environmental Protection Agency, 1986). Alkalinity resulting from naturally occurring carbonate and bicarbonate is not considered a health hazard in drinking water, and naturally occurring levels up to 400 mg/L as $CaCO_3$ are not considered a problem to human health (National Academy of Sciences, 1974). The median alkalinity in the long-term network was 122 mg/L as $CaCO_3$, with a range of 0 mg/L (at sites Q-1, S-1, and O-1) to 390 mg/L (at site C-2).

Acidity was measured at each site where the pH was 6.5 or less. Above a pH of 6.5, acidity was assumed to be near zero. Nine of the 100 samples had measurable acidity ranging from 9 mg/L as $CaCO_3$ (at site O-1) to 260 mg/L (at site Q-2), with a median value of 89 mg/L. Elevated acidity is almost always associated with some type of mining activity, as was previously discussed; however, if mining is present where limestone is near the surface, the buffering capabilities of the carbonates may reduce acidity.

The Middle Hocking River, Moxahala Creek, Short and Wheeling Creeks, and Raccoon Creek basins consistently had values at the high end of the range for many constituents, and low pH values. These basins exhibit the characteristics most commonly associated with acid mine drainage. They also were basins with a considerable amount of past as well as present coal mining.

Ground Water

Productive aquifers are present in three of the five basins: Stillwater Creek basin, Moxahala Creek basin, and Little Beaver Creek basin. The hydrogeology and results of chemical analyses are presented under the appropriate basin headings. Ground-water samples received supplemental analysis in addition to the constituents analyzed for in the surface-water samples.

Silicon in combination with oxygen, as the oxide SiO_2, is termed silica. It is present in solution mainly in water in contact with quartz-bearing rocks. Silica is not readily dissolved in water, although some analyses show increased solubility as water temperature rises (Hem, 1985). Warm ground waters may contain silica concentrations of up to 100 mg/L (Driscoll, 1986). The range of concentrations most commonly observed in natural waters is 1 to 30 mg/L (Hem, 1985). Davis (1964) quotes a median value of 17 mg/L for ground water. Higher concentrations are most commonly related to rock type, rate of movement, water temperature, and natural acids, such as carbonic acid, which affect weathering of rock materials. Although silica does not contribute to the hardness of ground water, it is one of the minerals that forms incrustations in water-supply systems. Silicate scale usually is in the form of calcium or magnesium silicate. Because silicate scale cannot be dissolved by acids or other chemicals commonly used in treatment of wells, water used in boilers must be treated before use by absorption or ion-exchange techniques (Driscoll, 1986). In the three basins having productive aquifers, silica concentrations ranged from 8.7 to 19 mg/L.

Hardness of water is defined as its content of metallic ions that react with sodium soaps to produce scummy residue and that react with negative ions, when the water is evaporated in boilers, to produce solid boiler scale (Camp, 1963). In freshwater, these ions are primarily calcium and magnesium. Hardness commonly is expressed as an equivalent concentration of calcium carbonate ($CaCO_3$). The following is a commonly used classification (U.S. Environmental Protection Agency, 1986):

Classification of Water by Hardness Content

[Concentration in mg/L as $CaCO_3$]

0-75------------------	soft
75-150-----------------	moderately hard
150-300----------------	hard
300 and up------------	very hard

Hardness is derived principally from calcium and magnesium. Its natural source is limestone dissolved by slightly acidic rainwater in contact with carbon dioxide. Industrial sources may include abandoned and active mines. Hardness is commonly reported in carbonate and noncarbonate fractions. The carbonate fraction is chemically equivalent to the bicarbonates present. Bicarbonates generally are measured as alkalinity; therefore, carbonate hardness usually is considered equal to the alkalinity (U.S. Environmental Protection Agency, 1986). If the hardness exceeds the alkalinity, the excess is reported as "noncarbonate hardness" (Hem, 1985). In the three basins having productive aquifers, hardness ranged from 100 to 840 mg/L.

Calcium is a major constituent of many common rock minerals. The most common forms in sedimentary rocks are carbonates. In sandstone, calcium carbonate commonly is present as a cement between particles. It is an essential element for plant and animal life forms and is a major component of the solutes in most natural water (Hem, 1985). In the three basins having productive aquifers, calcium concentrations ranged from 27 to 250 mg/L.

Magnesium is present in significant amounts in most limestones and dolomites. Dissolution of these materials brings magnesium into solution, but the process is not easily reversed. Precipitate from this solution may be nearly pure calcite. Concentrations of magnesium tend to increase along a ground-water flow path in limestones undergoing dissolution until a relatively high calcium:magnesium ratio is obtained (Hem, 1985). In the three basins having productive aquifers, magnesium concentrations ranged from 8.3 to 64 mg/L.

Sodium may be present in unaltered mineral grains as part of the cementing material or as crystals of sodium salts deposited with sediments left by saline water. After dissolution, sodium tends to remain dissolved. There are no important precipitation reactions that can maintain low sodium concentrations in water similar to the way that carbonate precipitation controls calcium concentration (Hem, 1985). The U.S. Environmental Protection Agency (1986) recommends a limit of 20 mg/L of sodium in water for very restricted sodium diets and 270 mg/L for moderately restricted diets. No specific criterion is set for drinking-water supplies. In the three basins having productive aquifers, sodium concentrations ranged from 4.6 to 73 mg/L.

Potassium is slightly less common than sodium in igneous rock but more abundant in all the sedimentary rocks. In most natural water, potassium concentrations are much lower than sodium concentrations. Potassium is commonly present in clay minerals and some evaporite rocks. Concentrations of potassium more than a few tens of milligrams per liter are very unusual except for waters with high dissolved-solids concentration (Hem, 1985). In the three basins having productive aquifers, potassium concentrations ranged from 1.1 to 4.5 mg/L.

Total organic carbon (TOC) is widely used as a measure of the total concentration of organic constituents in water. The determination of total organic carbon gives a better measure of organic matter present in aqueous solution and (or) suspension than does chemical oxygen demand (Goerlitz and Brown, 1972). In ground water, total organic carbon is likely to be equal to dissolved organic carbon. Thurman (1985) lists 0.7 mg/L as an approximate concentration for total organic carbon typical of natural ground water, most all of which occurs in the dissolved state. In the three basins having productive aquifers, concentrations of total organic carbon ranged from 0.4 to 6.0 mg/L.

Excessive dissolved solids are objectionable in drinking water for aesthetic reasons. Dissolved solids consist of inorganic salts, small amounts of organic matter, and dissolved materials (U.S. Environmental Protection Agency, 1986). For drinking water, the Ohio Environmental Protection Agency (1978) limits dissolved solids to 500 mg/L. In the three basins having productive aquifers, dissolved-solids concentrations ranged from 194 to 1,200 mg/L.

Because many ground-water sources are domestic or public supplies, the following Ohio Environmental Protection Agency (1978) water-quality standards are listed for reference:

Chlorides	250 mg/L
Dissolved solids	500 mg/L
Iron (dissolved)	300 µg/L
Manganese	50 µg/L
Sulfates	250 mg/L

All concentrations are expressed as total concentrations unless otherwise noted.

GEOLOGIC SETTING AND WATER QUALITY OF SELECTED BASINS

Stillwater Creek Basin

Geologic Setting

The Stillwater Creek basin (fig. 2) is within the stream-dissected Appalachian Plateaus physiographic province (Fenneman, 1938). The landscape is one of relatively narrow to broad stream valleys. Most of the basin is thoroughly dissected by drainageways that have cut deep valleys and left narrow ridgetops.

Bedrock beneath the Stillwater Creek basin consists of alternating layers of sandstone, shale, limestone, clay, and coal of Pennsylvanian age. The rock strata crop out in a west-to-east pattern from older to younger formations. The Allegheny Formation underlies the northwestern part of the basin and consists of mostly sandstones, some shales, and coal. Most of the basin is covered by strata of the Conemaugh Formation, which consist of shales, sandstones, limestones, and coal. In the extreme eastern part of the basin is a relatively small outcropping of the Monongahela Formation, which is made up of shales, limestones, sandstones, and some coal. The sandstone formations to the north in the basin may yield as much as 25 gal/min (gallons per minute). These sandstones are not uniform in thickness, character, or areal extent; therefore, locally large yields do not indicate extensive water-bearing sandstone deposits. Except for localized areas of thick sandstones, bedrock in the northern quarter of the basin will supply enough water for domestic and farm uses only (Walker, 1962a).

Logs on file at the Ohio Department of Natural Resources show that beneath the floodplains of parts of Stillwater and Little Stillwater Creeks are deposits of sand and gravel interbedded with silt and clay that may yield as much as 50 gal/min. The materials filling these valleys were deposited from glacial meltwaters to the north (Walker, 1962a). Continued exploration in these valleys would be needed to determine the extent of these permeable, water-bearing sands and gravels.

The fill elsewhere along Stillwater and Little Stillwater Creeks and their tributaries ranges from 20 to 200 feet in thickness, and consists largely of clay, silt, and fine sand, which is a poor source of ground water. Water-supply wells normally are drilled through these deposits to the underlying bedrock, although large-diameter dug wells may be developed. Similar materials are present in most stream valleys throughout the basin. Rarely, sand and gravel deposits of limited extent are encountered that can yield 25 gal/min or more. Such deposits have been located along Jockey Hollow Run north of Flushing. However, these are unusual and not found in most areas (Walker, 1962a).

In most of the basin, sandstone and sandy shale bedrock will supply limited quantities of water for domestic and farm use. Yields commonly average less than 3 gal/min from drilled wells and may be supplemented by springs or dug wells. Wells drilled to depths greater than 200 feet below stream level are likely to encounter saline water (Walker, 1962a).

Ground-water levels in the Stillwater Creek basin (fig. 8) were measured near the Village of Flushing and at Tappan Lake Park near Deersville. Water levels are presented in table 3.

The Village of Flushing water supply is located along the outwash valley of Jockey Hollow Run northwest of the village (fig. 9). The entire area is surrounded by land which has been or is being surface mined. Well records from the Village of Flushing indicate unusually high-yielding sand and gravel deposits with a developed capacity of up to 200 gal/min. There were not enough wells in the area to construct a contour map of the potentiometric surface from the water-level measurements.

Tappan Lake Park has drilled a total of 16 wells into the underlying shale and sandstone of the Conemaugh Formation as water supplies for recreational use. Five of these wells have been abandoned. Two of the wells have been allocated for use to the Village of Deersville. Of the remaining wells, one well, HR-32, supplies the cabin area, and the water is untreated. Water from wells HR-30, HR-33, HR-40, HR-41, and HR-43 is combined and processed through a treatment plant and sent to a holding tank before distribution to the park. Thirteen water-level measurements were obtained. Well locations are shown in figure 10.

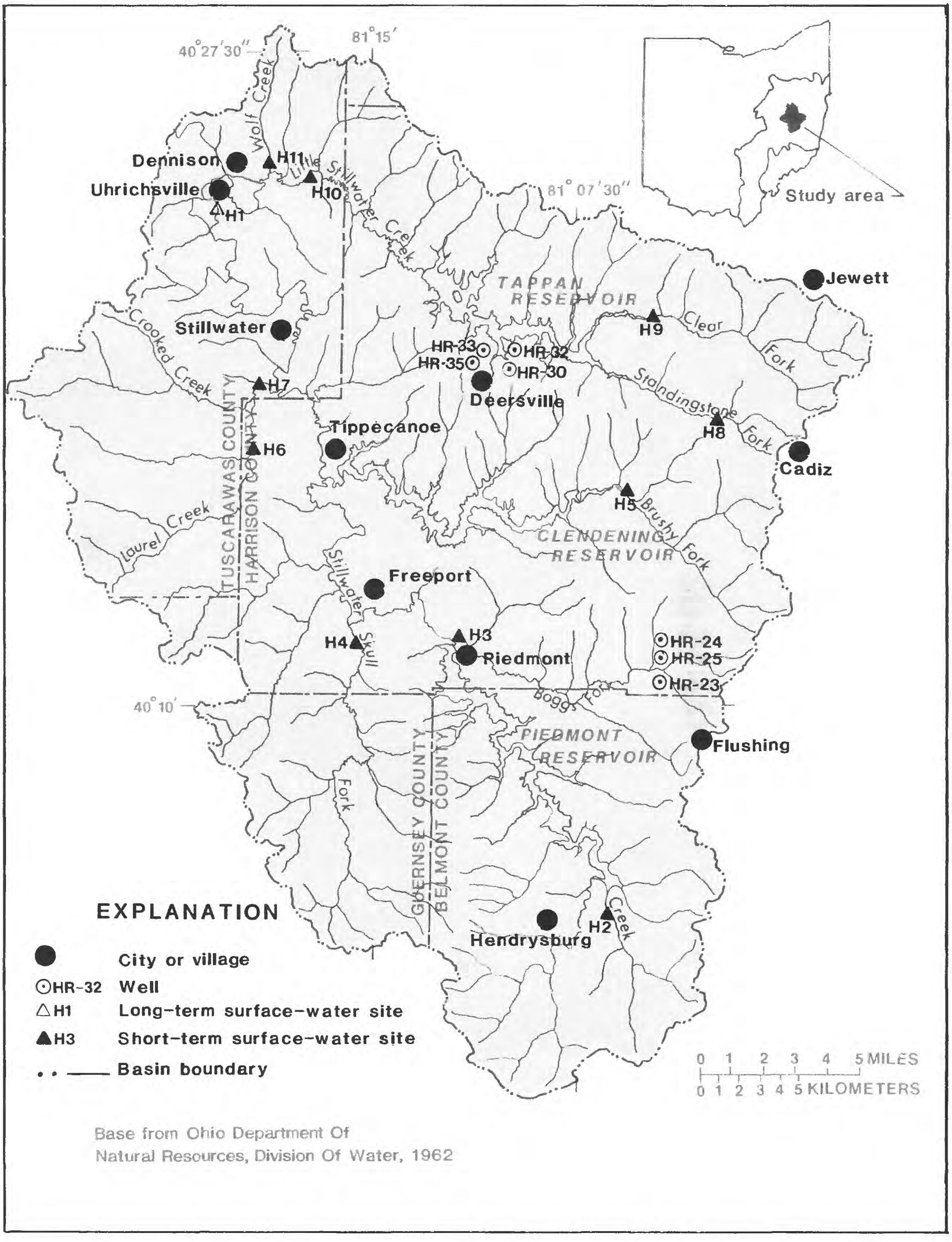


Figure 8.--Short-term and long-term surface-water sites and ground-water sites in the Stillwater Creek basin.

Table 3.--Ground-water-level measurements

Local number	Latitude	Longitude	Date	Water level[1]
Little Beaver Creek basin (Columbiana County)				
CO-1	404754	804537	09-02-86	44.87
CO-2	405008	804608	09-03-86	flowing
CO-3	404639	804833	09-02-86	44.20
CO-4	404846	804610	09-03-86	23.00
CO-5	404553	804317	09-02-86	28.89
CO-6	404506	804141	09-02-86	47.87
CO-7	404613	804341	09-03-86	107.00
CO-8	404456	803912	09-04-86	133.62
CO-9	404545	804149	09-03-86	8.55
CO-10	404620	804151	09-03-86	8.73
CO-11	404843	804523	09-04-86	35.57
CO-12	404940	804557	09-04-86	33.74
CO-13	404906	804513	09-04-86	40.59
CO-14	404847	804550	09-04-86	34.51
CO-15	404841	804650	09-04-86	98.23
CO-16	404751	804637	09-03-86	18.85
CO-17	404716	804548	09-03-86	44.87
CO-18	404546	804527	09-03-86	34.16
CO-19	404607	804625	09-03-86	5.28
CO-20	404705	804805	09-04-86	13.84
CO-21	404644	804839	09-03-86	74.39
CO-22	404652	805002	09-04-86	24.60
CO-23	404843	804608	09-01-86	23.00
Stillwater Creek basin (Harrison County)				
HR-23	401043	810528	11-21-85	--
HR-24	401049	810547	11-21-85	--
HR-25	401047	810547	11-21-85	16.80
HR-26	401045	810547	11-21-85	11.70
HR-27	401028	810514	11-21-85	flowing
HR-28	401011	810459	11-21-85	4.00
HR-29	401045	810533	11-21-85	3.00
HR-30	401920	811043	11-22-85	9.35
HR-31	401907	811045	11-22-85	9.60
HR-32	401937	811030	11-22-85	34.00
HR-33	401917	811112	11-22-85	10.00
HR-34	401915	811117	11-22-85	10.50
HR-35	401858	811122	11-22-85	--
HR-36	401903	811111	11-22-85	27.80
HR-37	401856	811123	11-22-85	26.50
HR-38	401859	811117	11-22-85	9.30

Table 3.--Ground-water-level measurements--Continued

Local number	Latitude	Longitude	Date	Water level[1]
HR-39	401856	811115	11-22-85	44.00
HR-40	401908	811111	11-22-85	18.00
HR-41	401911	811107	11-22-85	10.20
HR-42	401917	811039	11-22-85	14.80
HR-43	401912	811104	11-22-85	10.70
	Moxahala Creek basin (Perry County)			
PE-39	395204	821714	08-19-86	44.40
PE-40	395457	822431	08-18-86	3.75
PE-42	395336	821406	08-18-86	35.20
PE-43	395316	821902	08-19-86	18.78
PE-44	395320	821906	08-18-86	36.87
PE-45	395309	821925	08-19-86	--
PE-46	395353	821914	08-19-86	22.69
PE-47	395507	822105	08-18-86	0.0
PE-48	395424	822146	08-18-86	26.89
PE-49	395218	821517	08-22-86	1.08
PE-50	395431	821955	08-22-86	--
PE-51	395308	821450	08-18-86	9.68
PE-52	395346	821920	08-18-86	21.02
PE-53	395318	821826	08-18-86	74.80
PE-54	395428	822129	08-18-86	18.18
PE-55	395507	822150	08-18-86	2.40
PE-56	395401	821908	08-18-86	36.87

[1]Below land surface.

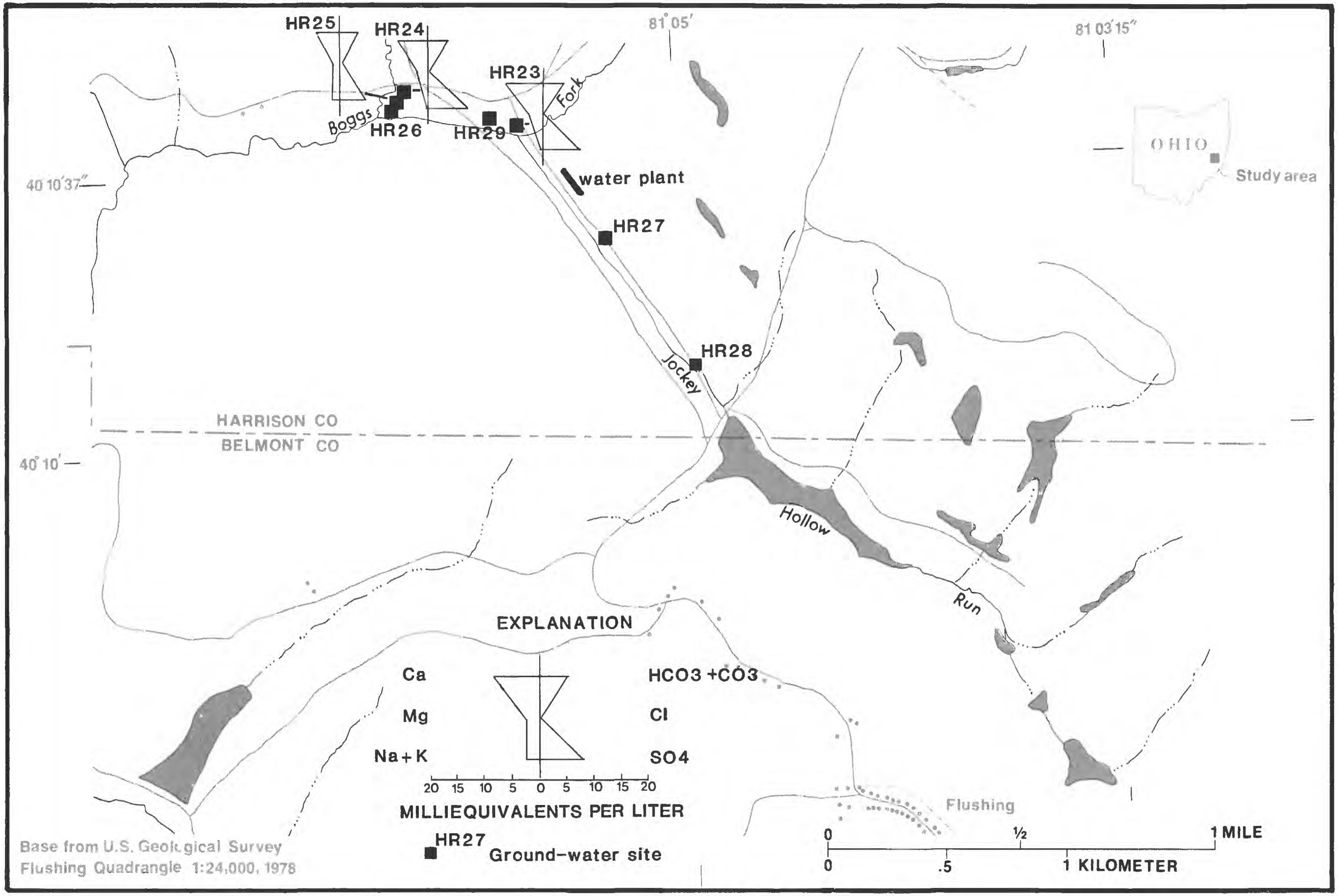


Figure 9.--Ground-water sites and Stiff diagrams for Stillwater Creek basin, Flushing, Ohio.

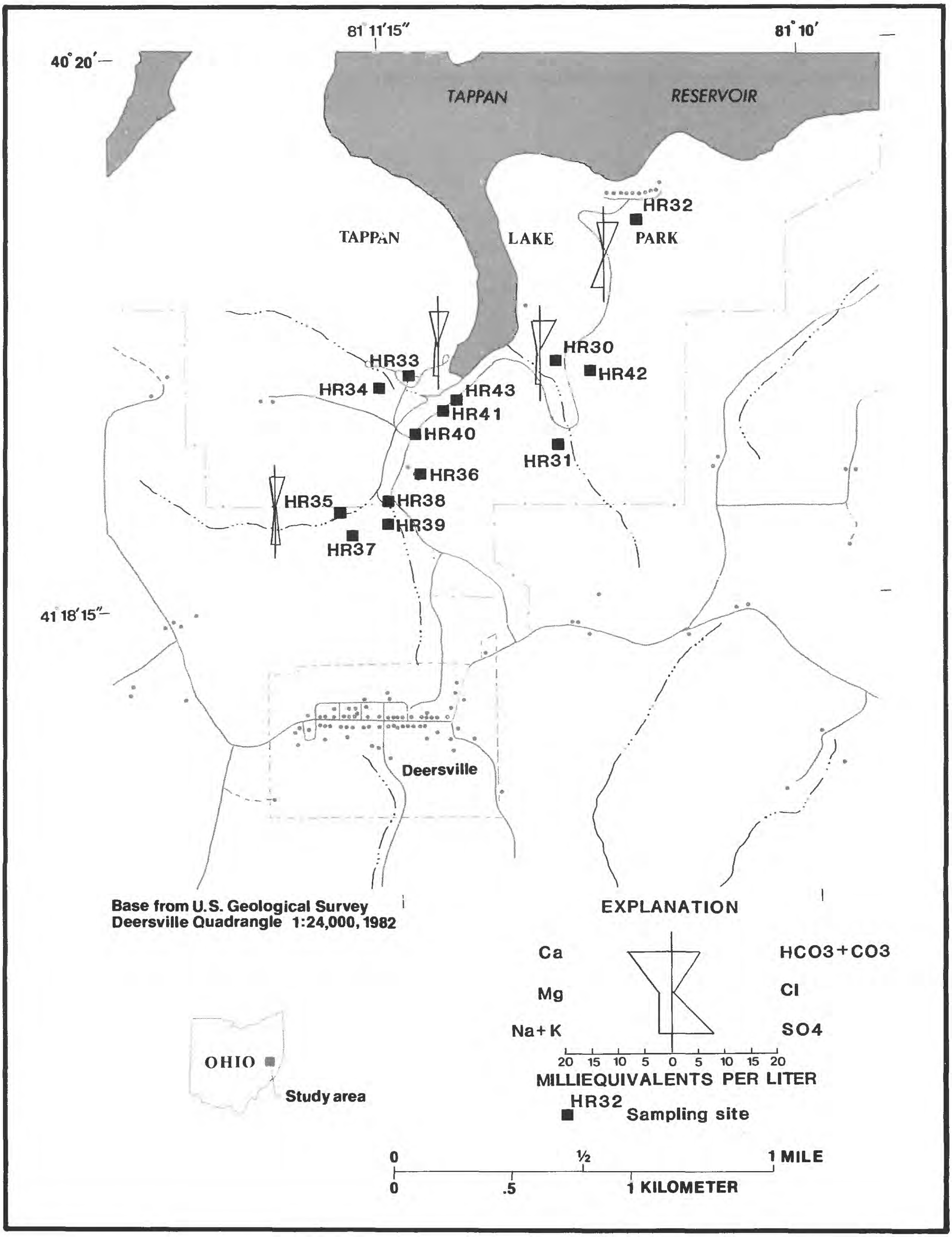


Figure 10.—Ground-water sites and Stiff diagrams for Stillwater Creek basin, Tappan Lake Park, Deersville, Ohio.

On the basis of the limited water-level data available, the ground water at Tappan Park appears to be flowing toward Tappan Lake. The wells closest to the lake approach or nearly match the level of the lake.

Water Quality

Surface-water quality of the Stillwater Creek basin was investigated by sampling 11 stream sites at low flow (fig. 8). Ground-water quality was investigated by sampling seven sites in two distinct aquifers in the basin, at the Village of Flushing, Ohio, and at Tappan Lake Park near Deersville, Ohio (figs. 9 and 10).

Surface Water

A total of 11 water-quality samples were collected from Stillwater Creek (2 sites), Boggs Fork, Brushy Fork, Clear Fork, Crooked Creek, Little Stillwater Creek, Laurel Creek, Skull Fork, Standingstone Fork, and Wolf Run, during the period September 30 through October 2, 1985 (fig. 8). Results of chemical analyses are presented in table 4 and figure 11.

Specific conductance ranged from 390 µS/cm (at site H-6) to 3,300 µS/cm (at site H-5), with a median of 1,300 µS/cm.

Values for pH ranged from 7.00 (at site H-4) to 8.00 (at site H-5), with a median of 7.60. Alkalinity concentrations ranged from 78 mg/L as $CaCO_3$ (at site H-4) to 372 mg/L (at site H-11), with a median of 212 mg/L.

The dissolved-sulfate concentration ranged from 15 mg/L (at site H-6) to 1,900 mg/L (at site H-5), with a median of 580 mg/L.

Total-iron concentrations ranged from 290 µg/L (at site H-9) to 16,000 µg/L (at site H-10), with a median of 850 µg/L. Dissolved-iron concentrations ranged from less than 10 µg/L (at site H-1) to 130 µg/L (at site H-3), with a median of 30 µg/L.

Concentrations of total aluminum ranged from 100 µg/L (at sites H-7 and H-9) to 6,500 µg/L (at site H-10), with a median of 300 µg/L. Dissolved-aluminum concentrations ranged from less than 100 µg/L (at sites H-5, H-7, H-8, and H-9) to 300 µg/L (at sites H-1 and H-3), with a median of 100 µg/L.

Total-manganese concentrations ranged from 160 µg/L (at site H-2) to 2,900 µg/L (at site H-10), with a median of 310 µg/L. Dissolved-manganese concentrations ranged from 90 µg/L (at site H-5) to 1,700 µg/L (at site H-10), with a median of 220 µg/L.

Ground Water

Three ground-water samples were obtained from the sand and gravel deposits of the water supply at the Village of Flushing (fig. 9), and four samples were obtained from shallow bedrock wells (HR-30, HR-32, HR-33, and HR-35) at Tappan Lake Park near Deersville (fig. 10). A corresponding Stiff (1951) water-quality diagram also is shown for each sampled well. Table 5 lists the results of chemical analyses. Stiff water-quality diagrams are shown in figure 10.

Most of the ground water in the Flushing area (fig. 9) can be classified as a very hard calcium sulfate type that is high in dissolved solids. In comparison to other outwash aquifers in Ohio (Evans, 1977; deRoche and Razem, 1984; Norris and Fidler, 1969), the water at Flushing appears to have elevated values of specific conductance (1,100 to 1,350 µS/cm) and total dissolved solids (883 to 1,200 mg/L). Values for pH ranged from 7.10 to 7.50, which is typical. The high carbonate concentration in water in the Conemaugh Formation may be helping to buffer acids formed as a result of mining activities if water from the bedrock below were flowing with an upward vertical component. Alkalinity ranged from 274 to 340 mg/L as $CaCO_3$.

Calcium is the most abundant cation, and ranges from 170 to 250 mg/L for the three samples. Sulfate, the most abundant anion, ranged from 390 to 590 mg/L, which exceeds the Ohio Environmental Protection Agency (OEPA) standard for public supply and is much greater than the sulfate concentration of water from other outwash aquifers. Concentrations of magnesium ranged from 31 to 54 mg/L, and sodium concentrations ranged from 20 to 56 mg/L, both slightly elevated compared with other outwash aquifers in Ohio. Hardness ranged from 550 to 840 mg/L as $CaCO_3$. Potassium concentrations ranged from 1.1 to 1.4 mg/L, which is typical of outwash aquifers in the State. Concentrations of silica and chloride ranged from 10 to 12 mg/L and 3.7 to 15 mg/L, respectively.

Concentrations of dissolved iron ranged from 17 to 3,300 µg/L; concentrations in two samples exceeded the OEPA standard for public supply. The lowest value (17 µg/L) was found in HR-24, where most of the dissolved iron and manganese had precipitated out after filtration. The precipitation was possibly caused by inadvertent aeration of the water before the sample could be taken. Total-iron concentrations ranged from 1,400 to 3,500 µg/L. Total concentrations of manganese ranged from 1,400 to 3,100 µg/L and dissolved manganese from 780 to 3,100 µg/L. All three of the samples exceeded the OEPA standard. Concentrations of total aluminum were 100 µg/L in all three samples. Total organic carbon ranged from 2.2 to 4.2 mg/L, which is considerably higher than the approximate natural concentration of 0.7 mg/L for Ohio ground water reported by Thurman (1985).

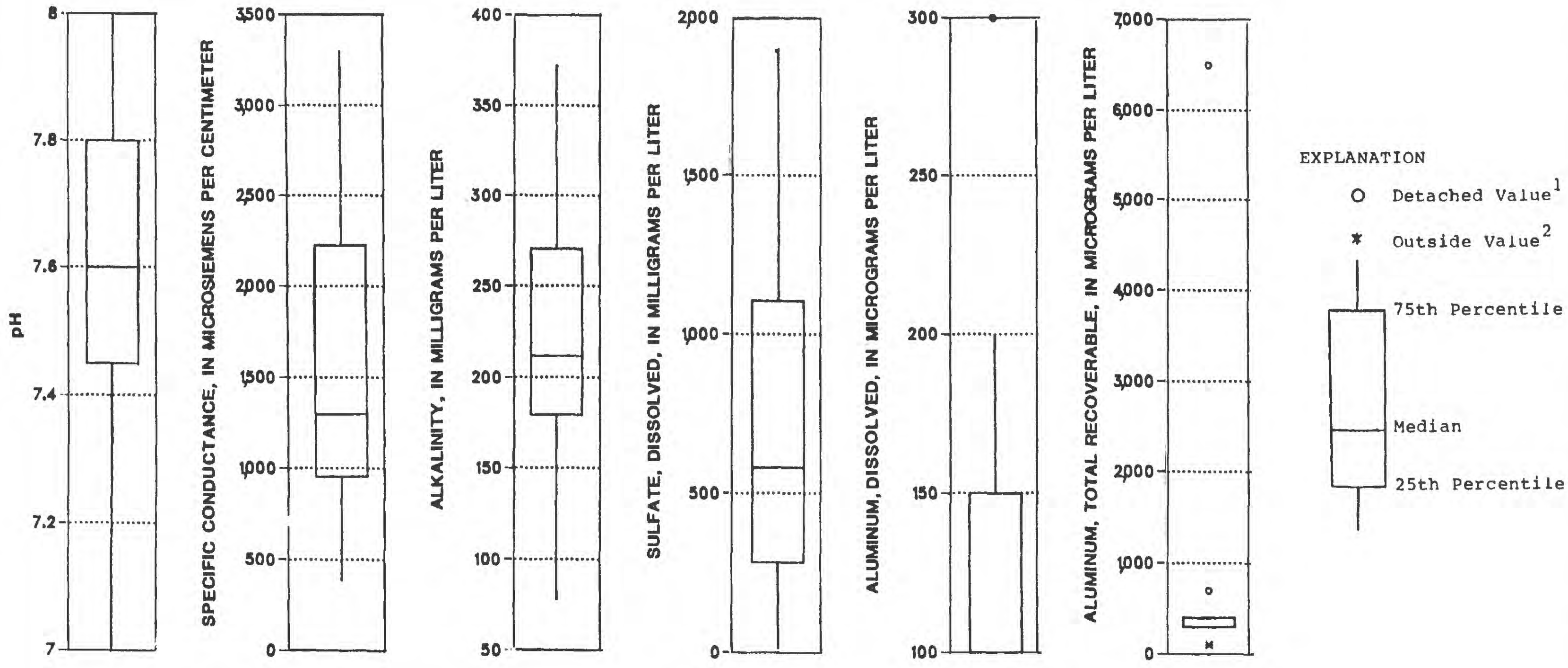
Table 4.--Water-quality data for short-term

[deg. C, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter;

Date	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duc-tance (µS/cm)	ph (stand-ard units)	Temper-ature (deg. C)	Acidity (mg/L as $CaCO_3$)	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Alum-inum, total recov-erable (µg/L as Al)
03127500 H-1 Stillwater C at Uhrichsville OH (lat 40 23 10n long 081 20 50w)								
Sep 1985 30...	12	1,200	7.60	19.0	--	206	390	700
400506081073900 H-2 Stillwater C nr Hendrysburg OH (lat 40 05 06n long 081 07 39w)								
Oct 1985 02...	2.2	2,580	7.70	14.0	--	256	1,300	300
401126081121600 H-3 Boggs Fork at Piedmont OH (lat 40 11 26n long 081 12 16w)								
Oct 1985 01...	4.6	1,950	7.70	15.0	--	233	910	300
03126170 H-4 Skull F at Freeport OH (lat 40 11 52n long 081 16 13w)								
Sep 1985 30...	0.28	1,300	7.00	14.0	--	78	580	300
401538081070100 H-5 Brushy Fork nr Cadiz OH (lat 40 15 38n long 081 07 01w)								
Oct 1985 01...	3.7	3,300	8.00	14.0	--	285	1,900	--
401647081194200 H-6 Laurel Cr nr Tippecanoe OH (lat 40 16 47n long 081 19 42w)								
Sep 1985 30...	0.3	390	7.50	18.0	--	155	15	400
03127100 H-7 Crooked C nr Stillwater OH (lat 40 18 29n long 081 19 26w)								
Sep 1985 30...	0.18	500	7.40	18.0	--	212	19	100
401724081032100 H-8 Standingstone F nr Cadiz OH (lat 40 17 16n long 081 02 33w)								
Oct 1985 01...	1.1	2,500	7.90	13.0	--	295	1,400	300
402012081051300 H-9 Clear Fork nr Jewett OH (lat 40 20 12n long 081 05 13w)								
Oct 1985 01...	0.45	1,900	7.60	14.5	--	182	910	100
03128600 H-10 L Stillwater C nr Dennison OH (lat 40 24 19n long 081 17 18w)								
Oct 1985 01...	8.4	710	7.20	15.0	--	177	230	6,500
402429081185300 H-11 Wolf Run nr Dennison OH (lat 40 24 29n long 081 18 53w)								
Oct 1985 01...	0.8	1,300	7.90	11.5	--	372	340	300

µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Aluminum, suspended recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Iron, total recoverable (µg/L as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03127500 H-1 Stillwater C at Uhrichsville OH (lat 40 23 10n long 081 20 50w)							
400	300	1,700	--	<10	1,300	900	400
400506081073900 H-2 Stillwater C nr Hendrysburg OH (lat 40 05 06n long 081 07 39w)							
200	100	580	530	50	160	20	140
401126081121600 H-3 Boggs Fork at Piedmont OH (lat 40 11 26n long 081 12 16w)							
0	300	380	250	130	310	110	200
03126170 H-4 Skull F at Freeport OH (lat 40 11 52n long 081 16 13w)							
200	100	540	490	50	530	120	410
401538081070100 H-5 Brushy Fork nr Cadiz OH (lat 40 15 38n long 081 07 01w)							
--	<100	1,200	1,200	30	210	120	90
401647081194200 H-6 Laurel Cr nr Tippecanoe OH (lat 40 16 47n long 081 19 42w)							
300	100	1,100	1,000	60	640	110	530
03127100 H-7 Crooked C nr Stillwater OH (lat 40 18 29n long 081 19 26w)							
--	<100	850	760	90	720	40	680
401724081032100 H-8 Standingstone F nr Cadiz OH (lat 40 17 16n long 081 02 33w)							
--	<100	530	520	10	220	10	210
402012081051300 H-9 Clear Fork nr Jewett OH (lat 40 20 12n long 081 05 13w)							
--	<100	290	270	20	250	30	220
03128600 H-10 L Stillwater C nr Dennison OH (lat 40 24 19n long 081 17 18w)							
6400	100	16,000	16,000	10	2,900	1,200	1,700
402429081185300 H-11 Wolf Run nr Dennison OH (lat 40 24 29n long 081 18 53w)							
100	200	950	940	10	230	30	200



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a >1.5 and ≤3 interquartile ranges from the box.

n = 11 samples

Figure 11.--Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Stillwater Creek basin.

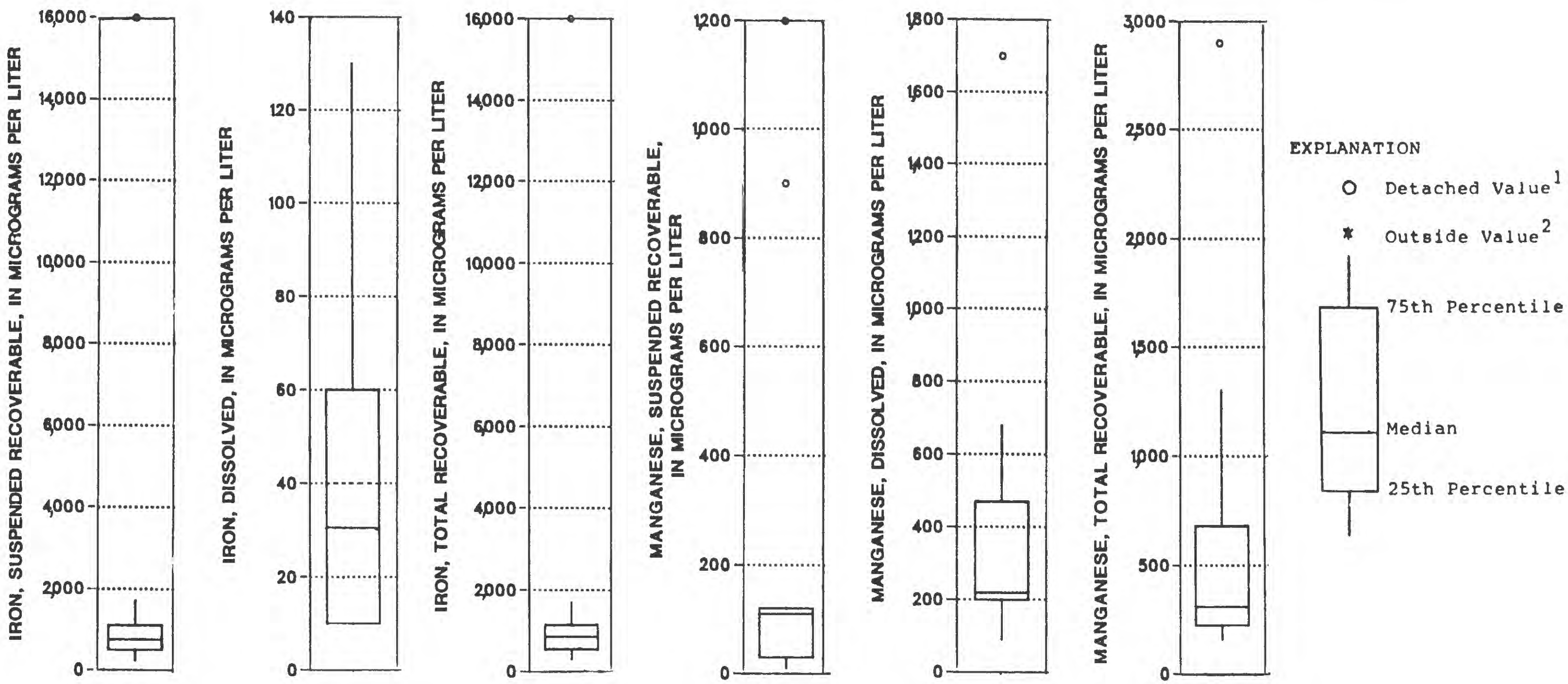


Figure 11.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Stillwater Creek basin--Continued.

Tappan Lake Park (fig. 10), the second area in the Stillwater Creek basin to be evaluated for ground-water quality, is located near Deersville, and is owned and administrated by the Muskingum Watershed Conservancy District. No coal has been mined in this area. The results of this evaluation will provide background data on the quality of shallow bedrock aquifers in this part of Ohio.

Analyses show that Tappan Park has a moderately hard to hard calcium bicarbonate type ground water. Dissolved-solids concentrations ranged from 194 to 311 mg/L, which is below the limit of 500 mg/L recommended by the U.S. Environmental Protection Agency (1986) for a public supply and is slightly below the average noted in other bedrock aquifers in Ohio (Razem and Sedam, 1985). Specific conductance ranged from 320 to 500 µS/cm. Values for pH ranged from 7.20 to 7.70. Alkalinity ranged from 173 to 263 mg/L as $CaCO_3$.

Calcium is the most abundant cation with a range of 27 to 50 mg/L for the four samples. One sample (HR-35) did not have a dominant cation, and one sample (HR-32) had unusually high concentrations of sodium and potassium (73 mg/L and 3.2 mg/L, respectively). Bicarbonate, the most abundant anion, was present in concentrations of 211 to 321 mg/L. Magnesium concentrations ranged from 8.3 to 12 mg/L, and sodium concentrations ranged from 21 to 73 mg/L. Hardness ranged from 100 to 170 mg/L as $CaCO_3$, which is classified by the USEPA as moderately hard to hard. Potassium concentrations ranged from 1.5 to 3.2 mg/L. Silica and chloride concentrations ranged from 11 to 17 mg/L and from 3.7 to 14 mg/L, respectively. Total organic carbon in the Tappan wells ranged from 0.8 to 1.4 mg/L.

Concentrations of iron (1,400 to 2,000 µg/L total and 710 to 1,200 µg/L dissolved) and manganese (80 to 370 µg/L total) exceeded the OEPA standards for public supply in the four samples. Total aluminum was 100 µg/L in three samples; in water from HR-30, the total aluminum concentration was 600 µg/L.

Table 5.--Ground-water analyses for the Stillwater Creek basin, Flushing, Ohio, and Tappan Lake Park, Deersville, Ohio

[deg. C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Date	Depth below land surface (water level) (feet)	Specific conductance (µS/cm)	ph (standard units)	Temperature (deg. C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate, field (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
Flushing wells:									
401043081052800 HR-23 (lat 40 10 43n long 081 05 28w)									
11/21/85	--	1,350	7.10	10.0	2.0	840	500	250	53
401049081054700 HR-24 (lat 40 10 49n long 081 05 47w)									
11/21/85	--	1,350	7.30	10.0	--	770	460	220	54
401047081054700 HR-25 (lat 40 10 47n long 081 05 47w)									
11/21/85	16.80	1,100	7.50	10.0	--	550	280	170	31
Tappan wells:									
401920081104300 HR-30 (lat 40 19 20n long 081 10 43w)									
11/22/85	9.35	400	7.40	11.0	0.7	170	0	50	12
401937081103000 HR-32 (lat 40 19 37n long 081 10 30w)									
11/22/85	34.00	500	7.65	11.5	0.4	100	0	27	8.3
401917081111200 HR-33 (lat 40 19 17n long 081 11 12w)									
11/22/85	10.00	380	7.70	11.5	--	150	0	42	10
401858081112200 HR-35 (lat 40 18 58n long 081 11 22w)									
11/22/85	--	320	7.20	11.5	0.2	120	0	33	9.4

Table 5.--Ground-water analyses for the Stillwater Creek basin, Flushing, Ohio, and Tappan Lake Park, Deersville, Ohio--Continued

Date	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate, field (mg/L as HCO_3)	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Silica, dis-solved (mg/L as SiO_2)	Solids, residue at 180 deg. C dis-solved (mg/L)
Flushing wells:								
401043081052800 HR-23 (lat 40 10 43n long 081 05 28w)								
11/21/85	20	1.4	415	340	560	6.2	12	1,200
401049081054700 HR-24 (lat 40 10 49n long 081 05 47w)								
11/21/85	20	1.4	371	304	590	3.7	12	1,200
401047081054700 HR-25 (lat 40 10 47n long 081 05 47w)								
11/21/85	56	1.1	334	274	390	15	10	883
Tappan wells:								
401920081104300 HR-30 (lat 40 19 20n long 081 10 43w)								
11/22/85	21	1.7	306	251	18	6.0	14	248
401937081103000 HR-32 (lat 40 19 37n long 081 10 30w)								
11/22/85	73	3.2	321	263	11	14	11	311
401917081111200 HR-33 (lat 40 19 17n long 081 11 12w)								
11/22/85	23	1.5	257	211	9.9	3.7	16	222
401858081112200 HR-35 (lat 40 18 58n long 081 11 22w)								
11/22/85	22	2.3	211	173	12	6.1	17	194

Table 5.--Ground-water analyses for the Stillwater Creek basin, Flushing, Ohio, and Tappan Lake Park, Deersville, Ohio--Continued

Date	Solids, sum of constituents, dissolved (mg/L)	Aluminum, total recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Aluminum, suspended recoverable (µg/L as Al)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Carbon, organic total (mg/L as C)
Flushing wells:									
401043081052800 HR-23 (lat 40 10 43n long 081 05 28w)									
11/21/85	1,100	100	<100	--	3,500	3,300	3,100	3,100	2.2
401049081054700 HR-24 (lat 40 10 49n long 081 05 47w)									
11/21/85	1,100	100	<100	--	3,000	17	2,800	780	2.7
401047081054700 HR-25 (lat 40 10 47n long 081 05 47w)									
11/21/85	840	100	100	0	1,400	1,100	1,400	1,600	4.2
Tappan wells:									
401920081104300 HR-30 (lat 40 19 20n long 081 10 43w)									
11/22/85	270	600	<100	--	1,400	710	250	300	1.4
401937081103000 HR-32 (lat 40 19 37n long 081 10 30w)									
11/22/85	310	100	100	0	1,800	1,200	80	72	0.8
401917081111200 HR-33 (lat 40 19 17n long 081 11 12w)									
11/22/85	230	100	<100	--	1,800	730	370	390	1.4
401858081112200 HR-35 (lat 40 18 58n long 081 11 22w)									
11/22/85	210	100	<100	--	2,000	910	140	160	1.4

Symmes, Ice, and Indian Guyan Creeks Basin

Geologic Setting

The Symmes, Ice, and Indian Guyan Creeks basin (fig. 2) is principally in the Lexington Peneplain section of the Appalachian Plateaus physiographic province (Fenneman, 1938). It is deeply dissected by streams and is rugged and hilly, with numerous, V-shaped steep valleys with steeply sloping sides. Most streams are in a youthful stage--that is, they have no flood plains and are actively downcutting. Symmes Creek, however, is in a mature stage, and the valley is broad and bordered by low, rounded hills. The western part of the basin, including Ice Creek, is largely underlain by sandstone of the Allegheny Formation, which forms steep cliffs or outlying knobs or hills in many areas. Commonly, streams have steep, rock-walled, overhanging valleys. The Symmes and Indian Guyan Creeks valleys to the east are underlain by more shaly rock of the Conemaugh and Monongahela Formations, which are characterized by more gentle slopes. The divides in the eastern part of the basin are long and broad.

The subsurface of the Symmes, Ice, and Indian Guyan Creeks basin is composed of layers of shale, sandstone, coal, and limestone of Pennsylvanian age. Because of the slight dip of the rock strata to the east at an average of 25 feet per mile (Stout, 1916), these layers crop out in irregular north-south bands across the basin and are successively younger from west to east (Maxey, 1940). The Allegheny Formation, which consists of mostly sandstone and shale, crops out in the extreme western and north-central parts of the basin. The Conemaugh Formation, which consists of shales, limestone, coal, and sandstone, covers the central part of the basin in a wide belt. Only in the extreme eastern part of the basin does the Monongahela Formation crop out. It consists of shales, limestones, coal, and sandstones (Pree, 1962).

Pleistocene and Holocene alluvial deposits of gravel, sand, silt, and clay overlie the bedrock throughout the uplands and generally are less than 50 feet thick. The flood plains of many of the streams in the basin are underlain by thin deposits composed of clay, silt, and only small amounts of sand and gravel. The deposits along the Ohio River, which consist of thick, permeable sand and gravel and interbedded clays, are more than 78 feet thick along the reach of river in this basin and some wells yield as much as 1,000 gal/min with proper development (Pree, 1962).

The bedrock in this basin yields generally less than 5 gal/min. Most wells are finished in sandstone of the Conemaugh Formation. Logs from these wells indicate that the sandstone beds generally are thin and range from 5 to 30 feet in thickness. In many parts of the basin, cisterns are used as a supplementary source of water (Pree, 1962).

All streams in the basin flow into the Ohio River. A few streams in the extreme eastern and southern parts of the basin that drain directly into the Ohio River (that is, are not tributary to the Symmes, Ice, or Indian Guyan Creeks) are included in this basin for purposes of this study.

Water Quality

Surface-water quality of the Symmes, Ice, and Indian Guyan Creeks basin was investigated by sampling 12 stream sites at low flow (fig. 12). Ground-water quality was not investigated in this basin because of a lack of a productive aquifer.

Surface-water-quality samples were collected from Symmes Creek (two sites), Indian Guyan Creek (two sites), Ice Creek, Little Indian Guyan Creek, Black Fork, Sand Fork, Johns Creek, Aaron Creek, Long Creek, and Swan Creek on October 1, 1985, between November 25 and 26, 1985, or on December 19, 1985 (fig. 12). Results of chemical analyses are presented in table 6 and figure 13.

Specific conductance ranged from 250 μS/cm (at site T-3) to 465 μS/cm (at site T-2), with a median of 370 μS/cm.

Values of pH ranged from 6.70 (at site T-11) to 7.90 (at site T-7), with a median of 7.50. Alkalinity ranged from 10 mg/L as $CaCO_3$ (at site T-11) to 182 mg/L (at site T-2), with a median of 94 mg/L.

Dissolved-sulfate concentrations ranged from 53 mg/L (at site T-1) to 170 mg/L (at site T-11), with a median of 81 mg/L.

Total-iron concentrations ranged from 350 μg/L (at site T-5) to 1,000 μg/L (at site T-6), with a median of 680 μg/L. Dissolved-iron concentrations ranged from 20 μg/L (at site T-9) to 150 μg/L (at site T-1), with a median of 90 μg/L. Concentrations of total aluminum ranged from 100 μg/L (at sites T-2, T-5, and T-12) to 2,000 μg/L (at site T-11), with a median of 200 μg/L. Dissolved-aluminum concentrations were less than 100 or 100 μg/L at all sites. Total-manganese concentrations ranged from 120 μg/L (at site T-7) to 1,700 μg/L (at site T-1), with a median of 235 μg/L; dissolved-manganese concentrations ranged from 120 μg/L (at site T-7) to 1,400 μg/L (at site T-1), with a median of 230 μg/L.

Table 6.--Water-quality data for short-term surface-water

[deg. C, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter;

Date	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duc-tance (µS/cm)	ph (stand-ard units)	Temper-ature (deg. C)	Acidity (mg/L as $CaCO_3$)	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/l as SO_4)	Alum-inum, total recov-erable (µg/L as Al)
383005082280600 T-1 Symmes C nr Getaway OH (lat 38 30 05n long 082 28 06w)								
Oct 1985								
01...	1.3	410	7.10	15.0	--	105	53	200
382715082242400 T-2 Indian Guyan C nr Bradrick OH (lat 38 27 15n long 082 24 24w)								
Oct 1985								
01...	0.24	465	7.50	14.5	--	182	74	100
385026082294700 T-3 Black F nr Gallia OH (lat 38 50 26n long 082 29 47w)								
Nov 1985								
26...	25	250	7.20	10.0	--	38	62	200
385028082293700 T-4 Symmes C nr Gallia OH (lat 38 50 28n long 082 29 37w)								
Nov 1985								
26...	16	360	7.10	9.5	--	41	110	300
384613082233600 T-5 Sand F nr Patriot OH (lat 38 46 13n long 082 23 36w)								
Nov 1985								
26...	12	340	7.50	11.5	--	103	100	100
384125082283700 T-6 Johns C nr Waterloo OH (lat 38 41 25n long 082 28 37w)								
Nov 1985								
26...	6.0	290	7.50	10.5	--	72	67	200
383841082271400 T-7 Long C nr Wilgus OH (lat 38 38 41n long 082 27 14w)								
Nov 1985								
26...	4.0	350	7.90	10.5	--	133	71	200
383943082291700 T-8 Aaron C nr Arabia OH (lat 38 39 43n long 082 29 17w)								
Nov 1985								
26...	2.6	400	7.80	11.0	--	113	110	200
03216050 T-9 Ice C at Ironton OH (lat 38 31 01n long 082 38 29w)								
Nov 1985								
25...	14	410	7.80	9.0	--	83	87	200
383332082205600 T-10 Indian Guyan C at Platform OH (lat 38 33 32n long 082 20 56w)								
Dec 1985								
19...	--	435	7.30	0.5	--	87	140	200
383301082231400 T-11 L Indian Guyan C at Scottown OH (lat 383301n long 082 23 14w)								
Dec 1985								
19...	7.4	380	6.70	2.0	--	10	170	2,000
383657082124400 T-12 Swan C nr Bladen OH (lat 38 36 57n long 082 12 44w)								
Nov 1985								
25...	2.8	310	7.80	9.0	--	100	64	100

µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Aluminum suspended recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Iron, total recoverable (µg/L as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
383005082280600 T-1 Symmes C nr Getaway OH (lat 38 30 05n long 082 28 06w)							
--	<100	860	710	150	1,700	300	1,400
382715082242400 T-2 Indian Guyan C at Bradrick OH (lat 38 27 15n long 082 24 24w)							
--	<100	360	220	140	550	100	450
385026082294700 T-3 Black F nr Gallia OH (lat 38 50 26n long 082 29 47w)							
--	<100	850	780	70	480	20	460
385028082293700 T-4 Symmes C nr Gallia OH (lat 38 50 28n long 082 29 37w)							
200	100	900	790	110	230	10	220
384613082233600 T-5 Sand F nr Patriot OH (lat 38 46 13n long 082 23 36w)							
0	100	350	300	50	220	0	220
384125082283700 T-6 Johns C nr Waterloo OH (lat 38 41 25n long 082 28 37w)							
--	<100	1,000	860	140	240	0	240
383841082271400 T-7 Long C nr Wilgus OH (lat 38 38 41n long 082 27 14w)							
100	100	670	630	40	120	0	120
383943082291700 T-8 Aaron C nr Arabia OH (lat 38 39 43n long 082 29 17w)							
100	100	560	480	80	160	0	160
03216050 T-9 Ice C at Ironton OH (lat 38 31 01n long 082 38 29w)							
100	100	690	670	20	200	0	200
383332082205600 T-10 Indian Guyan C at Platform OH (lat 38 33 32n long 082 20 56w)							
--	<100	540	440	100	310	0	310
383301082231400 T-11 L Indian Guyan C at Scottown OH (lat 383301n long 0822314w)							
--	<100	960	830	130	1,300	0	1,300
383657082124400 T-12 Swan C nr Bladen OH (lat 38 36 57n long 082 12 44w)							
0	100	640	590	50	140	0	140

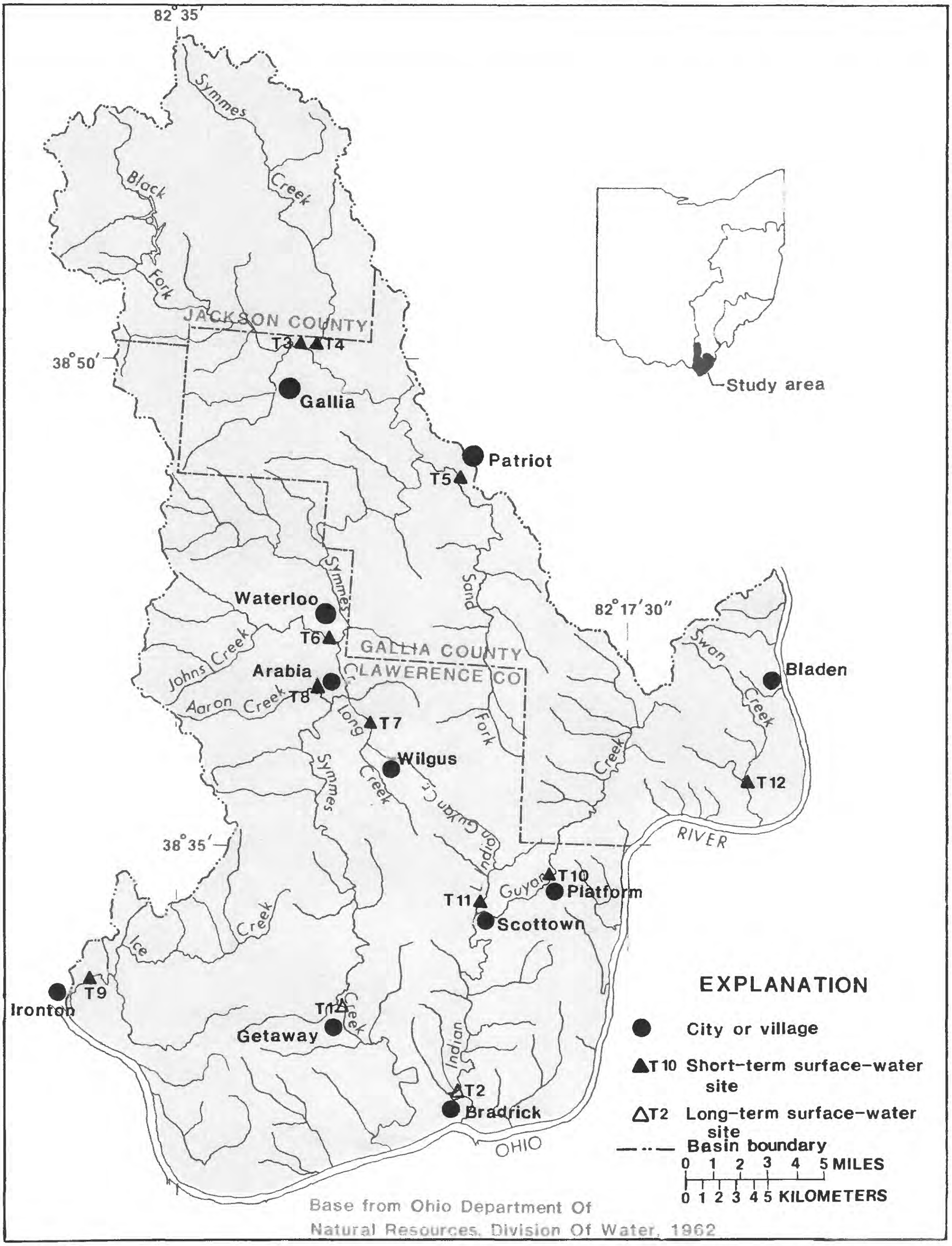
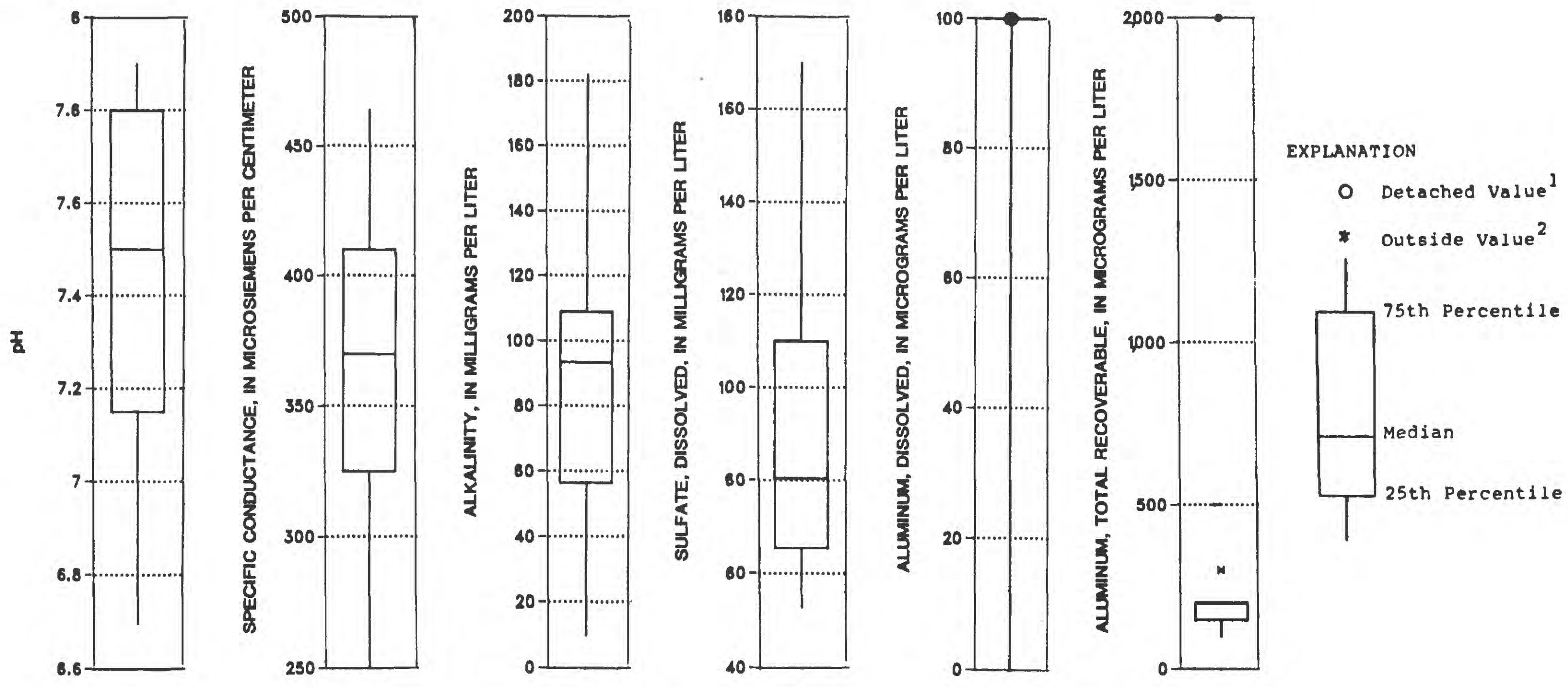


Figure 12.--Short-term and long-term surface-water sites in the Symmes, Ice, and Indian Guyan Creeks basin.



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a >1.5 and ≤3 interquartile ranges from the box.

n = 12 samples

Figure 13.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Symmes, Ice, and Indian Guyan Creeks basin.

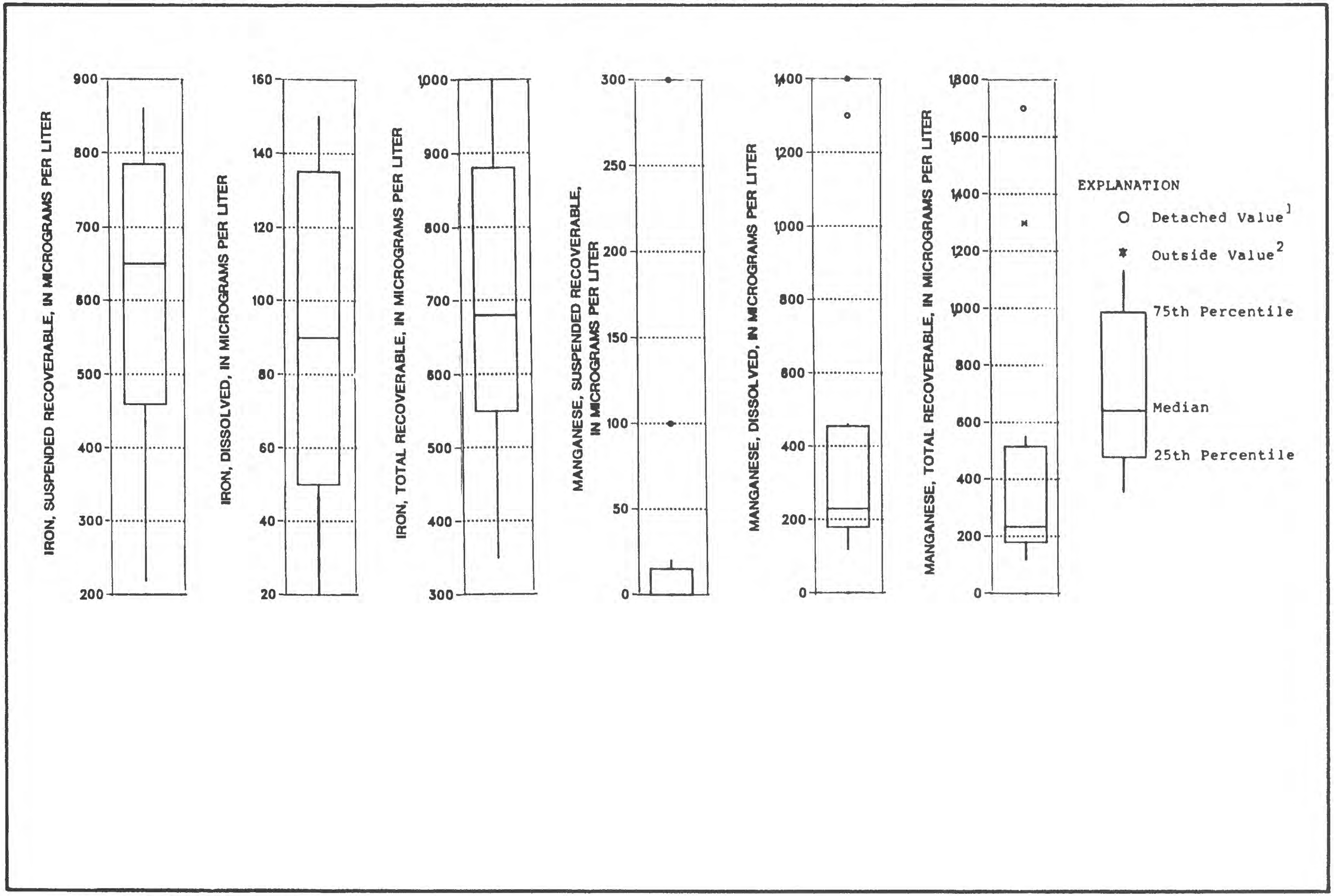


Figure 13.--Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Symmes, Ice, and Indian Guyan Creeks basin--Continued.

Moxahala Creek Basin

Geologic Setting

The geologic formations underlying the Moxahala Creek basin (fig. 2) consist of sandstone, shale, limestone, and coal of Mississippian and Pennsylvanian age and glacial deposits of clay, silt, sand, and gravel of Quaternary age.

Most of the basin is included in the Kanawha section of the Appalachian Plateaus physiographic province (Fenneman, 1938). There is a sharp contrast between the topography of the northwestern part of the basin, in which glaciation makes the area one of subdued topography with a relief of about 100 feet, and the unglaciated southeastern part of the basin, where the topography is mature and the relief averages 200 feet.

The Moxahala Creek basin lies on the eastern flank of the Cincinnati Arch, which dips to the east-southeast at an average rate of 25 to 30 feet per mile. Therefore, the oldest rocks of Mississippian age crop out in the western and northwestern part of the basin, and the youngest beds, those of the Conemaugh Formation, are exposed in the eastern and southeastern part of the basin (Flint, 1951).

The northwestern part of the basin lies within the glaciated part of Ohio. The drift deposits average 30 feet in thickness over the bedrock in the upland areas, and are primarily clay containing lenses of sand and gravel. Most wells are drilled through the thin drift into the underlying sandstone and shale. Wells drilled in these bedrock formations generally yield adequate water supplies for farm and domestic needs. Although small industrial and municipal supplies have been reported from sandstones, yields of 5 to 10 gal/min are more typical of bedrock wells in the basin. In the unglaciated part of the basin, the depth to bedrock averages 10 feet. In the southeastern part of the basin, where shales predominate, supplies of less than 5 gal/min are to be expected. Many wells drilled in this area have inadequate yields, and owners must rely on shallow dug wells and cisterns (Walker, 1962b).

Deposits of sand, gravel, and clay that fill a buried valley beneath the present valley of Jonathan Creek are more than 200 feet thick in places. Wells in these deposits have yields of as much as 200 gal/min (Walker, 1962b). Additional drilling and aquifer tests would be needed to locate and fully define permeable horizons within this buried valley. Other unconsolidated deposits as much as 80 feet thick fill parts of the Moxahala and Jonathan Creeks valley (Walker, 1962b).

Ground water was investigated in the glacial outwash deposit that follows the valley of Jonathan Creek, a major tributary to Moxahala Creek (fig. 14). Seventeen water-level measurements were obtained and are listed in table 3. The available wells

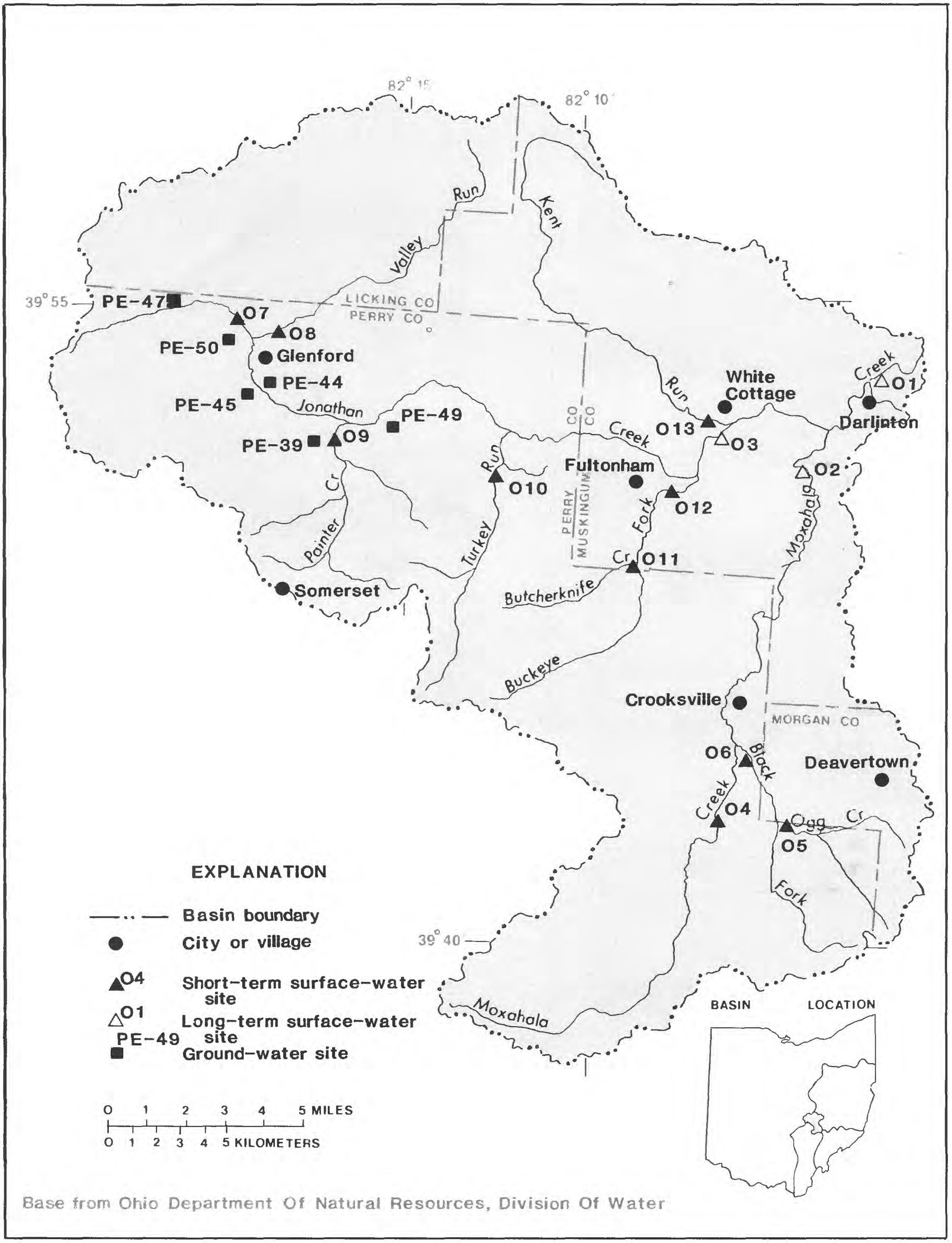


Figure 14.—Short-term and long-term surface-water sites and ground-water sites in Moxahala Creek basin.

completed in the sand and gravel did not extend far beyond the stream valley; therefore, it was impossible to draw a meaningful potentiometric surface with this limited number of observations, but it is likely that the local ground-water flow is toward the stream. Locations of wells are shown in figure 15.

Water Quality

Surface-water quality of the Moxahala Creek basin was investigated by sampling 13 stream sites at low flow (fig. 14). The ground-water quality was investigated in the Jonathan Creek valley near Glenford, Ohio (fig. 15).

Surface Water

Water-quality samples were collected from Moxahala Creek (three sites), Ogg Creek, Black Fork, Jonathan Creek (two sites), Valley Run, Painter Creek, Turkey Run, Butcherknife Creek, Buckeye Fork, and Kent Run during the period October 20 through October 22, 1986 (fig. 14). Results of chemical analyses are presented in table 7 and figure 16. Mining is presently active immediately adjacent to Ogg Creek in this basin.

Specific conductance ranged from 520 µS/cm (at site O-9) to 4,600 µS/cm (at site O-6), with a median of 1,600 µS/cm.

pH ranged from 3.44 (at site O-2) to 9.20 (at site O-8), with a median of 6.60. Six samples had measurable acidity. The concentrations ranged from 9.0 mg/L as $CaCO_3$ (at site O-1) to 465 mg/L (at site O-5), with a median of 163 mg/L. Ten samples had measurable alkalinity. Alkalinity concentrations ranged from 2.0 mg/L as $CaCO_3$ (at site O-6) to 425 mg/L (at site O-8), with a median of 88 mg/L.

Dissolved-sulfate concentrations ranged from 42 mg/L (at site O-7) to 2,800 mg/L (at site O-5), with a median of 800 mg/L.

Total-iron concentrations ranged from 400 µg/L (at sites O-7 and O-9) to 110,000 µg/L (at site O-5), with a median of 1,000 µg/L. Dissolved-iron concentrations ranged from 30 µg/L (at site O-3) to 120,000 µg/L (at site O-5), with a median of 500 µg/L. Total-manganese concentrations ranged from 90 µg/L (at site O-9) to 25,000 µg/L (at site O-4), with a median of 5,900 µg/L. Dissolved-manganese concentrations ranged from 80 µg/L (at site O-9) to 23,000 µg/L (at site O-4), with a median of 5,700 µg/L. Concentrations of total aluminum ranged from 70 µg/L (at site O-9) to 26,000 µg/L (at site O-5), with a median of 360 µg/L. Dissolved-aluminum concentrations ranged from 10 µg/L (at site O-9) to 24,000 µg/L (at site O-5), with a median of 80 µg/L. Water with a pH below 4.0 can contain several hundred or even several thousand milligrams of aluminum per liter.

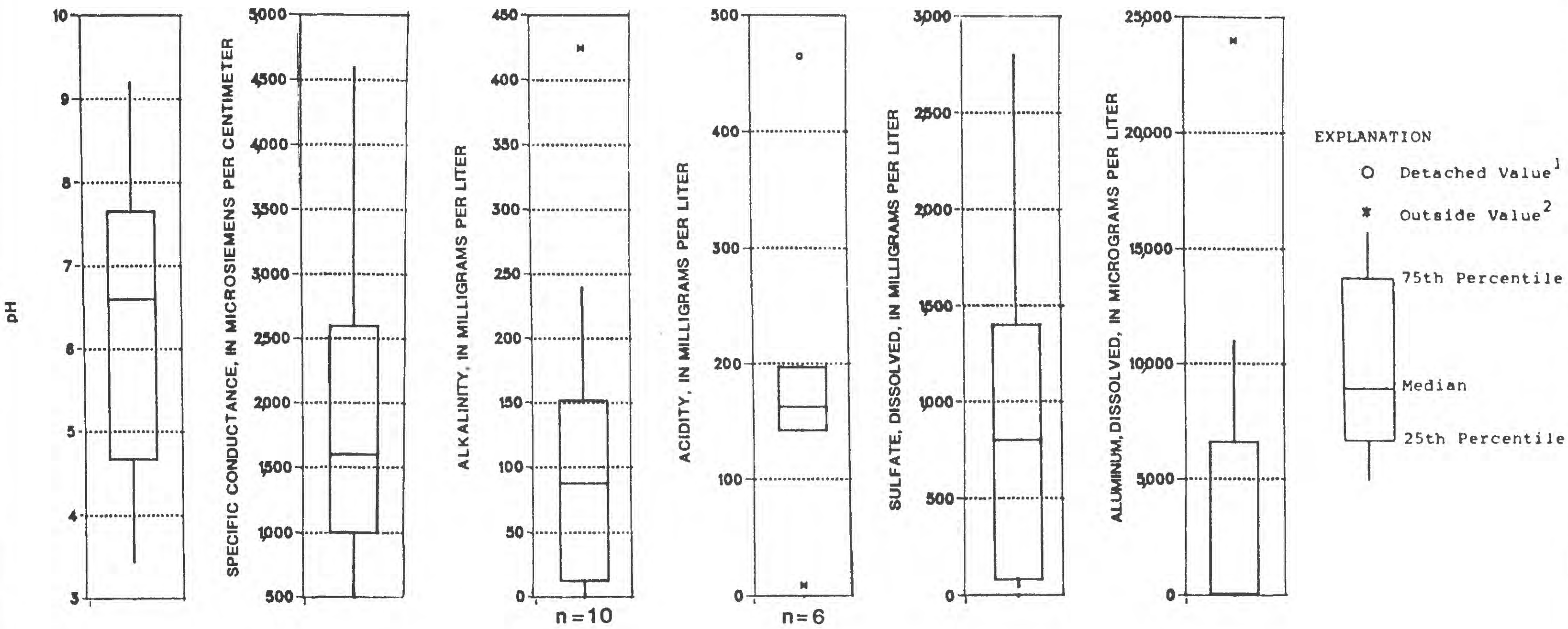
Table 7.--Water-quality data for short-term

[deg. C, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter;

Date	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duc-tance (µS/cm)	ph (stand-ard units)	Temper-ature (deg. C)	Acidity (mg/L as $CaCO_3$)	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Alum-inum, total recov-erable (ug/L as Al)
395337082011100 O-1 Moxahala C nr Darlington OH (lat 39 53 37n long 082 01 11w)								
Oct 1986								
22...	25	1,600	6.30	12.0	9.0	25	800	360
03148400 O-2 Moxahala C at Roberts OH (lat 39 51 17n long 082 03 23w)								
Oct 1986								
22...	12	2,600	3.44	11.0	148	--	1,400	8,600
395214082055470 O-3 Jonathan C at White Cottage OH (lat 395214n long 0820547w								
Oct 1986								
22...	9.5	1,050	7.46	12.5	--	120	310	280
03148150 O-4 Moxahala C nr Crooksville OH (lat 39 43 52n long 082 06 04w)								
Oct 1986								
21...	6.4	2,600	3.50	11.0	197	--	1,600	7,500
394340082041200 O-5 Ogg C nr Deavertown OH (lat 39 43 40n long 082 04 12w)								
Oct 1986								
21...	0.13	4,500	4.67	15.5	465	8	2,800	26,000
394519082051600 O-6 Black F nr Crooksville OH (lat 39 45 19n long 082 05 16w)								
Oct 1986								
21...	1.2	4,600	4.89	12.0	177	2	2,700	4,200
395432082194000 O-7 Jonathan C nr Glenford OH (lat 39 54 32n long 082 19 40w)								
Oct 1986								
20...	2.1	540	7.10	8.0	--	240	42	100
395419082184400 O-8 Valley Rn nr Glenford OH (lat 39 54 19n long 082 18 44w)								
Oct 1986								
20...	2.2	540	9.20	8.0	--	425	60	270
395210082165600 O-9 Painter C nr Somerset OH (lat 39 52 10n long 082 16 56w)								
Oct 1986								
20...	0.57	520	8.42	8.0	--	152	59	70
395128082121600 O-10 Turkey Rn nr Somerset OH (lat 39 51 28n long 082 12 16w)								
Oct 1986								
20...	0.39	1,000	7.65	8.5	--	56	390	110
394919082082000 O-11 Butcherknife C nr Fultonham OH (lat 394919n long 0820820w)								
Oct 1986								
20...	0.39	1,600	3.77	9.0	142	--	960	12,000
395048082072000 O-12 Buckeye F nr East Fultonham OH (lat 395048n long 0820720w)								
Oct 1986								
22...	1.8	1,600	6.60	12.0	--	13	900	1,200
395217082055300 O-13 Kent Rn at White Cottage OH (lat 39 52 17n long 082 05 53w)								
Oct 1986								
22...	0.13	1,100	7.86	12.0	--	151	82	190

µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Aluminum, suspended recoverable (µg/L as Al)	Aluminum, dissolved (µg/L) as Al)	Iron, total recoverable (µg/L) as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L) as Fe)	Manganese, total recoverable (µg/L) as Mn)	Manganese, suspended recoverable (µg/L) as Mn)	Manganese, dissolved (µg/L) as Mn)
395337082011100 O-1 Moxahala C nr Darlington OH (lat 39 53 37n long 082 01 11w)							
300	60	1,100	250	850	6,400	0	6,600
03148400 O-2 Moxahala C at Roberts OH (lat 39 51 17n long 082 03 23w)							
400	8,200	11,000	0	11,000	14,000	0	16,000
395214082054700 O-3 Jonathan C at White Cottage OH (lat 39 52 14n long 082 05 47w)							
200	80	420	390	30	2,500	0	2,600
03148150 O-4 Moxahala C nr Crooksville OH (lat 39 43 52n long 082 06 04w)							
900	6,600	24,000	4,000	20,000	25,000	2,000	23,000
394340082041200 O-5 Ogg C nr Deavertown OH (lat 39 43 40n long 082 04 12w)							
2,000	24,000	11,000	0	12,000	9,300	0	9,500
394519082051600 O-6 Black F nr Crooksville OH (lat 39 45 19n long 082 05 16w)							
600	3,600	64,000	5,000	59,000	5,900	200	5,700
395432082194000 O-7 Jonathan C nr Glenford OH (lat 39 54 32n long 082 19 40w)							
80	20	400	330	70	120	0	120
395419082184400 O-8 Valley Rn nr Glenford OH (lat 39 54 19n long 082 18 44w)							
250	20	1,000	920	80	190	0	190
395210082165600 O-9 Painter C nr Somerset OH (lat 39 52 10n long 082 16 56w)							
60	10	400	320	80	90	10	80
395128082121600 O-10 Turkey Rn nr Somerset OH (lat 39 51 28n long 082 12 16w)							
90	20	440	380	60	2,300	0	2,300
394919082082000 O-11 Butcherknife C nr Fultonham OH (lat 394919n long 0820820w)							
1,000	11,000	3,200	400	2,800	16,000	0	18,000
395048082072000 O-12 Buckeye F nr East Fultonham OH (lat 395048n long 0820720w)							
570	630	600	100	500	14,000	0	17,000
395217082055300 O-13 Kent Rn at White Cottage OH (lat 39 52 17n long 082 05 53w)							
170	20	550	500	50	160	20	140



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a value >1.5 and ≤3 interquartile ranges from the box.

n= 13 samples

Figure 16.--Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Moxahala Creek basin.

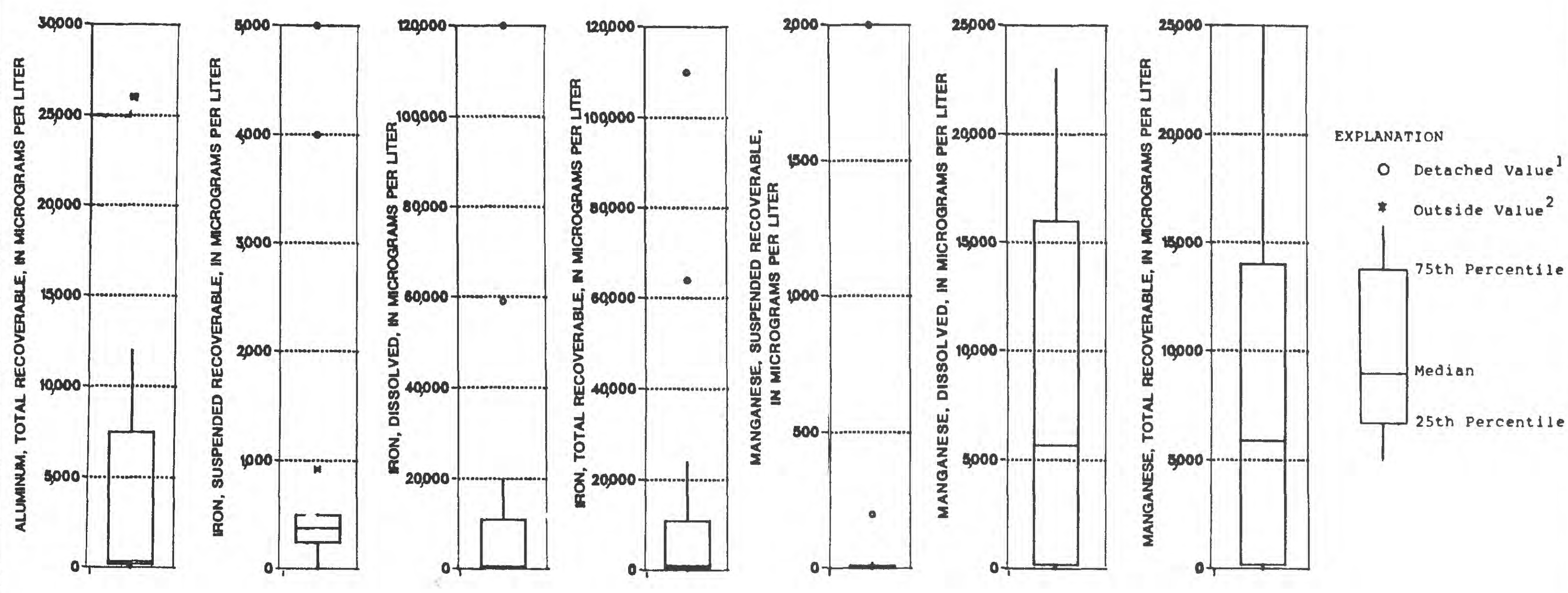


Figure 16.--Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Moxahala Creek basin--Continued.

Such water often occurs as drainage from mines (Hem, 1985). This is the case at sites O-1, O-2, O-4, and O-11 in the Moxahala Creek basin.

Ground Water

Ground-water samples were collected from five domestic wells completed in the sand and gravel aquifer at Glenford, Ohio, and vicinity in the Moxahala Creek basin (fig. 15). There are many active and abandoned mines in the Moxahala Creek basin, but, at present, only a few small mines are in operation southeast of Glenford. Table 8 lists the results of chemical analyses.

In general, the chemical quality is typical of other outwash aquifers in Ohio (Evans, 1977; deRoche and Razem, 1984; Norris and Fidler, 1969). This aquifer has a hard to very hard calcium bicarbonate type water with moderately high concentrations of dissolved solids. Specific conductance ranged from 447 to 670 µS/cm, and dissolved-solids concentrations ranged from 268 to 384 mg/L. Values for pH ranged from 7.20 to 7.80, and alkalinity ranged from 155 to 323 mg/L as $CaCO_3$, both typical of outwash aquifers in Ohio.

Calcium is the most abundant cation and ranged from 52 to 87 mg/L in the five samples. Bicarbonate, the most abundant anion, ranged from 189 to 395 mg/L. Concentrations of magnesium ranged from 21 to 28 mg/L, and concentrations of sodium ranged from 12 to 23 mg/L. Hardness ranged from 220 to 330 mg/L as $CaCO_3$, which classifies the water as hard to very hard. Potassium concentrations ranged from 1.1 to 4.5 mg/L. Concentrations of silica and chloride ranged from 10 to 15 mg/L and 5.2 to 40 mg/L, respectively. Total organic carbon in these wells, which are completed in sand and gravel, ranged from 0.6 to 1.0 mg/L, that are well within the average range for natural ground water. Three samples exceeded the OEPA standard for a public supply in dissolved-iron concentrations, and two were well within the limit (range, less than 3 to 4,400 µg/L). Total-iron concentrations ranged from 60 to 5,900 µg/L. Total-manganese concentrations ranged from less than 10 to 280 µg/L, and three of the five samples exceeded the OEPA recommended criterion for a public supply. Dissolved-manganese concentrations ranged from less than 1 to 290 µg/L. Total-aluminum concentrations ranged from less than 10 to 890 µg/L; two samples greatly exceeded the concentration of the other samples. Dissolved-aluminum concentrations ranged from less than 10 to 20 µg/L. Clays are the most common of all the sedimentary aluminum-bearing minerals. The polymerization of aluminum hydroxide species proceeds in a different way in the presence of silica. When sufficient silica is present, the aluminum appears to be rapidly precipitated (Hem, 1985). Lenses of clay appear throughout this outwash aquifer. In the Moxahala Creek basin, the samples from wells for which logs indicate considerable amounts of clay generally had aluminum concentrations that were above average and silica concentrations that were slightly below average.

Table 8.--Ground-water analyses for the Moxahala Creek basin, Glenford, Ohio, and vicinity

[deg. C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Date	Depth below land surface (water level) (feet)	Specific conductance (uS/cm)	ph (standard units)	Temperature (deg. C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate, field (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
395320082190600 PE-44 (lat 39 53 20n long 082 19 06w)									
08/18/86	36.87	584	7.40	13.0	5.6	290	22	79	23
395309082192500 PE-45 (lat 39 53 09n long 082 19 25w)									
08/19/86	--	480	7.20	13.0	--	220	65	52	22
395507082210500 PE-47 (lat 39 55 07n long 082 21 05w)									
08/18/86	0.0	448	7.80	13.0	0	240	0	63	21
395218082151700 PE-49 (lat 39 52 18n long 082 15 17w)									
08/22/86	1.08	573	7.50	14.0	0	250	0	62	23
395431082195500 PE-50 (lat 39 54 31n long 082 19 55w)									
08/22/86	--	670	7.60	13.0	3.1	330	52	87	28

Date	Sodium, dissolved (mg/l as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, field (mg/L as HCO_3)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)
395320082190600 PE-44 (lat 39 53 20n long 082 19 06w)								
08/18/86	13	4.5	329	270	47	13	14	329
395309082192500 PE-45 (lat 39 53 09n long 082 19 25w)								
08/19/86	12	1.5	189	155	34	40	10	271
395507082210500 PE-47 (lat 39 55 07n long 082 21 05w)								
08/18/86	17	1.1	395	324	3.5	7.2	13	268
395218082151700 PE-49 (lat 39 52 18n long 082 15 1								
08/22/86	23	3.0	312	256	63	5.2	13	278
395431082195500 PE-50 (lat 39 54 31n long 082 19 55w)								
08/22/86	18	1.9	343	281	36	36	15	384

Date	Solids, sum of constituents, dissolved (mg/L)	Aluminum, total recoverable (ug/L as Al)	Aluminum, dissolved (ug/L as Al)	Aluminum, suspended recoverable (ug/L as Al)	Iron, total recoverable (ug/L as Fe)	Iron, dissolved (ug/L as Fe)	Manganese, total recoverable (ug/L as Mn)	Manganese, dissolved (ug/L as Mn)	Carbon, organic total (mg/L as C)
395320082190600 PE-44 (lat 39 53 20n long 082 19 06w)									
08/18/86	360	40	<10	--	60	6	<10	<1	1.0
395309082192500 PE-45 (lat 39 53 09n long 082 19 25w)									
08/19/86	270	20	<10	--	690	620	60	57	0.6
395507082210500 PE-47 (lat 39 55 07n long 082 21 05w)									
08/18/86	320	890	<10	--	1,500	1,400	280	290	1.0
395218082151700 PE-49 (lat 39 52 18n long 082 15 17w)									
08/22/86	350	480	20	460	5,900	4,400	170	290	0.7
395431082195500 PE-50 (lat 39 54 31n long 082 19 55w)									
08/22/86	390	<10	<10	--	80	<3	<10	1	0.6

Little Beaver Creek Basin

Geologic Setting

The Little Beaver Creek basin (fig. 2) is located on the stream-dissected Appalachian Plateau (Fenneman, 1938). The bedrock consists of sandstone, siltstone, clay, shale, and limestone of Pennsylvanian age. These rocks were elevated several times, thus, the present land surface is a series of stepped levels, each a remnant of sporadic erosion. The high valleys have been entrenched in the eastern part of the basin through changes in drainage brought about by Pleistocene glaciation in the northern part of the basin. These processes formed the narrow valleys and gorges in the basin that range in elevation from 920 feet at the headwaters of Little Beaver Creek to 650 feet along the Ohio River (Lessig and others, 1968).

The sedimentary rocks underlying the Little Beaver Creek basin are relatively impermeable sandstone and shale of the Allegheny and Conemaugh Formations. The southern part of the basin is hilly and rugged. Here, the Allegheny rocks crop out in the valley walls and dip about 8 feet per mile to the southeast. On uplands in the southern part of the basin, most of the rocks exposed belong to the lower part of the Conemaugh Formation. This part of the basin, the unglaciated section, has a potential ground-water yield of less than 5 gal/min (Lessig and others, 1968).

Little Beaver Creek has a limited area for the development of large ground-water supplies. Wells completed in the glacial deposits beneath the narrow flood plain of the Ohio River have an estimated potential yield of 500 to 1,000 gal/min. There are little accurate data that reveal this potential; however, some driller's logs report as much as 42 feet of sand and gravel beneath a thin layer of alluvium (Lessig and others, 1968).

Sand and gravel are abundant in the northern part of the basin. Many quarries have operated in the past, and a number of smaller pits are operated intermittently. Although most of the drilled wells are developed in the bedrock, many well logs reveal lenses of sand and gravel above bedrock. Wells in these unconsolidated deposits have a potential yield of 5 to 25 gal/min. Where these deposits are thin, the underlying bedrock may yield up to 25 gal/min (Schmidt, 1959a).

Uplands in the northern part of the basin are covered by thick glacial till of Wisconsin age ranging from 10 to more than 160 feet in thickness. Till and outwash of Wisconsin age are deposited along Little Beaver Creek and its tributaries. About 70 percent of this material is of local origin, mostly sedimentary rocks. The rest has been transported from Canada and other areas to the north. Clay is more abundant in the northwestern part of the basin (Lessig and others, 1968).

The glacial fill in the discontinuous valleys beneath some of the minor streams consists of thick deposits of clay interbedded with thin to thick layers of fine sand and gravel. Yields of as much as 65 gal/min have been reported, yet favorably sited wells having yields of as much as 100 gal/min appear possible (Schmidt, 1959a). Sand and gravel deposits with the greatest potential yield are the preglacial and interglacial drainage channels, which are now wholly or partially filled with glaciofluvial deposits of varying thickness. The complex valleys of Middle Fork Little Beaver Creek, and East Branch Middle Fork Little Beaver Creek, in Columbiana County, also have large deposits that contain water (White and Totten, 1985).

Ground-water levels were measured in 23 wells in the area near Lisbon (fig. 17), and are presented in table 3. Locations of wells are shown in figure 18.

Water Quality

Surface-water quality of the Little Beaver Creek basin was investigated by sampling 12 stream sites at low flow (fig. 17). Ground-water quality was investigated by sampling five wells near Lisbon (fig. 18).

Surface Water

Water-quality samples were collected from Little Beaver Creek, Middle Fork Little Beaver Creek (two sites), North Fork Little Beaver Creek, West Fork Little Beaver Creek, East Branch Middle Fork Little Beaver Creek, Bull Creek, Longs Run, Cold Run, Brush Creek, Elk Run, and Little Yellow Creek during the period October 21 through October 23, 1986 (fig. 17). Results of chemical analyses are presented in table 9 and figure 19.

Specific conductance ranged from 330 µS/cm (at site A-6) to 1,210 µS/cm (at site A-3), with a median of 665 µS/cm.

Values for pH ranged from 7.49 (at site A-12) to 8.83 (at site A-1), with a median of 8.37. Alkalinity ranged from 35 mg/L as $CaCO_3$ (at site A-12) to 257 mg/L (at site A-4), with a median of 153 mg/L.

Dissolved-sulfate concentrations ranged from 41 mg/L (at site A-6) to 250 mg/L (at site A-11), with a median of 145 mg/L.

Total-iron concentrations ranged from 150 µg/L (at site A-5) to 2,700 µg/L (at site A-3), with a median of 410 µg/L. Dissolved-iron concentrations ranged from 20 µg/L (at site A-12) to 80 µg/L (at site A-9), with a median of 50 µg/L.

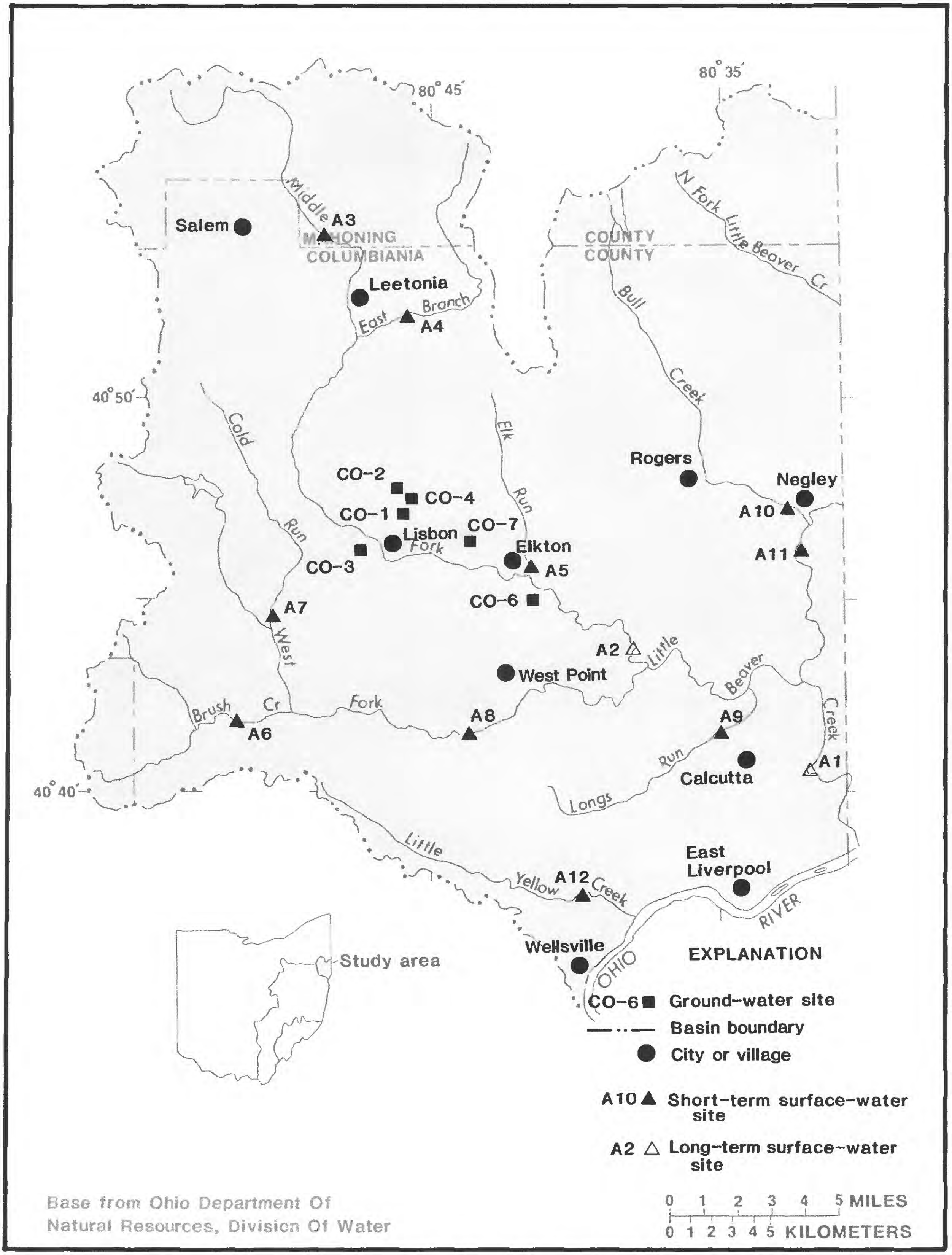


Figure 17.—Short-term and long-term surface-water sites and ground-water sites in the Little Beaver Creek basin.

Total-manganese concentrations ranged from 50 µg/L (at site A-1) to 780 µg/L (at site A-3), with a median of 85 µg/L. Dissolved-manganese concentrations ranged from 20 µg/L (at site A-12) to 760 µg/L (at site A-3), with a median of 55 µg/L.

Concentrations of total aluminum ranged from 20 µg/L (at site A-10) to 390 µg/L (at site A-7), with a median of 125 µg/L. Dissolved-aluminum concentrations ranged from less than 10 µg/L (at sites A-9 and A-10) to 30 µg/L (at site A-12), with a median of 20 µg/L.

Ground Water

Ground water in the Little Beaver Creek basin was investigated in the vicinity of Lisbon, Ohio (fig. 17), mainly in the shallow sandstone of the Conemaugh Formation. One sample was collected from an outwash glacial deposit north of the village (well CO-2) for comparison with the bedrock water. The northwestern and central parts of the basin are covered with glacial deposits, but most are relatively thin; water users generally drill through the glacial cover to the underlying sandstone. The Village of Lisbon has a public water supply north of town, and one of these wells (CO-4) was used for sampling. The other four samples were collected from domestic wells in the area. Table 10 lists the results of chemical analyses. Surface mining is present in much of the basin, although, in general, it is characterized by groups of small mines rather than by sweeping coverage of the entire area. Well locations and Stiff water-quality diagrams are shown in figure 18.

A very hard calcium bicarbonate type water is present in the Lisbon area. In general, the water quality in this area is typical of bedrock aquifers in eastern Ohio (Razem and Sedam, 1985). Water quality of the sample from the outwash aquifer (CO-2) was similar to the bedrock water quality but was slightly higher in iron and manganese. One sample (CO-1) had higher concentrations of the metallic ions and dissolved solids and lower pH. This well, located downgradient from a nearby surface-mining operation, could possibly have received contaminants through the aquifer. The water from well CO-1 was classified as a calcium sulfate type.

Overall, specific conductance ranged from 511 to 1,300 µS/cm. Dissolved-solids concentrations ranged from 293 to 1,050 mg/L. Only well CO-1 exceeded the OEPA standard for a public supply in these constituents. Values for pH ranged from 6.65 to 7.20. Alkalinity ranged from 210 to 365 mg/L as $CaCO_3$.

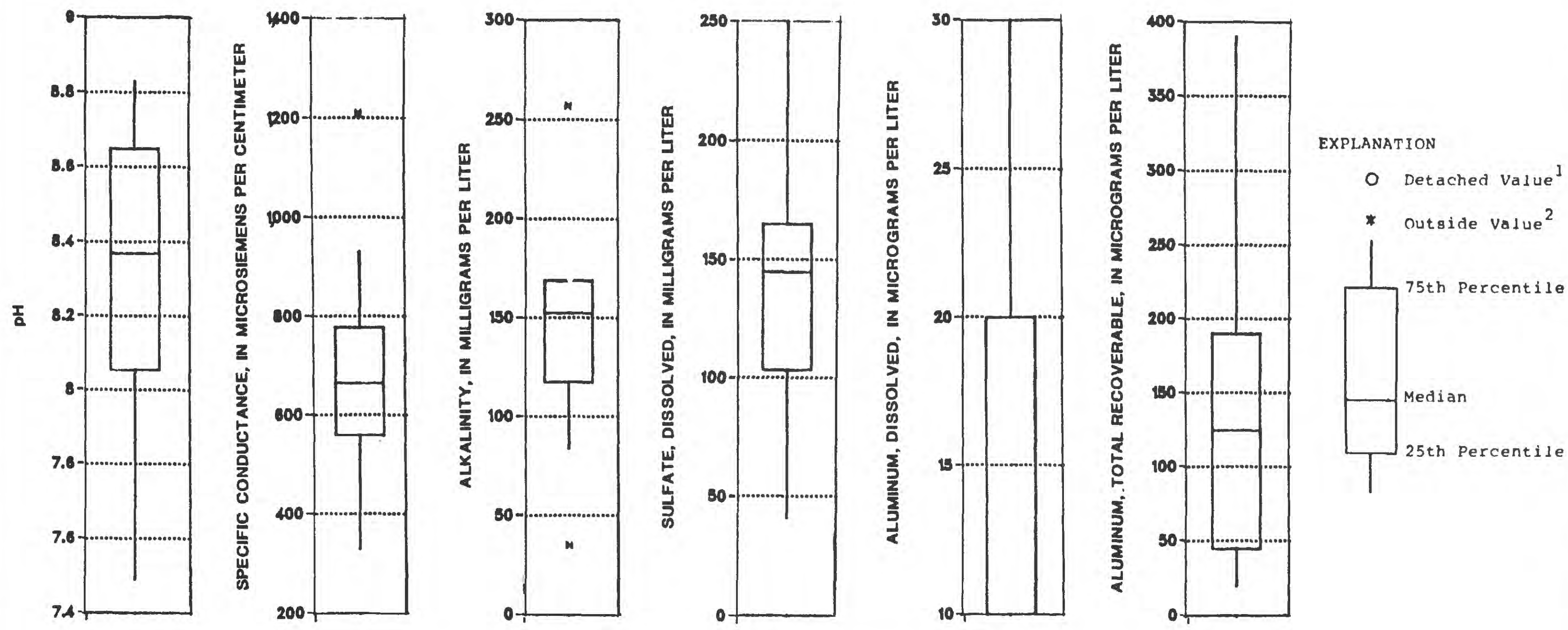
[deg. C, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter;

Date	Stream-flow, instan-taneous (ft^3)	Spe-cific con-duc-tance (µS/cm)	ph (stand-ard units)	Temper-ature (deg. C)	Acidity (mg/L as $CaCO_3$)	Alka-linity, field (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Alum-inum, total recov-erable (µg/L as Al)
03109500 A-1 L Beaver C nr East Liverpool OH (lat 40 40 33n long 080 32 27w)								
Oct 1986								
22...	93	700	8.83	12.5	--	130	160	90
03109100 A-2 M F L Beaver C nr Rogers OH (lat 40 43 22n long 080 38 03w)								
Oct 1986								
21...	27	765	8.81	12.0	--	147	150	130
03108980 A-3 M F L Beaver C nr Salem OH (lat 40 54 20n long 080 48 17w)								
Oct 1986								
21...	7.7	1,210	7.73	8.0	--	158	160	219
03108990 A-4 E B M F L Beaver C at Leetonia OH (lat 40 52 16n long 080 45 54w)								
Oct 1986								
21...	2.0	790	8.14	7.5	--	257	140	200
404544080415400 A-5 Elk Rn at Elkton OH (lat 40 45 44n long 080 41 54w)								
Oct 1986								
21...	2.4	650	8.76	12.0	--	138	170	30
404204080515600 A-6 Brush C nr West Point OH (lat 40 42 04n long 080 51 56w)								
Oct 1986								
21...	0.58	330	8.54	11.0	--	84	41	120
404423080502900 A-7 Cold Rn nr Lisbon OH (lat 40 44 23n long 080 50 29w)								
Oct 1986								
21...	2.0	520	8.44	10.0	--	158	79	390
03109200 A-8 W F L Beaver C at West Point OH (lat 40 42 38n long 080 41 49w)								
Oct 1986								
22...	28	450	8.18	9.0	--	169	97	140
404140080351100 A-9 Longs Rn nr Calcutta OH (lat 40 41 40n long 080 35 11w)								
Oct 1986								
23...	0.89	600	7.97	10.0	--	105	109	40
03109395 A-10 Bull C at Negley OH (lat 40 47 15n long 080 32 42w)								
Oct 1986								
22...	11	670	8.30	9.0	--	170	109	20
03109400 A-11 N F L Beaver C nr Negley OH (lat 40 46 30n long 080 32 36w)								
Oct 1986								
22...	29	930	8.44	9.5	--	169	250	50
403715080391400 A-12 L Yellow C nr Wellsville OH (lat 40 37 15n long 080 39 14w)								
Oct 1986								
23...	0.52	660	7.49	9.5	--	35	230	180

surface-water sites in the Little Beaver Creek basin

µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Aluminum, suspended recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Iron, total recoverable (µg/L as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03109500 A-1 Beaver C nr East Liverpool OH (lat 40 40 33n long 080 32 27w)							
80	10	340	290	50	50	20	30
03109100 A-2 M F L Beaver C nr Rogers OH (lat 40 43 22n long 080 38 03w)							
110	20	560	530	30	80	40	40
03108980 A-3 M F L Beaver C nr Salem OH (lat 40 54 20n long 080 48 17w)							
199	20	2,700	2,700	50	780	20	760
03108990 A-4 E B M F L Beaver C at Leetonia OH (lat 40 52 16n long 080 45 54w)							
190	10	1,100	1,100	40	300	90	210
404544080415400 A-5 Elk Rn at Elkton OH (lat 40 45 44n long 080 41 54w)							
10	20	150	100	50	120	10	109
404204080515600 A-6 Brush Cr nr West Point OH (lat 40 42 04n long 080 51 56w)							
100	20	720	660	60	90	40	50
404423080502900 A-7 Cold Rn nr Lisbon OH (lat 40 44 23n long 080 50 29w)							
380	10	1,300	1,200	50	160	50	109
03109200 A-8 W F L Beaver C at West Point OH (lat 40 42 38n long 080 41 49w)							
120	20	480	450	30	90	30	60
404140080351100 A-9 Longs Rn nr Calcutta OH (lat 40 41 40n long 080 35 11w)							
--	<10	320	240	80	80	40	40
03109395 A-10 Bull C at Negley OH (lat 40 47 15n long 080 32 42w)							
--	<10	190	140	50	70	0	70
03109400 A-11 N F L Beaver C nr Negley OH (lat 40 46 30n long 080 32 36w)							
30	20	290	250	40	60	10	50
403715080391400 A-12 L Yellow C nr Wellsville OH (lat 40 37 15n long 080 39 14w)							
150	30	280	260	20	60	40	20



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a >1.5 and ≤3 interquartile ranges from the box.

n=12 samples

Figure 19.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Little Beaver Creek basin.

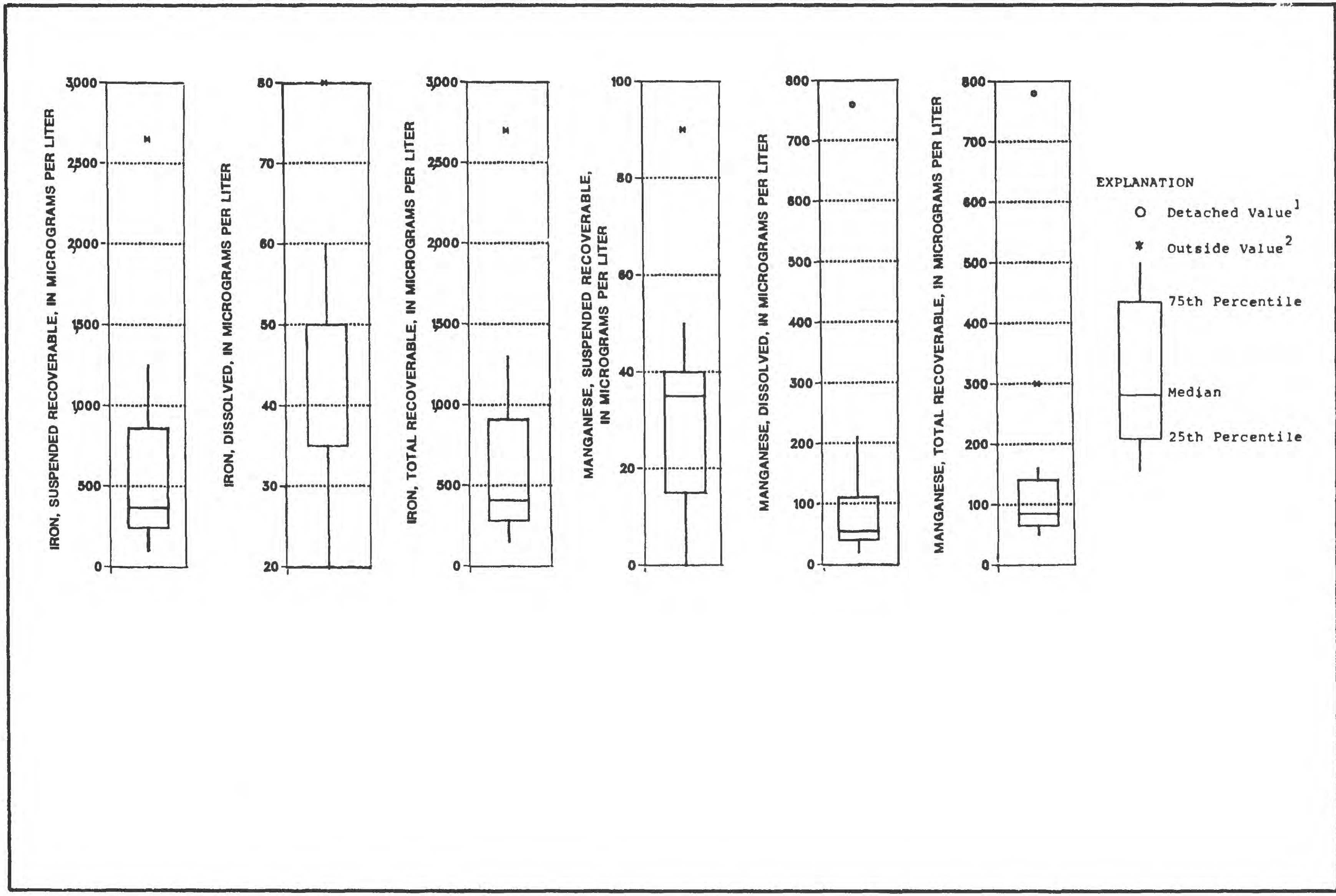


Figure 19.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the Little Beaver Creek basin—Continued.

Table 10.--Ground-water analyses for the Little Beaver Creek basin, Lisbon, Ohio, and vicinity

[deg. C, degrees Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter; uS/cm, microsiemens per centimeter at 25 degrees Celsius]

Date	Depth below land surface (water level) (feet)	Specific conductance (uS/cm)	ph (standard units)	Temperature (deg. C)	Oxygen, dissolved (mg/L)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate, field (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
404754080453700 CO-1 (lat 40 47 54n long 080 45 37w)									
09/02/86	44.87	1,300	6.65	14.0	0	790	460	210	64
405008080460800 CO-2 (lat 40 50 08n long 080 46 08w)									
09/03/86	0.0	750	7.10	11.5	0.1	440	65	120	33
404639080483300 CO-3 (lat 40 46 39n long 080 48 33w)									
09/02/86	44.20	570	6.80	14.0	0	320	99	90	22
404846080461000 CO-4 (lat 40 48 46n long 080 46 10w)									
09/03/86	23.00	512	7.20	10.5	0.3	260	0	75	18
404506080414100 CO-6 (lat 40 45 06n long 080 41 41w)									
09/02/86	47.87	650	6.90	13.5	2.2	360	110	98	27

Date	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate, field (mg/L as HCO_3)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)
404754080453700 CO-1 (lat 40 47 54n long 080 45 37w)								
09/02/86	6.5	2.2	260	210	560	10	15	1050
405008080460800 CO-2 (lat 40 50 08n long 080 46 08w)								
09/03/86	8.3	1.9	450	365	76	4.2	19	304
404639080483300 CO-3 (lat 40 46 39n long 080 48 33w)								
09/02/86	4.6	1.3	260	214	100	8.2	8.7	315
404846080461000 CO-4 (lat 40 48 46n long 080 46 10w)								
09/03/86	13	2.0	330	273	57	8.2	13	293
404506080414100 CO-6 (lat 40 45 06n long 080 41 41w)								
09/03/86	11	1.4	300	248	120	2.2	15	408

Date	Solids, sum of constituents, dissolved (mg/L)	Aluminum, total recoverable (ug/L as Al)	Aluminum, dissolved (ug/L as Al)	Aluminum, suspended recoverable (ug/L as Al)	Iron, total recoverable (ug/L as Fe)	Iron, dissolved (ug/L as Fe)	Manganese, total recoverable (ug/L as Mn)	Manganese, dissolved (ug/L as Mn)	Carbon, organic total (mg/L as C)
404754080453700 CO-1 (lat 40 47 54n long 080 45 37w)									
09/02/86	1,000	20	<10	--	2,600	2,500	3,200	3,200	0.8
405008080460800 CO-2 (lat 40 50 08n long 080 46 08w)									
09/03/86	490	40	<10	--	1,700	1,700	390	390	0.4
404639080483300 CO-3 (lat 40 46 39n long 080 48 33w)									
09/02/86	360	30	<10	--	980	140	60	57	6.0
404846080461000 CO-4 (lat 40 48 46n long 080 46 10w)									
09/03/86	350	30	<10	--	890	800	250	240	0.4
404506080414100 CO-6 (lat 40 45 06n long 080 41 41w)									
09/02/86	420	80	<10	--	560	13	90	57	0.5

Calcium is the most abundant cation; concentrations ranged from 75 to 210 mg/L for the five samples. Bicarbonate is the most abundant anion; concentrations ranged from 260 to 450 mg/L. Concentrations of magnesium ranged from 18 to 64 mg/L, and concentrations of sodium ranged from 4.6 to 13 mg/L. Hardness ranged from 260 to 790 mg/L as $CaCO_3$, which classifies the water as hard to very hard. Potassium concentrations ranged from 1.3 to 2.2 mg/L. Concentrations of silica and chloride ranged from 8.7 to 19 mg/L and 2.2 to 10 mg/L, respectively. Total organic carbon ranged from 0.4 to 0.8 mg/L in four wells but was elevated to 6.0 mg/L in well CO-3.

Concentrations of total iron ranged from 560 to 2,600 μg/L, and concentrations of dissolved iron ranged from 13 to 2,500 μg/L. Three of the five samples exceeded the OEPA standard for a public supply. Total-manganese concentrations (60 to 3,200 μg/L) exceeded the OEPA limit for a public supply in all 5 wells. Total-aluminum concentrations ranged from 20 to 80 μg/L, whereas dissolved-aluminum concentrations were less than 10 μg/L in all samples.

McMahon, Captina, and Sunfish Creeks Basin

Geologic Setting

The McMahon, Captina, and Sunfish Creeks basin (fig. 2) is in the unglaciated, dissected Appalachian Plateau region of Ohio (Fenneman, 1938). The eastern part of the basin is the most rugged. Ridgetops and valleys are narrow, and side slopes are steep. To the west and along drainage divides the basin is not quite as rugged. In this area, ridgetops are wider and more gently sloping, and hills are less steep. The western part of the basin has been extensively surface mined. The average relief in the area is 700 feet. All three streams in this basin flow into the Ohio River. The rock strata in the basin are comprised of the Conemaugh and Monongahela Formations of Pennsylvanian age and the Dunkard Group of Pennsylvanian and Permian age. These layers generally dip to the southeast with an average slope of 18 feet per mile (Hayhurst and others, 1974).

The Conemaugh Formation, principally limestone and sandstone, is the least exposed formation in the basin. It crops out only in the extreme western part of the basin and in the valleys on the northeastern side of the basin. The Monongahela Formation, which consists of shale, limestone, sandstone, and coal, is located in the western part of the basin and along the major streams. The Dunkard Group is extensively exposed in the basin and crops out predominantly in the eastern and central parts of the basin. It consists of a variable sequence of limestones, sandstones, and shales (Rubel and others, 1981).

Less than 5 percent of the basin is suitable for the development of large industrial or municipal ground-water supplies. The glacial outwash deposits beneath the narrow flood plain adjacent to the Ohio River may yield 500 to 1,000 gallons per minute to properly developed wells. Accurate data to substantiate this potential is scarce, but the logs of drilled wells in the basin are similar to those of wells having similar yields developed in the permeable outwash deposits found elsewhere in the Ohio River flood plain (Schmidt, 1959b).

The potential yield of wells drilled beyond the influence of the Ohio River is 25 to 100 gal/min. Although these wells penetrate unconsolidated deposits similar to those beneath the Ohio River, yields are limited by the location with respect to recharge and proximity to the bedrock valley wall (Schmidt, 1959b).

More than 90 percent of the basin is underlain by bedrock formations that provide relatively low yields to wells. Yields of less than 2 gal/min are developed in the various layers of sandstone, shale, and limestone. The variation in the physical characteristics of the bedrock and the topography influences the yields of wells developed in this area. The most productive bedrock wells are developed in the valleys adjacent to the streams. Locally, sandstones may yield as much as 5 gal/min or more. However, the rapid runoff of precipitation from the rugged hillsides generally directs the infiltration of recharge to the more permeable deposits along valley drainage (Schmidt, 1959b).

The Holocene alluvium deposits on the broader flood plains of McMahon, Captina, and Sunfish Creeks often consist of fine sand, gravel, silt, and clay. Where these materials are permeable, they may yield as much as 25 gal/min to large-diameter drilled or dug wells. In addition, these alluvial deposits, even though relatively thin, can provide recharge to the underlying bedrock and thereby influence yields of wells developed in that material (Schmidt, 1959b).

Water Quality

Surface-water quality of the McMahon, Captina, and Sunfish Creeks basin was investigated by sampling 13 stream sites at low flow (fig. 20). The ground-water quality was not investigated because a productive aquifer is absent.

Surface-water-quality samples were collected from McMahon Creek (two sites), Captina Creek, Sunfish Creek (two sites), South Fork Captina Creek, North Fork Captina Creek, Williams Creek, Little McMahon Creek, Bend Fork, Pea Vine Creek, Baker Fork, and Piney Fork, from October 20 through October 22, 1986 (fig. 20). Results of chemical analyses are presented in table 11 and figure 21.

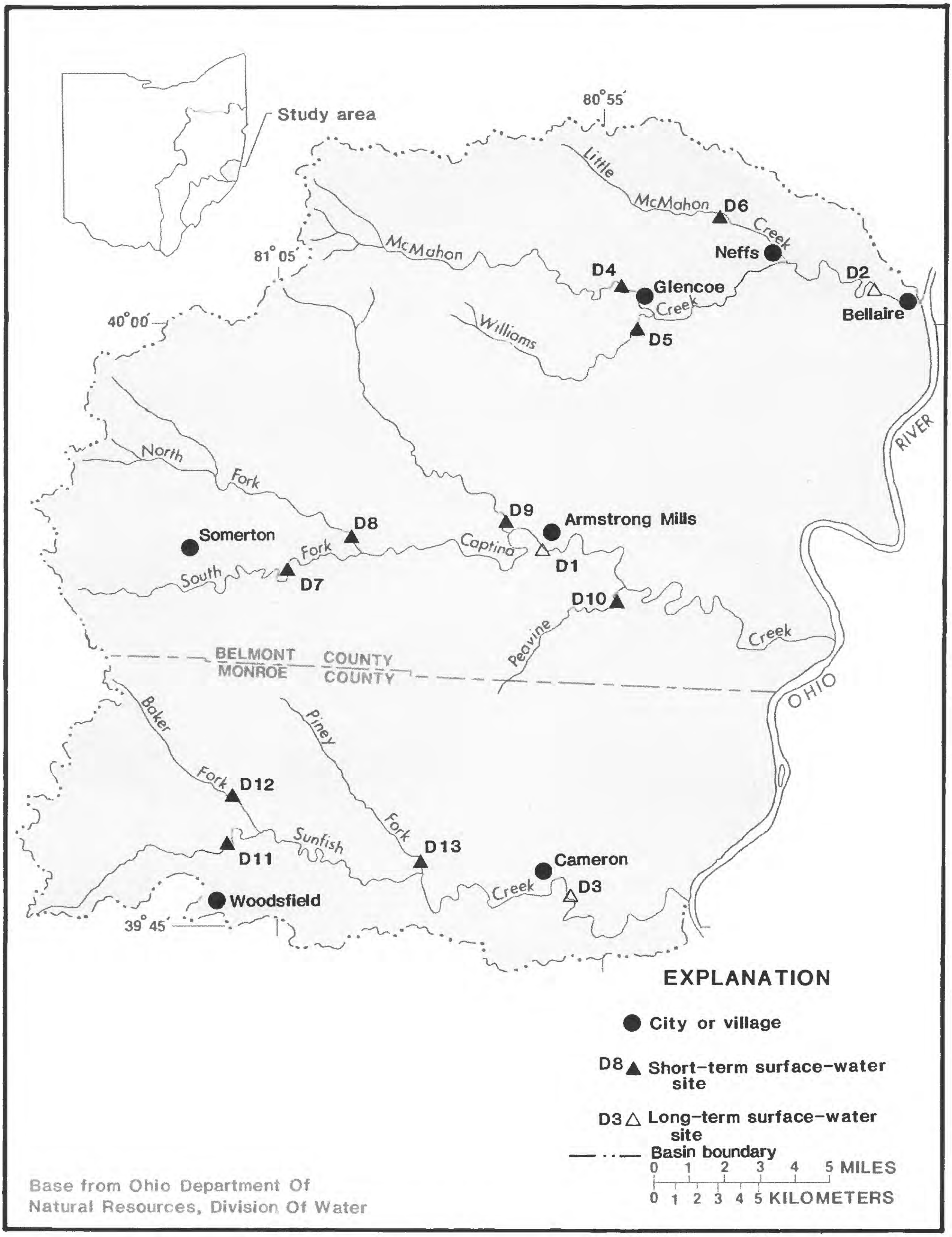


Figure 20.--Short-term and long-term surface-water sites in the McMahon, Captina, and Sunfish Creeks basin.

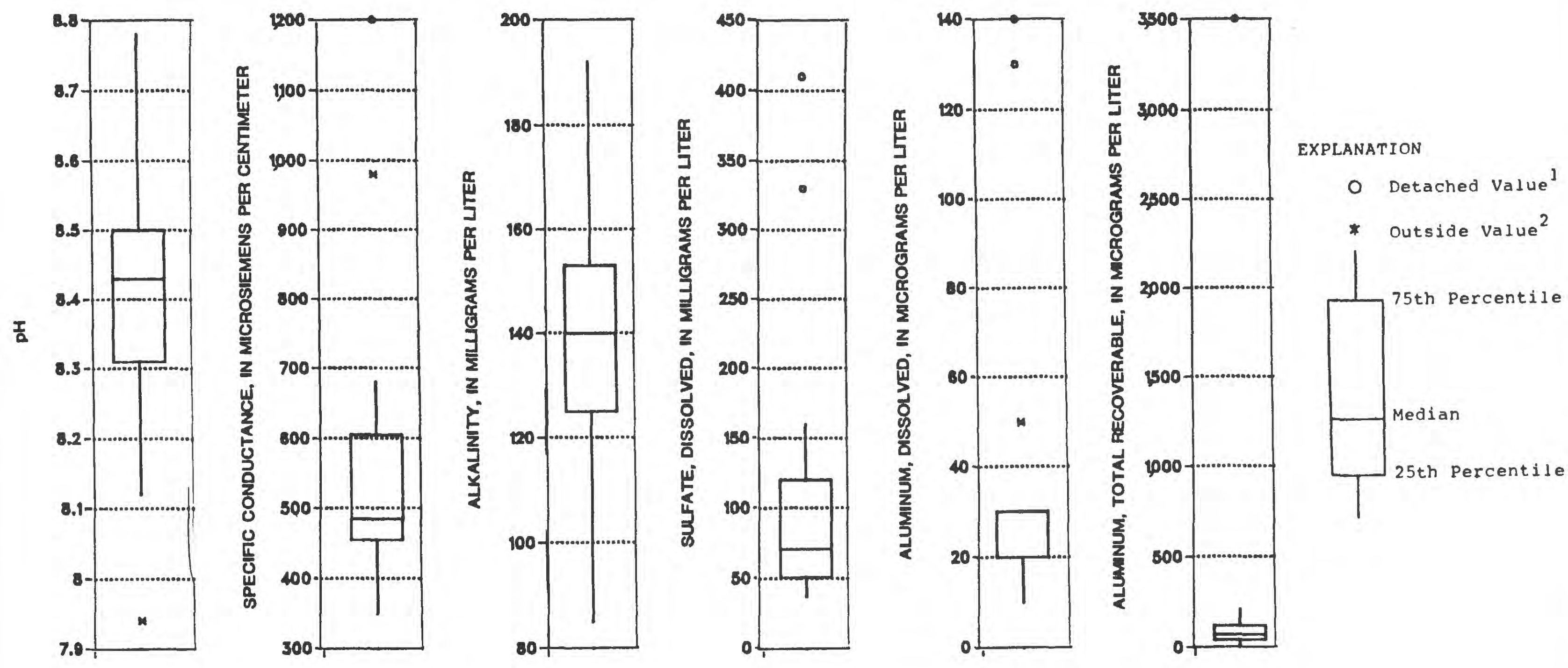
Table 11.--Water-quality data for short-term surface-water

[deg. C, degrees Celsius; ft^3/s, cubic feet per second; mg/L, milligrams per liter;

Date	Streamflow, instantaneous (ft^3/s)	Specific conductance (µS/cm)	ph (standard units)	Temperature (deg. C)	Acidity (mg/L as $CaCO_3$)	Alkalinity, field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Aluminum, total recoverable (µg/L as Al)
03114000	D-1 Captina C at Armstrongs Mills OH (lat 395431n long 0805527w)							
Oct 1986								
21...	13	605	8.39	8.5	--	141	120	120
03113550	D-2 McMahon C at Bellaire OH (lat 40 00 39n long 080 45 45w)							
Oct 1986								
20...	15	980	8.31	10.5	--	146	330	210
03114250	D-3 Sunfish C at Cameron OH (lat 39 46 00n long 080 56 09w)							
Oct 1986								
22...	4.3	435	8.31	10.5	--	125	52	70
400023080532000	D-4 McMahon C at Glencoe OH (lat 40 00 23n long 080 53 20w)							
Oct 1986								
21...	9.6	680	8.63	10.5	--	134	160	90
400013080533000	D-5 Williams C at Glenco OH (lat 40 00 13n long 080 53 30w)							
Oct 1986								
21...	1.2	485	8.47	13.5	--	153	71	50
400225080504100	D-6 L McMahon C nr Neffs OH (lat 40 02 25n long 080 50 41w)							
Oct 1986								
20...	1.8	1,200	7.94	12.0	--	192	410	3,500
395419081044800	D-7 S F Captina C nr Somerton OH (lat 39 54 19n long 081 04 48w)							
Oct 1986								
21...	2.0	485	8.48	9.5	--	134	37	170
395444081025000	D-8 N F Captina C Somerton OH (lat 39 54 44n long 081 02 50w)							
Oct 1986								
21...	4.5	550	8.75	8.5	--	165	79	110
95502080575700	D-9 Bend Fk nr Armstrongs Mills OH (lat 39 55 02n long 080 57 57w)							
Oct 1986								
21...	2.4	455	8.50	7.0	--	140	73	30
95333080541300	D-10 Pea Vine C nr Armstrongs Mills OH (lat 395333n long 0805413w)							
Oct 1986								
21...	0.41	475	8.33	7.5	--	186	59	40
394712081070100	D-11 Sunfish C nr Woodsfield OH (lat 39 47 12n long 081 07 01w)							
Oct 1986								
22...	0.28	495	8.78	10.0	--	105	51	40
394827081065300	D-12 Baker Fk nr Woodsfield OH (lat 39 48 27n long 081 06 53w)							
Oct 1986								
22...	0.27	350	8.12	9.0	--	85	38	50
394645081004100	D-13 Piney Fk nr Woodsfield OH (lat 39 46 45n long 081 00 41w)							
Oct 1986								
22...	0.58	350	8.43	8.5	--	119	46	10

µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius]

Aluminum, suspended recoverable (µg/L as Al)	Aluminum, dissolved (µg/L as Al)	Iron, total recoverable (µg/L as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)
03114000 D-1 Captina C at Armstrongs Mills OH (lat 39 54 31n long 080 55 27w)							
100	20	270	240	30	20	10	10
03113550 D-2 McMahon C at Bellaire OH (lat 40 00 39n long 080 45 45w)							
70	140	490	470	20	90	0	90
03114250 D-3 Sunfish C at Cameron OH (lat 39 46 00n long 080 56 09w)							
40	30	150	120	30	20	0	20
400023080532000 D-4 McMahon C at Glencoe OH (lat 40 00 23n long 080 53 20w)							
40	50	220	140	80	20	0	20
00013080533000 D-5 Williams C at Glenco OH (lat 40 00 13n long 080 53 30w)							
40	10	150	110	40	<10	--	10
400225080504100 D-6 L McMahon C nr Neffs Oh (lat 40 02 25n long 080 50 41w)							
3,370	130	3,100	3,100	20	120	10	110
395419081044800 D-7 S F Captina C nr Somerton OH (lat 39 54 19n long 081 04 48w)							
140	30	380	350	30	30	20	10
395444081025000 D-8 N F Captina C Somerton OH (lat 39 54 44n long 081 02 50w)							
80	30	240	160	80	50	20	30
395502080575700 D-9 Bend Fk nr Armstrongs Mills OH (lat 39 55 02n long 080 57 57w)							
0	30	120	100	20	<10	--	10
395333080541300 D-10 Pea Vine C nr Armstrongs Mills OH (lat 39 53 33n long 080 54 13w)							
30	10	120	100	20	20	10	10
394712081070100 D-11 Sunfish C nr Woodsfield OH (lat 39 47 12n long 081 07 01w)							
10	30	150	100	50	40	0	40
394827081065300 D-12 Baker Fk nr Woodsfield OH (lat 39 48 27n long 081 06 53w)							
30	20	150	110	40	20	0	20
394645081004100 D-13 Piney Fk nr Woodsfield OH (lat 39 46 45n long 081 00 41w)							
--	20	60	40	20	<10	--	10



[1]A detached value is defined as a value which is greater than 3 times the interquartile range beyond the box.

[2]An outside value is defined as a >1.5 and ≤3 interquartile ranges from the box.

n=13 samples

Figure 21.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the McMahon, Captina, and Sunfish Creeks basin.

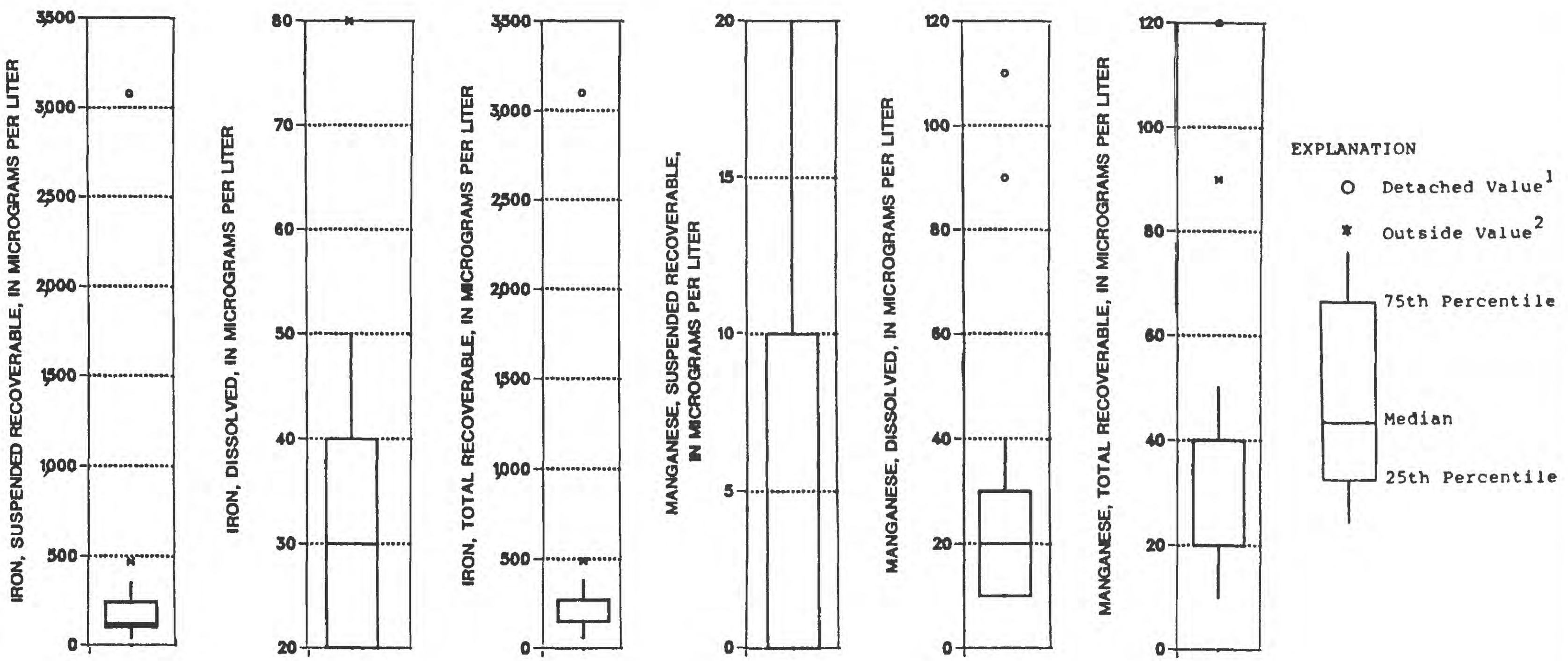


Figure 21.—Box plots showing the range, percentiles, and median values of constituents at surface-water sites in the McMahon, Captina, and Sunfish Creeks basin—Continued.

Specific conductance ranged from 350 μS/cm (at sites D-12 and D-13) to 1,200 μS/cm (at site D-6), with a median of 485 μS/cm.

pH ranged from 7.94 (at site D-6) to 8.78 (at site D-11), with a median of 8.43. Alkalinity ranged from 85 mg/L as $CaCO_3$ (at site D-12) to 192 mg/L (at site D-6), with a median of 140 mg/L.

Dissolved-sulfate concentrations ranged from 37 mg/L (at site D-7) to 410 mg/L (at site D-6), with a median of 71 mg/L.

Total-iron concentrations ranged from 60 μg/L (at site D-13) to 3,100 μg/L (at site D-6), with a median of 150 μg/L. Dissolved-iron concentrations ranged from 20 μg/L (at sites D-2, D-6, D-9, D-10, and D-13) to 80 μg/L (at sites D-4 and D-8), with a median of 30 μg/L.

Concentrations of total aluminum ranged from 10 μg/L (at site D-13) to 3,500 μg/L (at site D-6), with a median of 70 μg/L. Dissolved-aluminum concentrations ranged from 10 μg/L (at sites D-5 and D-10) to 140 μg/L (at site D-2), with a median of 30 μg/L.

Total-manganese concentrations ranged from less than 10 μg/L (at sites D-5, D-9, and D-13) to 120 μg/L (at site D-6), with a median of 20 μg/L. Dissolved-manganese concentrations ranged from 10 μg/L (at sites D-1, D-5, D-7, D-9, D-10, and D-13) to 110 μg/L (at site D-6), with a median of 20 μg/L.

SUMMARY

Twenty basins were selected in the coal-bearing region of Ohio for the study of surface- and ground-water quality. The study area is mostly within the unglaciated eastern part of Ohio with local relief as much as 500 feet. The area is underlain by limestones, sandstones, shale, and coal of Mississippian, Pennsylvanian, and Permian age that dip to the southeast at approximately 30 feet per mile. Unconsolidated deposits are found chiefly in old valleys that now have no major drainage. These deposits are chiefly glacial outwash, and some have a yield greater than the 5- to 10-gal/min yield of some in bedrock aquifers.

One to three long-term surface-water sites were selected in each basin for sampling three times during low flow. All samples were analyzed for specific conductance, pH, alkalinity, acidity, dissolved sulfate, total and dissolved iron, total and dissolved manganese, and total and dissolved aluminum. Specific conductance in these 100 samples ranged from 270 μS/cm to 2,800 μS/cm.

Dissolved-sulfate concentrations ranged from 17 mg/L to 1,400 mg/L. Dissolved-iron concentrations ranged from less than 10 µg/L to 54,000 µg/L, dissolved-manganese concentrations ranged from 10 µg/L to 16,000 µg/L, and dissolved-aluminum concentrations ranged from less than 10 µg/L to 18,000 µg/L. Elevated concentrations of these constituents commonly are used as indicators of acid mine drainage.

Five individual basins selected for intensive investigation were Stillwater Creek basin; Symmes, Ice, and Indian Guyan Creeks basin; Moxahala Creek basin; Little Beaver Creek basin; and McMahon, Captina, and Sunfish Creeks basin. Intensive study included one-time sampling of 12 to 13 surface-water sites within the basin, study of a productive aquifer in parts of the three basins, and a description of the geologic setting. If a productive aquifer were present, three to five ground-water samples were collected, and water levels associated with that aquifer were measured. In addition to all of the physical properties and chemical constituents analyzed for in the stream samples, the ground-water samples were analyzed for silica, calcium, magnesium, sodium, chloride, potassium, total organic carbon, and total dissolved solids.

The Stillwater Creek basin is underlain by shale, sandstone, coal, and limestone of the Conemaugh Formation. Eleven surface-water samples had a range in specific conductance of 390 to 3,300 µS/cm. Dissolved-sulfate concentrations ranged from 15 to 1,900 mg/L. Concentrations of dissolved iron ranged from less than 10 to 130 µg/L, dissolved-manganese concentrations ranged from 90 to 1,700 µg/L, and dissolved-aluminum concentrations ranged from less than 100 to 300 µg/L.

Ground-water quality was investigated at two locations within the Stillwater Creek basin. At the Village of Flushing, as much as 200 gal/min have been pumped from wells in the glacial outwash deposits along Jockey Hollow Run. The water is a very hard calcium sulfate type that is extremely high (883 to 1,200 mg/L) in dissolved solids, which may indicate acid mine drainage. Dissolved-sulfate concentrations ranged from 390 to 590 mg/L, and exceeded the concentrations found in other typical Ohio outwash aquifers and the OEPA standard for a public supply. Elevated concentrations of dissolved iron (17 to 3,300 µg/L) and manganese (780 to 3,100 µg/L) also were found. Samples also were collected from Tappan Lake Park near Deersville. The wells in the park are drilled into the Conemaugh Formation, which yields 5 to 10 gal/min. Analyses show that Tappan Park has a moderately hard to hard calcium bicarbonate type ground water. Dissolved-solids concentrations ranged from 194 to 311 mg/L. Concentrations of dissolved iron (710 to 1,200 µg/L) and total manganese (80 to 370 µg/L) exceeded OEPA standards in all samples.

Strata beneath the Symmes, Ice, and Indian Guyan Creeks basin range from sandstone and shale of the Allegheny Formation in the western part of the basin to the predominantly shaly rock of the Conemaugh and Monongahela Formations to the east. Alluvial deposits of gravel, sand, silt, and clay overlie the bedrock throughout the uplands and generally are less than 50 feet thick. Most bedrock wells yield less than 5 gal/min. Specific conductance of 12 surface-water samples ranged from 250 to 465 µS/cm. Dissolved-sulfate concentrations ranged from 53 to 170 mg/L. Concentrations of dissolved iron ranged from 20 to 150 µg/L, and dissolved-manganese concentrations ranged from 120 to 1,400 µg/L.

Bedrock in the Moxahala Creek basin consists of sandstone, shale, and limestone of Mississippian and Pennsylvanian age. Glacial deposits of clay, silt, sand, and gravel overlie the bedrock in the northwestern part of the basin. Yields of 5 to 10 gal/min are typical of bedrock wells. Wells in glacial deposits have yielded as much as 200 gal/min, but 20 gal/min is typical. Specific conductance of 13 surface-water samples ranged from 520 to 4,600 µS/cm. Dissolved-sulfate concentrations ranged from 42 to 2,800 mg/L. Dissolved-iron concentrations ranged from 30 to 120,000 µg/L, dissolved-manganese concentrations ranged from 80 to 23,000 µg/L, and dissolved-aluminum concentrations ranged from 10 to 24,000 µg/L.

Ground-water quality was investigated in the glacial outwash deposits of the Jonathan Creek Valley near Glenford. This aquifer has a hard to very hard calcium bicarbonate type water that is moderately high in dissolved solids. Most coal mining is located to the east and southeast of Glenford, and probably has little effect on the water quality in this area. Dissolved-solids concentrations ranged from 268 to 384 mg/L. Hardness ranged from 220 to 330 mg/L as $CaCO_3$. Three of the five samples exceeded the OEPA limits for these constituents in a public water supply. Concentrations of dissolved iron and dissolved manganese ranged from less than 3 to 4,400 µg/L and less than 1 to 290 µg/L, respectively.

Rock formations underlying the Little Beaver Creek basin consist of sandstone, limestone, coal, and shale of the Allegheny and Conemaugh Formations. The southern part of the basin is unglaciated and has the potential to provide yields of less than 5 gal/min to wells. Glacial till and outwash deposits are located along Little Beaver Creek and its tributaries in the northern part of the basin and may yield 5 to 25 gal/min to wells. Specific conductance of 12 surface-water samples ranged from 330 to 1,210 µS/cm. Dissolved-sulfate concentrations ranged from 41 to 250 mg/L. Dissolved-iron concentrations ranged from 20 to 80 µg/L, and dissolved-manganese concentrations ranged from 20 to 760 µg/L.

Ground-water quality near Lisbon, mainly in the shallow sandstone of the Conemaugh Formation, is a very hard calcium bicarbonate type water. Mining is confined to small operations scattered throughout the basin, and one sample (CO-1) down-gradient from such a mine showed evidence of possible acid mine drainage. Specific conductance of five samples ranged from 511 to 1,300 µS/cm. Hardness ranged from 260 to 790 mg/L. Total organic carbon ranged from 0.4 to 0.8 mg/L in four wells, but was elevated to 6.0 mg/L in a fifth well. Concentrations of dissolved iron ranged from 13 to 2,500 µg/L, and three samples exceeded the OEPA standard for a public supply. Total-manganese concentrations (60 to 3,200 µg/L) exceeded the standard in all samples.

The McMahon, Captina, and Sunfish Creeks basin is underlain by rocks of the Conemaugh and Monongahela Formations of Pennsylvanian age and the Dunkard Group of Pennsylvanian and Permian age. Yields of 2 to 5 gal/min are developed in the bedrock. Alluvial deposits on the creek flood plains may yield up to 25 gal/min to wells. Specific conductance of 13 surface-water samples ranged from 350 to 1,200 µS/cm. Dissolved-sulfate concentrations ranged from 37 to 410 mg/L. Dissolved-iron concentrations ranged from 20 to 80 µg/L, and dissolved-manganese concentrations ranged from 10 to 110 µg/L.

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Table 2.--Water-quality data for long-term surface-water sites

The following table contains water-quality data collected at long-term sites. The sites are listed alphanumerically by basin-identification number. For each site, the station number, local identifier, station name, latitude, and longitude are given. Data for selected properties and constituents are listed for each observation. Missing data are represented with a dash. Site information is presented in the following format:

Station number	Basin identification	Station name	Latitude	Longitude
385612082095900	J-1 L	KYGER C NR KYGER OH	(LAT 385612	LONG 0820959)

STANDARD ABBREVIATIONS USED IN STATION NAMES

AB	Above	F	Fork	NR	Near
B	Branch	G	Great	R	River
BK	Brook	L	Little	RN	Run
BL	Below	LK	Lake	S	South
C	Creek	M	Middle	TR	Tributary
E	East	N	North	W	West

OTHER SYMBOLS AND ABBREVIATIONS USED IN TABLE 2

UG/L	micrograms per liter	CL	chloride (Cl)
UG/G	micrograms per gram	NI	nickel (Ni)
US/CM	microsiemens per centimeter	SO4	sulfate (SO_4)
FE	iron (Fe)	CACO3	calcium carbonate ($CaCO_3$)
AS	arsenic (As)	HCO3	bicarbonate (HCO_3)
HG	mercury (Hg)	CFS	cubic feet per second
CU	copper (Cu)	FM	from
CR	chromium (Cr)	RECOV.	recoverable
AL	aluminum (Al)	FET-FLD	fixed endpoint titration - field determination
MN	manganese (Mn)		
ZN	zinc (Zn)		
MG/L	milligrams per liter		

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUC-TANCE (US/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG. C)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY, FIELD MG/L AS CACO3	SULFATE DIS-SOLVED (MG/L AS SO4)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL)
03109500	A-1 L BEAVER C NR EAST LIVERPOOL OH (LAT 40 40 33N LONG 080 32 27W)							
OCT 1985								
02...	61	950	8.20	12.0	--	193	230	200
JUN 1986								
25...	70	750	8.40	19.5	--	105	170	200
OCT								
22...	93	700	8.83	12.5	--	130	160	90
03109100	A-2 M F L BEAVER C NR ROGERS OH (LAT 40 43 22N LONG 080 38 03W)							
OCT 1986								
21...	27	765	8.81	12.0	--	147	150	130
03110000	B-1 YELLOW C NR HAMMONDSVILLE OH (LAT 40 32 16N LONG 080 43 31W)							
OCT 1985								
02...	6.2	770	7.50	12.5	--	155	240	200
JUN 1986								
25...	24	497	8.40	21.5	--	93	120	100
OCT								
22...	14	570	8.42	13.5	--	101	150	80
401857080391700	B-2 CROSS C NR MINGO JUNCTION OH (LAT 40 18 57N LONG 080 39 17W)							
OCT 1985								
02...	13	1,750	7.90	12.5	--	173	780	500
JUN 1986								
25...	16	1,420	8.70	22.5	--	175	610	510
OCT								
20...	20	1,300	8.78	10.5	--	135	600	840
401716080451300	B-3 MCINTYRE C NR SMITHFIELD OH (LAT 40 17 16N LONG 080 45 13W)							
OCT 1986								
20...	4.9	2,000	8.35	10.0	--	203	1,000	60
03111548	C-1 WHEELING C BL BLAINE OH (LAT 40 04 01N LONG 080 48 31W)							
OCT 1985								
03...	15	2,400	8.00	13.5	--	248	1,000	300
JUN 1986								
24...	28	2,400	8.00	24.0	--	197	960	450
OCT								
20...	22	2,250	8.24	7.5	--	220	1,100	420
03111500	C-2 SHORT C NR DILLONVALE OH (LAT 40 11 36N LONG 080 44 04W)							
OCT 1985								
02...	24	2,600	8.00	13.5	--	390	1,200	400
JUN 1986								
25...	31	2,360	8.40	22.5	--	198	1,100	310
OCT								
20...	31	2,400	8.32	8.5	--	255	1,100	320
03114000	D-1 CAPTINA C AT ARMSTRONGS MILLS OH (LAT 39 54 31N LONG 080 55 27W)							
OCT 1985								
02...	1.7	1,250	7.90	19.0	--	136	450	100
JUN 1986								
24...	5.7	1,100	8.20	24.5	--	137	71	160
OCT								
21...	13	605	8.39	8.5	--	141	120	120
03113550	D-2 MCMAHON C AT BELLAIRE OH (LAT 40 00 39N LONG 080 45 45W)							
OCT 1985								
03...	3.2	1,700	7.50	12.5	--	151	730	100
JUN 1986								
24...	8.0	1,100	7.90	24.0	--	135	360	290
OCT								
20...	15	980	8.31	10.5	--	146	330	210

ALUMINUM, SUSPENDED RECOVERABLE (µG/L AS AL)	ALUMINUM, DISSOLVED (µG/L AS AL)	IRON, TOTAL RECOVERABLE (µG/L AS FE)	IRON, SUSPENDED RECOVERABLE (µG/L AS FE)	IRON, DISSOLVED (µG/L AS FE)	MANGANESE, TOTAL RECOVERABLE (µG/L AS MN)	MANGANESE, SUSPENDED RECOVERABLE (µG/L AS MN)	MANGANESE, DISSOLVED (µG/L AS MN)
03109500 A-1 L BEAVER C NR EAST LIVERPOOL OH (LAT 40 40 33N LONG 080 32 27W)							
--	<100	340	330	10	50	30	20
170	30	290	240	50	130	60	70
80	10	340	290	50	50	20	30
03109100 A-2 M F L BEAVER C NR ROGERS OH (LAT 40 43 22N LONG 080 38 03W)							
110	20	560	530	30	80	40	40
03110000 B-1 YELLOW C NR HAMMONDSVILLE OH (LAT 40 32 16N LONG 080 43 31W)							
--	<100	370	360	10	30	10	20
40	60	380	350	30	40	20	20
50	30	310	290	20	20	10	10
401857080391700 B-2 CROSS C NR MINGO JUNCTION OH (LAT 40 18 57N LONG 080 39 17W)							
300	200	310	--	<10	220	50	170
280	230	520	470	50	240	30	210
770	70	560	530	30	170	40	130
401716080451300 B-3 MCINTYRE C NR SMITHFIELD OH (LAT 40 17 16N LONG 080 45 13W)							
20	40	200	170	30	100	0	100
03111548 C-1 WHEELING C BL BLAINE OH (LAT 40 04 01N LONG 080 48 31W)							
--	<100	490	460	30	650	140	510
300	150	1,600	1,600	20	140	10	130
320	100	920	900	20	190	0	190
03111500 C-2 SHORT C NR DILLONVALE OH (LAT 40 11 36N LONG 080 44 04W)							
200	200	800	760	40	90	50	40
70	240	590	570	20	60	20	40
210	110	700	680	20	90	10	80
03114000 D-1 CAPTINA C AT ARMSTRONGS MILLS OH (LAT 39 54 31N LONG 080 55 27W)							
0	100	240	200	40	40	10	30
130	30	40	0	40	70	50	20
100	20	270	240	30	20	10	10
03113550 D-2 MCMAHON C AT BELLAIRE OH (LAT 40 00 39N LONG 080 45 45W)							
0	100	550	530	20	70	10	60
210	80	950	910	40	120	20	100
70	140	490	470	20	90	0	90

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUC-TANCE (µS/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG. C)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY, FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL)
03114250 D-3 SUNFISH C AT CAMERON OH (LAT 39 46 00N LONG 080 56 09W)								
OCT 1986								
22...	4.3	435	8.31	10.5	--	125	52	70
03117500 E-1 SANDY C AT WAYNESBURG OH (LAT 40 40 21N LONG 081 15 36W)								
OCT 1985								
02...	35	1,660	7.70	13.5	--	154	730	200
JUN 1986								
24...	70	600	8.70	21.5	--	117	110	100
OCT								
22...	68	340	8.03	13.5	--	116	120	70
403823081213700 E-2 NIMISHILLEN C AT SANDYVILLE OH (LAT 40 38 23 LONG 081 21 37)								
OCT 1985								
03...	70	1,440	7.60	12.0	--	207	210	<200
JUN 1986								
24...	95	1,410	8.50	22.0	--	240	180	140
OCT								
22...	81	1,120	8.12	15.0	--	216	180	100
403426081211900 F-1 CONOTTON C NR SOMERDALE OH (LAT 40 34 26N LONG 081 21 19W)								
OCT 1985								
03...	12	665	7.50	11.5	--	88	180	200
JUL 1986								
07...	202	340	7.70	24.0	--	123	65	2,700
OCT								
22...	46	310	7.66	14.0	--	79	120	250
03123000 G-1 SUGAR C AB BEACH CITY DAM AT BEACH CITY OH (LAT 403924 LONG 0813437)								
OCT 1985								
02...	14	755	7.30	14.0	--	216	59	800
JUN 1986								
24...	19	650	7.80	23.5	--	232	66	1,000
OCT								
22...	19	720	7.80	18.5	--	192	74	870
03116950 G-2 NEWMAN C NR MASSILLON OH (LAT 40 49 22N LONG 081 33 06W)								
OCT 1986								
22...	1.8	460	8.24	13.0	--	209	110	200
03127500 H-1 STILLWATER C AT UHRICHSVILLE OH (LAT 40 23 10N LONG 081 20 50W)								
SEP 1985								
30...	12	1,200	7.60	19.0	--	206	390	700
JUN 1986								
24...	65	820	7.60	22.5	--	137	270	480
OCT								
22...	88	890	7.69	12.5	--	95	340	300
03129100 I-1 WHITE EYES C NR FRESNO OH (LAT 40 18 17N LONG 081 45 01W)								
OCT 1985								
01...	0.79	445	6.60	14.0	--	95	63	100
JUN 1986								
23...	14	380	7.80	24.5	--	96	58	330
OCT								
23...	14	420	7.67	12.5	--	89	66	240

ALUM-INUM, SUS-PENDED RECOV-ERABLE (µG/L AS AL)	ALUM-INUM, DIS-SOLVED (µG/L AS AL)	IRON, TOTAL RECOV-ERABLE (µG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (µG/L AS FE)	IRON, DIS-SOLVED (µG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, DIS-SOLVED (µG/L AS MN)
03114250 D-3 SUNFISH C AT CAMERON OH (LAT 39 46 00N LONG 080 56 09W)							
40	30	150	120	30	20	0	20
03117500 E-1 SANDY C AT WAYNESBURG OH (LAT 40 40 21N LONG 081 15 36W)							
--	<100	270	240	30	80	0	90
60	40	750	730	20	400	60	340
50	20	520	500	20	410	10	400
403823081213700 E-2 NIMISHILLEN C AT SANDYVILLE OH (LAT 40 38 23 LONG 081 21 37)							
--	200	520	500	20	110	20	90
100	40	790	710	80	100	60	40
90	10	840	810	30	170	0	170
403426081211900 F-1 CONOTTON C NR SOMERDALE OH (LAT 40 34 26N LONG 081 21 19W)							
--	<100	1,600	1,500	90	1,900	0	1,900
2,670	30	8,900	8,800	50	1,400	530	870
200	50	2,000	1,700	330	1,000	0	1,100
03123000 G-1 SUGAR C AB BEACH CITY DAM AT BEACH CITY OH (LAT 403924 LONG 0813437)							
700	100	1,600	1,600	40	230	60	170
980	20	2,300	2,300	20	370	50	320
690	180	1,700	1,320	380	220	60	160
03116950 G-2 NEWMAN C NR MASSILLON OH (LAT 40 49 22N LONG 081 33 06W)							
180	20	940	910	30	180	30	150
03127500 H-1 STILLWATER C AT UHRICHSVILLE OH (LAT 40 23 10N LONG 081 20 50W)							
400	300	1,700	--	<10	1,300	900	400
450	30	1,100	--	<10	600	60	540
260	40	840	820	20	450	30	420
03129100 I-1 WHITE EYES C NR FRESNO OH (LAT 40 18 17N LONG 081 45 01W)							
--	<100	2,300	2,200	90	490	30	460
250	80	1,500	1,400	100	310	30	280
200	40	1,600	1500	70	390	0	400

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUC-TANCE (µS/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG. C)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY, FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	ALUM-INUM, TOTAL RECOV-ERABLE (µG/L AS AL)
401624081363400 I-2 BUCKHORN C AT NEWCOMERSTOWN OH (LAT 40 16 24N LONG 081 36 34W)								
OCT 1985								
02...	0.35	710	7.60	10.0	--	148	120	100
JUN 1986								
24...	3.3	410	7.70	20.5	--	67	80	110
OCT								
23...	12	360	7.50	12.0	--	60	76	160
03140000 J-1 MILL C NR COSHOCTON OH (LAT 40 21 46N LONG 081 51 45W)								
OCT 1985								
01...	0.43	470	7.60	11.5	--	125	30	400
JUN 1986								
23...	6.1	385	8.00	24.0	--	128	42	250
OCT								
21...	5.3	380	7.81	10.0	--	93	54	80
401936082001400 J-2 SIMMONS RN NR WARSAW OH (LAT 40 19 36N LONG 082 00 14W)								
SEP 1985								
30...	0.19	1,070	6.80	16.0	--	134	430	100
JUN 1986								
23...	1.6	1,010	7.70	21.0	--	103	430	410
OCT								
21...	3.9	760	8.04	8.0	--	100	250	40
395417081323000 K-1 WILLS C AT PLEASANT CITY OH (LAT 39 54 17N LONG 081 32 30W)								
OCT 1985								
01...	1.7	2,500	7.80	15.0	--	248	1,400	600
JUN 1986								
25...	4.7	2,800	7.90	21.5	--	200	1,200	680
OCT								
22...	11	2,050	8.21	11.5	--	201	930	520
400117081362600 L-1 CROOKED C NR CAMBRIDGE OH (LAT 40 01 17N LONG 081 36 26W)								
OCT 1985								
02...	0.14	670	7.40	13.5	--	169	140	200
JUN 1986								
25...	1.0	640	7.70	21.5	--	145	110	620
OCT								
22...	4.6	630	7.97	12.5	--	149	110	240
400920081432900 L-2 WHITE EYES C NR PLAINFIELD OH (LAT 40 09 20N LONG 081 43 29W)								
OCT 1985								
01...	1.3	960	6.70	14.0	--	52	410	300
JUN 1986								
26...	4.5	660	8.30	20.5	--	79	200	180
OCT								
23...	17	700	7.44	13.0	--	85	240	110
410616082075500 M-1 WAKATOMIKA C NR FRAZEYSBURG OH (LAT 41 06 16N LONG 082 07 55W)								
SEP 1985								
30...	5.5	445	6.80	15.0	--	131	17	200
JUN 1986								
26...	25	410	7.70	18.0	--	81	21	540
OCT								
21...	41	410	7.50	8.5	--	75	25	60

ALUMINUM, SUSPENDED RECOVERABLE (µG/L AS AL)	ALUMINUM, DISSOLVED (µG/L AS AL)	IRON, TOTAL RECOVERABLE (µG/L AS FE)	IRON, SUSPENDED RECOVERABLE (µG/L AS FE)	IRON, DISSOLVED (µG/L AS FE)	MANGANESE, TOTAL RECOVERABLE (µG/L AS MN)	MANGANESE, SUSPENDED RECOVERABLE (µG/L AS MN)	MANGANESE, DISSOLVED (µG/L AS MN)
401624081363400 I-2 BUCKHORN C AT NEWCOMERSTOWN OH (LAT 40 16 24N LONG 081 36 34W)							
--	<100	230	170	60	60	20	40
70	40	570	500	70	330	30	300
140	20	770	750	20	550	0	560
03140000 J-1 MILL C NR COSHOCTON OH (LAT 40 21 46N LONG 081 51 45W)							
--	<100	2,700	2,500	190	250	140	110
220	30	1,200	1,100	70	240	40	200
--	<10	1,600	1,500	60	270	0	280
401936082001400 J-2 SIMMONS RN NR WARSAW OH (LAT 40 19 36N LONG 082 00 14W)							
--	<100	220	210	10	130	50	80
390	20	1,200	1,200	20	600	140	460
30	10	420	380	40	280	0	280
395417081323000 K-1 WILLS C AT PLEASANT CITY OH (LAT 39 54 17N LONG 081 32 30W)							
300	300	550	540	10	240	90	150
640	40	950	940	10	350	180	170
490	30	610	570	40	170	90	80
400117081362600 L-1 CROOKED C NR CAMBRIDGE OH (LAT 40 01 17N LONG 081 36 26W)							
--	<100	380	350	30	450	60	390
600	20	1,200	1,200	30	860	70	790
220	20	630	--	<10	290	200	90
400920081432900 L-2 WHITE EYES C NR PLAINFIELD OH (LAT 40 09 20N LONG 081 43 29W)							
100	200	1,600	1,400	160	1,700	0	1,700
150	30	1,100	1,000	70	800	0	800
100	10	890	790	100	940	0	970
410616082075500 M-1 WAKATOMIKA C NR FRAZEYSBURG OH (LAT 41 06 16N LONG 082 07 55W)							
--	<100	540	460	80	150	30	120
520	20	1,500	1,400	110	200	70	130
50	10	840	750	90	90	0	90

TABLE 2.--WATER-QUALITY DATA FOR

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUC-TANCE (US/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG. C)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY, FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL)
400912082014700 M-2 L WAKATOMIKA C NR TRINWAY OH (LAT 40 09 12N LONG 082 01 47W)								
SEP 1985								
30...	2.3	1,690	6.70	14.5	--	75	980	200
JUN 1986								
26...	6.8	1,400	8.00	17.0	--	75	590	160
OCT								
21...	21	970	7.84	9.0	--	104	390	80
03149500 N-1 SALT C NR CHANDLERSVILLE OH (LAT 39 54 31N LONG 081 51 38W)								
OCT 1985								
01...	0.24	580	7.60	15.0	--	146	52	200
JUN 1986								
25...	4.9	510	7.70	19.5	--	116	65	140
OCT								
21...	5.7	480	7.40	7.5	--	110	69	140
03150250 N-2 MEIGS C NR BEVERLY OH (LAT 39 36 00N LONG 081 42 42W)								
SEP 1985								
30...	2.6	650	8.00	17.5	--	134	130	100
JUN 1986								
23...	19	1,200	7.70	26.5	--	145	490	380
OCT								
21...	7.4	1,400	7.70	9.0	--	163	630	270
395337082011100 O-1 MOXAHALA C NR DARLINGTON OH (LAT 39 53 37N LONG 082 01 11W)								
OCT 1985								
01...	19	1,800	3.70	14.5	99	0	980	8,000
JUN 1986								
23...	41	1,300	6.50	27.5	--	16	530	320
OCT								
22...	25	1,600	6.30	12.0	9.0	25	800	360
03148400 O-2 MOXAHALA C AT ROBERTS OH (LAT 39 51 17N LONG 082 03 23W)								
OCT 1986								
22...	12	2,600	3.44	11.0	148	--	1,400	8,600
395214082054700 O-3 JONATHAN C AT WHITE COTTAGE OH (LAT 39 52 14N LONG 082 05 47W)								
OCT 1986								
22...	9.5	1,050	7.46	12.5	--	120	310	280
03156700 P-1 RUSH C NR SUGAR GROVE OH (LAT 39 38 18N LONG 082 30 42W)								
SEP 1985								
30...	18	890	7.60	14.0	--	118	280	100
JUN 1986								
23...	22	830	7.60	26.0	--	85	230	340
OCT								
21...	24	515	8.20	7.5	--	101	120	340
03157000 P-2 CLEAR C NR ROCKBRIDGE OH (LAT 39 35 18N LONG 082 34 43W)								
OCT 1986								
21...	27	430	8.85	8.0	--	178	39	40
03158200 Q-1 MONDAY C AT DOANVILLE OH (LAT 39 26 07N LONG 082 11 30W)								
SEP 1985								
30...	2.5	1,200	3.20	15.0	199	0	660	18,000
JUN 1986								
23...	11	1,200	3.50	23.0	89	0	430	8,400
OCT								
21...	5.6	1,150	3.41	10.0	69	0	480	7,800

ALUM-INUM SUS-PENDED RECOV-ERABLE (µG/L AS AL)	ALUM-INUM, DIS-SOLVED (µG/L AS AL)	IRON, TOTAL RECOV-ERABLE (µG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (µG/L AS FE)	IRON, DIS-SOLVED (µG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, DIS-SOLVED (µG/L AS MN)
400912082014700 M-2 L WAKATOMIKA C NR TRINWAY OH (LAT 40 09 12N LONG 082 01 47W)							
100	100	570	540	30	940	80	860
130	30	610	570	40	830	0	830
70	10	710	650	60	1,100	0	1,100
03149500 N-1 SALT C NR CHANDLERSVILLE OH (LAT 39 54 31N LONG 081 51 38W)							
--	<100	740	720	20	440	0	510
120	20	790	680	110	370	50	320
120	20	980	850	130	260	0	260
03150250 N-2 MEIGS C NR BEVERLY OH (LAT 39 36 00N LONG 081 42 42W)							
--	<100	540	460	80	400	20	380
350	30	650	590	60	120	90	30
--	<10	520	500	20	140	60	80
395337082011100 O-1 MOXAHALA C NR DARLINGTON OH (LAT 39 53 37N LONG 082 01 11W)							
0	8,100	1,200	200	1,000	15,000	2,000	13,000
280	40	210	180	30	6,600	0	6,800
300	60	1,100	250	850	6,400	0	6,600
03148400 O-2 MOXAHALA C AT ROBERTS OH (LAT 39 51 17N LONG 082 03 23W)							
400	8,200	11,000	0	11,000	14,000	0	16,000
395214082054700 O-3 JONATHAN C AT WHITE COTTAGE OH (LAT 39 52 14N LONG 082 05 47W)							
200	80	420	390	30	2,500	0	2,600
03156700 P-1 RUSH C NR SUGAR GROVE OH (LAT 39 38 18N LONG 082 30 42W)							
0	100	350	330	20	2,100	0	2,100
310	30	870	790	80	2,000	100	1,900
320	20	1,100	1,100	30	1,700	0	1,700
03157000 P-2 CLEAR C NR ROCKBRIDGE OH (LAT 39 35 18N LONG 082 34 43W)							
20	20	280	230	50	40	0	40
03158200 Q-1 MONDAY C AT DOANVILLE OH (LAT 39 26 07N LONG 082 11 30W)							
0	18,000	4,100	0	4,200	4,700	0	4,400
200	8,200	1,400	100	1,300	3,700	0	3,700
200	7,600	2,500	300	2,200	3,900	100	3,800

DATE	STREAM-FLOW, INSTAN-TANEOUS (CFS)	SPE-CIFIC CON-DUC-TANCE (US/CM)	PH (STAND-ARD UNITS)	TEMPER-ATURE (DEG. C)	ACIDITY (MG/L AS CACO3)	ALKA-LINITY, FIELD (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL)
392342082072000 Q-2 SUNDAY C AT CHAUNCEY OH (LAT 39 23 42N LONG 082 07 20W)								
OCT 1986								
22...	6.9	2,000	2.70	8.0	260	--	1,000	3,500
385826082201800 R-1 RACCOON C AT VINTON OH (LAT 38 58 26N LONG 082 20 18W)								
SEP 1985								
30...	3.9	475	7.10	15.0	--	20	150	200
JUN 1986								
25...	28	390	6.70	23.0	--	19	110	110
OCT								
22...	11	450	7.13	9.0	--	33	140	70
390941082212200 R-2 ELK FK NR RADCLIFF OH (LAT 39 09 41N LONG 082 21 22W)								
OCT 1986								
22...	3.2	500	7.35	8.5	--	48	130	110
03201988 S-1 L RACCOON C NR VINTON OH (LAT 38 57 11N LONG 082 21 56W)								
SEP 1985								
30...	8.7	595	6.10	14.0	11	8	240	1,000
JUN 1986								
25...	4.9	455	6.80	20.0	--	6	160	290
OCT								
22...	6.6	790	4.75	8.5	31	0	340	4,100
03160105 S-2 CAMPAIGN C NR GALLIPOLIS OH (LAT 38 53 51N LONG 082 11 31W)								
OCT 1986								
23...	0.22	855	6.95	12.5	--	23	410	100
383005082280600 T-1 SYMMES C NR GETAWAY OH (LAT 38 30 05N LONG 082 28 06W)								
OCT 1985								
01...	1.3	410	7.10	15.0	--	105	53	200
JUN 1986								
24...	21	270	7.00	25.0	--	73	42	1,400
OCT								
23...	13	405	7.68	10.0	--	75	100	140
382715082242400 T-2 INDIAN GUYAN C NR BRADRICK OH (LAT 38 27 15N LONG 082 24 24W)								
OCT 1985								
01...	0.24	465	7.50	14.5	--	182	74	100
JUN 1986								
24...	2.2	565	7.60	23.0	--	86	150	310
OCT								
23...	2.6	615	7.76	10.5	--	85	200	160

ALUM-INUM, SUS-PENDED RECOV-ERABLE (µG/L AS AL)	ALUM-INUM, DIS-SOLVED (µG/L AS AL)	IRON, TOTAL RECOV-ERABLE (µG/L AS FE)	IRON, SUS-PENDED RECOV-ERABLE (µG/L AS FE)	IRON, DIS-SOLVED (µG/L AS FE)	MANGA-NESE, TOTAL RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, SUS-PENDED RECOV-ERABLE (µG/L AS MN)	MANGA-NESE, DIS-SOLVED (µG/L AS MN)
392342082072000 Q-2 SUNDAY C AT CHAUNCEY OH (LAT 39 23 42N LONG 082 07 20W)							
0	3,500	54,000	0	54,000	4,400	400	4,000
385826082201800 R-1 RACCOON C AT VINTON OH (LAT 38 58 26N LONG 082 20 18W)							
0	200	480	360	120	1,200	100	1,100
90	20	790	720	70	1,300	0	1,300
30	40	870	500	370	360	0	370
390941082212200 R-2 ELK FK NR RADCLIFF OH (LAT 39 09 41N LONG 082 21 22W)							
20	90	800	0	950	370	0	400
03201988 S-1 L RACCOON C NR VINTON OH (LAT 38 57 11N LONG 082 21 56W)							
700	300	700	550	150	1,900	0	2,000
270	20	1,000	850	150	2,000	0	2,000
0	4,100	430	80	350	4,100	0	4,300
03160105 S-2 CAMPAIGN C NR GALLIPOLIS OH (LAT 38 53 51N LONG 082 11 31W)							
80	20	610	480	130	7,100	0	7,300
383005082280600 T-1 SYMMES C NR GETAWAY OH (LAT 38 30 05N LONG 082 28 06W)							
--	<100	860	710	150	1,700	300	1,400
1,340	60	3,500	3,400	130	530	130	400
120	20	1,300	1,200	100	450	0	450
382715082242400 T-2 INDIAN GUYAN C NR BRADRICK OH (LAT 38 27 15N LONG 082 24 24W)							
--	<100	360	220	140	550	100	450
290	20	890	840	50	760	10	750
120	40	790	570	220	560	0	580